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Bachelor Degree Program ”Software Engineering” in the Higher School of Economics: Background and Perspectives

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1976-1989: Researcher, Central Scientific Research Institute 45 of Ministry of Defense 1989-1997: Senior Researcher, Scientific Computer Centre Russian Academy of Sciences 1997-2004: Full professor, Computer Systems Design Department, MATI – Russian State Technological University 2004-2015: Head of Computer Systems Design Department, MATI – Russian State Technological University 2015-: Head of Computer Systems Design Department, Moscow Aviation Institute (National Research University) (part time) 2015-: Full professor, Academic supervisor of BS program in Software Engineering, National Research University Higher School of Economics (full time)

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Invited lector, Moscow Institute of Physics and Technics (”Fiz-Tech”), 1999-2011 Invited lector, Hanoi University of Technology (Hanoi, Vietnam), 2005-2008 Invited lector, Hanoi Open University (Hanoi, Vietnam), 2009-2012

Awards:

IEEE Computer History Competition CHC’60 Award, 2006 IEEE 2010 Student Competition Best Architecture Prize, 2010 Yuri Gagarin medal from Federation of Cosmonautics of Russian, 2010

Books (in Russian):

Informatics (Moscow, 2003) (with coauthors) The Career in IT (Moscow, 2003) (with coauthors) The Chronicle of computational and information technologies. People. Events. Ideas. Parts 1-4 (Moscow, 2004-2007) Charles Stanhope. Scientific biography (Saint-Petersburg, 2011) (with Yu. Polunov) This wonderful history of informatics (Moscow, 2011) The History of Logical machines (Moscow, 2014)

Scientific papers:

More than 300 scientific papers in parallel architectures, compilers, history of computing etc. in Soviet, Russian and International editions.

Conferences:

Member of Organizing Committee, ”SoRuCom 2011” IFIP Conference (Novgorod, Russia) Member of Organizing Committee, International Gagarin Conference (Moscow, Russia, 2005-2015) Member of Organizing Committee, IV International Anatoly Kitov Conference (Moscow, Russia, 2014) Member of Program Committee, ”SoRuCom 2014” IFIP Conference (Kazan, Russia) Member of Program Committee, V International Anatoly Kitov Conference (Moscow, Russia, 2015)

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BACHELOR DEGREE PROGRAM "SOFTWARE ENGINEERING" IN THE HIGHER SCHOOL OF ECONOMICS: BACKGROUND AND PERSPECTIVES

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The Higher School of Economics (HSE), Moscow, Russia, was established in 1992 with the aim to promote economic and social reforms in Russia through education of a new generation of researchers and practitioners. Currently, HSE has a prestigious status of National Research University and is considered as a multi-discipline Centre of study and research. It established itself as a leading university in Russia in the field of economics, social and political sciences, informational technologies and mathematics. It is ranked among the top-three most popular universities in Russia. Our University enjoys effective partnership with leading foreign universities, international programs and organizations, research consortia and scientific periodicals/editions, foreign companies and transnational corporations (over 130). The HSE is rapidly developing university which actively perceives the most advanced ideas. So it was with software engineering.

Software engineering is a relatively young scientific discipline. For the first time, the term "Software Engineering" was proposed in 1968 at the NATO conference at Garmisch-Partenkirchen devoted to the so-called "software crisis" that has arisen with the development of computers of the third generation, allowing the realization not previously implemented software projects. There was a need for new technologies and methods of management for the development of complex large software systems. In Russia, the HSE in 2006 began to develop first domestic standard on software engineering. In 2010 it was adopted by Ministry of Education and Science of Russian Federation and our University started to train specialists in this field. Other Russian universities began to enroll students on this specialty only next year.
At the present time, the bachelor degree program "Software Engineering" is realized on the Faculty of Computer Science at the Department of Software Engineering established at HSE in 2014. The aim of this program is training of technical experts, skilled developers, software architects and software quality managers. The need for such specialists is dictated by the ever-growing demands of the information and communication industry: the organizing of IT-technology parks, the rapid development of offshore market and custom programming, computerization of government agencies, the private commercial business needs, etc. It also worth to mention that HSE is the only Registered Education Provider of the IEEE Computer Society in Russia.

The educational BS program "Software Engineering" is fully consistent with international guidelines on the teaching of software engineering in higher education: Computing Curricula 2005, Computer Science Curricula 2001/2008/2013 and Software Engineering 2004/2014. It covers all aspects of the world's best knowledge and practice in software production: mathematical, methodological, economical, legislative, marketing, etc. In 2011 our program was honored the prestigious IBM Faculty Award.

Our students study core disciplines such as mathematical analysis, algebra, discrete mathematics, probability theory and mathematical statistics, statistical and empirical methods of computing, programming, data structures and algorithms, distributed computing, architecture of computer systems, operating systems and databases. Professional cycle includes software architecture, design of software systems, quality control and testing, software project management, psychology in IT, group dynamics and communication in professional practice of software engineering, economics of the firm, economics of software engineering, intellectual property law and some others. Above this, every student chooses elective disciplines, research seminars, computer practicums, and university-wide minors. The study of English language is of great importance. Future specialists are expected to work in international environment and be acquainted with the most modern world achievements in computer science. Some disciplines of professional cycle are taught in English as well.

The benefits of the program are the following:

1. *Combination of theoretical training with practical work experience in companies.*
We have partner relations with more than 60 leading domestic (Yandex, Kaspersky Lab, etc.) and international (IBM, Microsoft, etc.) companies. It gives our students the opportunity to get knowledge in a wide range of real IT-projects during educational and technological internship, professionally oriented and graduation practices. Among the lecturers there are representatives of business sphere which promotes the integration of training and practice, the application of business ideas in the content of the SE courses. During the Sophomore Year students are encouraged to fulfill the software development projects in teams in framework of the discipline “Group Dynamics and Communications in Software Engineering Professional Practice” where real situations of team development and interaction of team members are considered. During the Senior Year students learn the discipline “Group Project on Software Engineering” where students’ teams develop a software product in cooperation with the customer of one of the partner companies in the real conditions. Thus, the educational and scientific process is focused on practical activities. Students throughout the training are acquainted with the real conditions of practical activity and many of them are invited to work in companies upon the results of team projects.

2. *High level of training*
Highly qualified staff from the Software Engineering Department and some other Higher School of Economics departments and faculties takes part in educational process. In addition, the staff of high-tech companies participates in the teaching as well. The representatives of leading Russian research organizations in the field of IT including the Institute for System Programming, Institute for Systems Analysis and Institute for Information Transmission Problems of the Russian Academy of Science are also involved in the training.

3. *Individual educational tracks.*
It is possible for students to choose various educational tracks by selecting elective disciplines, research seminars, computer practicums and university-wide minors.

4. *Active project and research work.*
Projects are the significant part of the entire educational program. Students can use all the resources of the Higher School of Economics as a research University, as well as partner companies. During the training students obtain the individual and teamwork skills in typical software development. Above this, they participate in real projects of leading Russian and foreign companies specializing in the software development, consulting and software project

management. Students from the first year of study involve in the research seminars of various directions, perform interdisciplinary course work. For the implementation of course projects, students use the knowledge and expertise gained during the study of the program disciplines. At the same time the themes of course works would suggest that the students have to find independently their own methods to apply acquired knowledge and technologies. The mandatory part of a course work is the development of software technical documentation. Results of some course works are introduced in training process. At research seminars students make presentations on actual scientific topics, conduct research, develop team projects, and learn how to prepare scientific publications. All these factors allow our students to participate successfully in various national and international competitions.

5. *Work perspectives*.
Graduates of the SE program work as the developers and software architects, software quality managers in industrial companies, research centers and governmental agencies. Philosophically, the aim of the program leading to the Bachelor of Software Engineering degree is to provide students with a strong theoretical and practical background in computer software along with the engineering analysis, design and implementation skills.

In 2014, Higher School of Economics modified its educational standards on the bachelor degree level. The main purpose of the reform was to improve the quality of education by decreasing the number of courses students take simultaneously (4 to 5 + foreign language) and strengthening emphasis on project and research activity, to give a chance to students to follow university-wide non-core courses (so-called "minors"), etc. As a result of changes made in the program, it has acquired the unique character for the Russian educational system. At present time Freshman and Sophomore Year students follow modified syllabi, but Junior and Senior Year students still follow the previous syllabi, which will cease in 2017. But, it is worth to note that most of the core required disciplines, all research/project seminars, some elective disciplines remained in modified curriculum. Thus, BSSE program continuity is preserved.

BSSE program is administered by Program Academic Supervisor and Program Academic Board.

Program Academic Board:

- develops educational program, submits it for approval to Faculty Academic Board and further to the HSE Directorate of Basic Education Programs and Vice-Rector for Academic Affairs;
- clarifies the curriculum for each academic year and suggests teaching staff for the program courses;
- submits a petition to the Department Chair for replacing lecturers in case of unsatisfactory results of monitoring the quality of teaching of specific courses;
- approves the course syllabi;
- generates suggestions for changes in the program educational standard and curriculum, based on international experience in realization of similar educational programs abroad;
- considers reports monitoring students' opinions about the quality of teaching.

Program Academic Supervisor:

- organizes a work of Program Academic Office (PAO) and teaching staff;
- determines the tasks for Program Manager and PAO;

- organizes interaction between the specialists from Tutor's Center and students;
- cooperates with managers and staff of HSE structural subdivisions on matters relating to the realization of the program;
- monitors the quality of teaching.

Graduation requirements for the program are the following. The name of the degree awarded in this program is **Bachelor of Software Engineering** regardless of track. Students are expected to complete their education in a timely manner. Their progress is monitored through an online ASPA (Applicant, Student, Postgraduate Student, Alumni) System. The ASPA's reports or audit are available to the students. Graduating students are carefully monitored to ensure that the curricula has been followed and successfully completed. Mentor of Bachelor degree Graduate Qualifying Work (GQW) and PAO control constantly from December to April of the fourth academic year the process of GQW preparation to be sure all requirements for graduation have been met. They also provide on request of the student the necessary consultations, which may also include the GQW public defending procedures. All students are required to present a final GQW variant not later than 10 days before public defending date.

The SE degree requirements consist of:

- ✓ 64 credit hours of mathematics and science;
- ✓ 112 credit hours of engineering topics;
- ✓ 49 credit hours of general education;
- ✓ 15 credit hours of internships and practices.

Three to five years after graduating with this degree graduates will be able to:

1. Excel in a career utilizing their education in Software Engineering;
2. Continue to enhance their knowledge;
3. Be effective in multidisciplinary and diverse professional environments;
4. Provide leadership and demonstrate professional integrity.

These are the main program educational objectives which are related with program student outcomes. The general outcomes of the Software Engineering Program are as follows. Graduates must be:

1. Able to learn and acquire new knowledge, skills, including areas different from a professional one;
2. Able to identify the essence of scientific problems in professional area;
3. Able to solve problems in a professional activity using the methods of analysis and synthesis;
4. Able to assess the need for resources and use it in solving the problems in professional activity;
5. Able to work with information: locate, evaluate and use the information from various sources necessary for solving of scientific and professional problems (including a systematic approach);
6. Able to carry out research, analyze problem, formulate goals and objectives, select research methods and assess its quality;
7. Able to work in a team;
8. Able to communicate competently considering the objectives and situation;
9. Able to critically assess and reassess the experience (own and others);
10. Able to work in an international environment.

The following table maps the program educational objectives to the program outcomes. Every program outcome is related to one or more program educational objectives, and every program educational objective is related to at least one program outcome.

Table 1.

Mapping of Program Outcomes to Program Educational Objectives.

	Excel in career	**Continue to enhance knowledge**	**Effective in diverse environment**	**Leadership and integrity**
...learn and acquire new knowledge, skills, including an area different from a professional one	**x**	**x**		
...identify the essence of scientific problems in professional area		**x**		
...solve problems in a professional activity using the methods of analysis and synthesis	**x**		**x**	
...assess the need for resources and use it in solving the problems in professional activity	**x**	**x**	**x**	
...work with information: locate, evaluate and use the information from various sources necessary for scientific and professional problems	**x**			
...carry out research, analyze problem, formulate goals and objectives, select research methods and assess its quality	**x**	**x**		**x**
...work in team	**x**		**x**	**x**
...communicate competently considering the objectives and situation	**x**		**x**	**x**
...critically assess and reassess the experience	**x**		**x**	**x**
...work in an international environment	**x**		**x**	**x**

The process for direct assessment of outcomes has three components (items *a*, *b*, *c* below).

a) Quantitative measurement of achievement of each outcome assessed in a subset of the required courses in the program.

This analysis is performed and reported by the PAO and instructor of each course. They establish the instruments to be used to assess each outcome. These are typically questions embedded in student assignments, exams, interviews, questionnaires` or other evaluative mechanisms. PAO also supplies the relevant statistics for the course. These include the number of students, the grading scale and the average score for the embedded question, the percentage of students who achieved the outcome. Finally, the course instructor makes any relevant comments regarding the achievement of the outcome. In addition, he prepares a set of course materials, which includes the course syllabus, copies of the instruments used to assess the outcomes and sample graded student work. PAO stores this information. These materials are the primary source of information for the next level of the assessment process – the SE Program Academic Board.

b) Qualitative evaluation of the achievement of all outcomes assessed in each course.
This evaluation is performed and reported by SE Program Academic Board. This board makes recommendations and suggestions for improvements in the course and its relation to other courses in the curriculum, improvements in the achievement of the outcomes, and improvements in the process itself. Twice per year the board is convened by SE Academic Supervisor and outcomes are assessed.

SE Program Academic Board is tasked with the following:

- To evaluate the course in terms of its contents and its place within the curriculum.
- To perform a qualitative analysis of the quantitative data in the course and course materials supplied by the PAO.
- To examine, evaluate, and ratify the quantitative criteria used, the instruments chosen, the statistics provided, and the sample student graded work.
- To generate suggestions/recommendations in three categories:
    1) Recommendations to future lecturers.
    2) Recommendations to curriculum governance.
    3) Recommendations on improvement of the process.

The results of SE Program Academic Board work are collected by the SE Academic Supervisor for the third and final component of the program outcomes assessment process.

c) Overall analysis of the achievement of each outcome across all courses in which it is assessed.
This analysis is performed by the SE Academic Supervisor who analyzes the reports produced by each individual course instructor and PAO, collects (and generates further) recommendations for improvements at all levels, directs those recommendations to the proper governance bodies, and follows up on actions triggered by those recommendations. He also gathers any feedback from other program-level indirect assessment mechanisms. The SE Academic Supervisor refers suggestions and recommendations to the proper governance bodies, particularly the SE Program Academic Board for consideration and/or action. The supervisor is also charged with following up in subsequent terms on such actions and determining whether recommendations initiated earlier to address any shortcomings have engendered program improvements.

Quantitative data are obtained in direct form from assessments administered by course instructors and PAO. These are validated by the SE Program Academic Board and performance is evaluated by SAO (Percentage of Students Achieving the Outcome that is a

percentage of students who received course final grade not less than 6 according to 10-point scale). Course lecturers apply the results of their assessments and SE Program Academic Board evaluations directly within their classes to remediate any shortcomings.

The SE Program Academic Board evaluates courses and outcomes measured within each course qualitatively and their reports are sent to the SE program academic supervisor. He considers these issues at the program level. Each outcome is considered across all courses, and areas where improvement can be made in specific courses in the curriculum as a whole, in the facilities, or in the assessment/improvement process itself, are considered. Appropriate recommendations are forwarded to the appropriate governance or executive body. Issues from previous terms are tracked and effects of changes monitored. The SE Academic Supervisor may also consider quantitative data from national benchmarks, course grades and evaluations as well as qualitative data from alumni surveys, e-mails, HSE Supervisory Board discussions, governance bodies, etc.
Indirect assessments are carried out via students' and alumni interviews and surveys.

The following is the BSSE Program Assessment Methods Table that shows the type of assessment method, frequency of assessment, media, responsible person and evaluation.

Table 2.

BSSE Program Assessment Methods.

Assessment Method	**Frequency of Assessment**	**Data Collected Media**	**From Whom Collected**	**Responsible for Collection**	**Who Evaluates Data**
Faculty course assessment reports	Course cycle	Online assessment reports	All faculty	Program Academic Supervisor and Program Academic Office	Program Academic Board
Student surveys	Course cycle	Online questionnaires	All students	Program Academic Office	Faculty and Program Academic Board
Meetings of Program Academic Board	Every year at the beginning of the I semester	Consideration and analysis of course programs	Course instructors	Program Academic Supervisor and Program Academic Office	Program Academic Board
Alumni surveys	Every 3 years	Questionnaires, interviews	Alumni within past 3 years	HSE Center of Internal Monitoring	Program Academic Board
Employer surveys	Every 3 years	Questionnaires, interviews	Employers identified by alumni	HSE Center of Internal Monitoring	Program Academic Board

In 2013 it was made self-examination of BSSE program and self-study report was issued upon the results. The following items have been examined:

- Legislative regulations of educational process;
- Organization of the educational process;
- Organization of scientific and methodical work;
- Organization of research work;
- Cooperation with other scientific, educational institutions, companies and enterprises, international cooperation;
- Facilities;

- Directions and methods to improve the implementation of SE program.

Upon the results of self-examination the following inferences have been made:

1. Structure and content of the curriculum, educational programs of the curriculum disciplines, textbooks and other teaching and methodical materials, faculty professional qualification, their teaching and research potential, requirements for the graduate qualifying works, the quality of students' knowledge, facilities fully meet all the requirements of the HSE educational standard and provide a high level of training quality;
2. Faculty and students of SE program carry out active research work in framework of scientific seminars and laboratories, including the international ones. Teachers demonstrate a high publication activity;
3. Dynamics of the basic quality indicators of SE educational program, level of applicants allow suggesting that this program will be actively developed.

The whole training process is organized on the basis of the curriculum which is developed according to the HSE and international educational standards and clarified for each academic year. Curriculum includes a list of all disciplines, their credit hours and sequence. The academic year is divided into two semesters, consisting of two modules (quarters) each. Duration of each module is 8-12 weeks. The exact start and end dates for each module depends on the weekends and holidays of the current year. There is an exam session after each of a module. Time to prepare for the exams is not provided. Students can be appointed 7 exams within seven days of the session, but not more than one exam per day.

Students graduating with the Bachelor degree in Software Engineering are prepared for engineering practice. Curriculum requires mathematics, social sciences, computer practicums in combination with courses in Software Engineering, and research seminars. Computer laboratories and classrooms ensure practical computing experience for every student in the program. The program education component of humanities, social sciences, and economics assures the students have achieved a well-rounded education. Exposure to aspects of engineering professionalism assures the students have been introduced to contemporary engineering issues. All these factors contribute to the achievement of Program Objective 1, to excel in a career utilizing their education in Software Engineering, and to Program Objective 2, to continue to enhance their knowledge.

In the general education courses, students gain fresh perspectives, methods and tools for understanding the traditional and the newly discovered knowledge. The Mathematical Sciences courses help students acquire concepts and skills in logic, inductive and deductive reasoning, and abstract and quantitative thinking. The Humanities courses enable students to think critically about what thinkers (past and present) have to teach us about the non-material qualities of human beings and human values. The Social Sciences courses enable students to investigate human behavior in its social and psychological context. The English language courses enable students to communicate in international environment and be acquainted with the most recent world achievements in the field of computing. The Philosophy course introduces students to the basic concepts of science and the scientific method and enhances awareness of scientific developments and their impact on society and the environment. All these factors contribute to the achievement of Program Objective 3, to be effective in multidisciplinary and diverse professional environments, and to Objective 4, to provide leadership and demonstrate professional integrity.

Besides the basic disciplines, which form the basis of future profession (*major*), students study elective disciplines. Large part of the time is allotted for the research seminars, project, course and practice work. Students are expected to solve real problems by using knowledge and skills obtained during the training. These problems can be both of academic and applied character. Project work includes student activities aimed at creating of a new not previously existing and unknown product (including analytical research). Various categories of employees such as academics and research staff from the HSE departments and institutions even external to the HSE can provide a project and course work. This work develops not only the professional but also universal and social student outcomes.

Curriculum provides also such important educational element as internships and practices. The practice of students is part of the basic educational program and is carried out in accordance with the educational plan and schedule of training process. Its main goal is to acquire the professional skills, to deep and consolidate the knowledge and outcomes obtained by students during a theoretical training.

BSSE program has the following types of practice: educational and technological internship, professionally oriented and graduation practices. Their distribution is as follows:

1. Educational Internship (Freshman Year) – 3 credit hours;
2. Technological Internship (Sophomore Year) – 3 credit hours;
3. Professionally Oriented Practice (Junior Year) – 3 credit hours;
4. Graduation Practice (Senior Year) – 6 credit hours.

Educational Internship is carried out in order to consolidate, extend and deep theoretical knowledge, get initial practical skills in solving of specific problems. Technological Internship and Professionally Oriented Practice are carried out in order to study the teaching, guidance and regulatory materials, specialized literature, to consolidate practical training skills, as well as to collect, systemize and generalize the materials for the graduate qualifying work. Graduation Practice is carried out in order to collect materials for the implementation of the GQW, to acquire professional experience, to improve the outcomes and to test readiness of the future specialists for individual work in professional sphere.

The internships and practices are carried out on the basis of agreements between HSE and enterprises, institutions, organizations irrespective of their organizational-legal forms and forms of ownership. In accordance with agreements these enterprises, institutions and organizations are obliged to provide a places for practical training of students.

The programs (tasks) of internships and practices are developed at SE Department according to the HSE educational standards. After completing the internship or practice students must present to the special commission reviews of practice supervisors and their own reports. The status of the practice bases (enterprises, companies, institutions, etc.) corresponds to appropriate state requirements and the list of companies where our students are trained is constantly reviewed and extended. The most contemporary information technologies are used during the practice training.

The important aim of a learning process is to obtain the individual and teamwork skills in typical software development by participation in real projects of the leading Russian and foreign companies. Our partners are the companies such as:

- *Group-IB* is one of the leading international companies for the prevention and investigation of cybercrime and fraud with the use of high-tech.
- *International company "Prognoz"* develops data visualization systems and advanced analytics for clients focused on improving the efficiency of management and implementation of innovative technologies.
- *Group PMSOFT* is Oracle Platinum level partner.
- *Company "DialogNauka"* is a system integrator, consultant and supplier of integrated solutions in the field of information security.
- *Company "ROSA"* is a Russian center for the development of system software, including the requirements of the Russian legislation in the field of information security.
- *International Center for Informatics and Electronics* is one of the leaders in consulting, project management, development and implementation of large complex projects on information technology and telecommunications.
- *Company "WebGames"* is one of the largest developers of free-to-play games in Russia.
- *NetCracker Technology* is the proven, strategic partner delivering mission-critical solutions to communications service providers around the world
- *Yandex* is a Russian Internet company which operates the largest search engine in Russia with about 60% market share in this country. It also develops a number of Internet-based services and products. Yandex ranked as the 4th largest search engine worldwide, with more than 150 million searches per day, and more than 50 million visitors (all company's services) daily.
- *R-Style Softlab* is a leading developer and integrator of banking software, belongs to the international group of companies Asseco.
- *FORS* – group of companies, whose activities cover the full range of tasks for the supply of software and hardware systems, designing informational systems, developing infrastructure solutions, rendering technical support and training.
- *Kaspersky Laboratory* is an international company working in the field of informational security.
- *InterProgma* is one of the leading Russian manufacturers of hi-tech and software.
- *Empatika Consulting Company* develops system solutions for business.
- *AT Consulting* is one of the strongest players in the market of information technology and IT services to telecommunication, financial, state, fuel, energy and other companies.
- *JetBrains* provides developers with smart professional tools that help them write clean, quality code and deliver better software faster.
- *Group HeadHunter* provides the searching of a job in various fields of human activity.

We want to confirm the high international educational level of our program. Taking into consideration the world recognized reputation of ABET HSE authorities adopted the decision to accredit BSSE program at ABET Engineering Accreditation Commission. In 2015 the process of accreditation was started and preliminary self-study report has been sent. We hope that program's level corresponds to the world recognized educational standards and accreditation will confirm this fact.

In our report we would like to share our ten-year experience in developing and implementing BS program in the continuously changing field of software engineering.