S-curves of R. Foster's Technological Processes and Labor Market Challenges to the Higher Education System

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Annotation

It is shown that the rapid changes taking place in modern society put forward new requirements for the training of engineering personnel and create certain challenges to the education system, which should not only train qualified personnel to work with existing high-tech technologies, but also work for the future. Under these conditions, new approaches have been used to effectively train IT specialists, allowing them to develop tolerance to uncertainty, and prepare them for life and work during technological discontinuity. The implementation of such approaches is carried out by developing a self-established educational standard of higher education in the field of training "Information systems and technologies", which takes into account the conflicting requirements of production and society based on the Federal state educational standard and professional standards in the relevant fields of activity. On the basis of the proposed standard three educational programs have been developed, taking into account both the needs of the regional labor market and the objectives of the programs "Digital Economy of the Russian Federation", the development of the North Caucasus Federal District and North Caucasus Federal University, which allows to prepare a competitive, ready for innovation activities and self-actualization of Master's degree.

Keywords [1]

Educational standard, educational program, technological discontinuities, professional competencies.

1. Introduction

In 1987, a translation of the book by American innovation specialist Richard Foster was published in Moscow, where a large number of examples analyzed the life cycle of various production technologies [1]. The main idea of R. Foster is that the life cycle of any technology corresponds to an S-curve (figure 1). In section I, efforts do not lead to noticeable results. This section corresponds to research, development, implementation, and pilot operation. In area II, relatively little effort can lead to noticeable results. This is the area of successful operation of the production technology. And in section III, efforts are yielding fewer results. In the end, any technology completes its life cycle completely and gives way to other technologies on the market. The transition from one technology to another or from one S-curve to another S-curve corresponds to a technological discontinuity.

If we analyze the technological discontinuities in the field of computer science and technology, it is easy to see that they occurred frequently in the twentieth century. The time required to complete the entire S-curve depends on many factors. In particular, the transition time from one generation of processors to another is measured in years, and the lifetime of data carriers can vary from tens of

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years for perforated tapes and perforated cards to thousands of years for paper. Technology discontinuities have become more frequent recently, and will continue to occur more frequently in the coming years. It is difficult to predict how many technological discontinuities will occur during the 40 years that a University graduate must work before retirement, how many new professions will appear during this time, and how many will disappear. But the high rate of development of the industry creates certain challenges to the education system, which usually lags behind the advanced achievements of production.

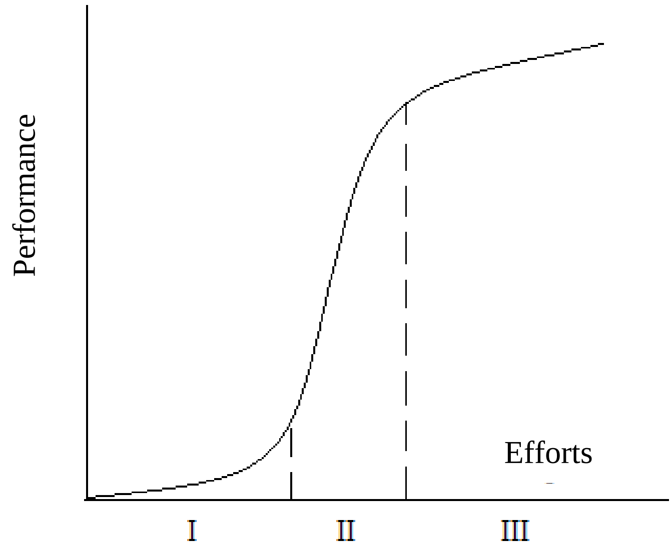

Figure 1: S-curve

The point of view of employers is usually reduced to the requirements to form the graduate's competencies and practical skills that will allow him to quickly master the work on a specific technology on the second section of the S-curve. There is often a fair remark from employers to Universities that graduates have to finish their education in the workplace.

The authors of the article have experience in successfully passing professional and public accreditation in the field of training 09.04.02 "Information systems and technologies". The requirements of the accreditation Agency were mainly limited to the application of a practice-oriented approach to the training of engineering personnel, which focuses on practice and the formation of practical skills. Thus, professional and public accreditation is focused on training personnel to work on the second section of the S-curve, and the approach of the accreditation Agency coincides with the approach of employers who need qualified personnel "here and now". The needs of society and the need for sustainable development of the Russian Federation dictate a slightly different approach. From the taxpayers ' point of view, the training of engineering and technical personnel is expensive and time-consuming, so if there are technological discontinuities, it is better to retain engineers, provide them with professional retraining or additional education, rather than training from the very beginning. Conflicting demands from employers and society create certain challenges to the education system, which must not only train qualified personnel to work with existing high-tech technologies, i.e. solve the problem of an acute shortage of qualified engineering and technical personnel at the present time, but also work for the future.

2. Goals and objectives of the study

A specialist in the field of computer science and computer engineering must understand the inevitability of constant changes and be ready to master new technologies. No matter how successful the information technology used today is, another one will come tomorrow. Therefore, the modern education system should prepare graduates not only to work with modern high-tech technologies today, but also to the technological discontinuities that will occur tomorrow. This means that the graduate must not only acquire the necessary set of competencies and practical skills to work on real projects today, but also acquire fundamental University knowledge that allows analyzing industry trends and making forecasts for both personal career and employer. Therefore, when developing curricula, Universities, in addition to practices and practice-oriented disciplines, must also include disciplines that form tolerance to uncertainty [2], intellectual curiosity, the ability to constantly learn new things, apply a systematic approach, and identify system-wide connections and patterns. These disciplines should prepare the graduate for life and work in conditions of uncertainty, i.e. during technological discontinuities.

Perhaps this approach was taken into account when working on the educational standards of the Federal state educational standard 3++, which increased the share of theoretical disciplines in the preparation of masters. For example, for the field of study 09.04.02 the transition to the new Federal state educational standards 3++ increased the volume of compulsory subjects is about 20 s.e. accordingly, reducing the amount of practices. In addition, the necessary universal competencies are formulated, mastering which graduates of the master's program will receive deep fundamental knowledge necessary for working not only with modern high-tech technologies, but also in conditions of uncertainty.

The purpose of this work was to present the self-established educational standard of higher education of the North Caucasus Federal University, to create and study educational programs of various profiles.

3. Analysis of literature

The need to develop tolerance to uncertainty is currently widely discussed. Various problems that arise in conditions of uncertainty are discussed in works that discuss the problems that arise when forming the course structure [3], when modifying the cognitive model of leadership in conditions of uncertainty [4], when building a system model of change processes [5], in the process of evolutionary activity education [2]. Tolerance to uncertainty as a psychological phenomenon is described in [6]. The conference "Man in the conditions of uncertainty" of the Samara state technical University was devoted to a wide coverage of educational problems in conditions of uncertainty (reference to the collected works is given in [2]). The requirements for an uncertainty-tolerant specialist formulated in [2] fully apply to the IT specialist. However, the training of an IT specialist should have features related to the fact that technological discontinuities in their professional activities occur much more often than in other industries. Therefore, when developing curricula and programs, it is necessary to take into account not only evolutionary, but also abrupt changes.

A list of the key competencies of the digital economy formulated in the document "the Order of Ministry of economic development dated 24 January 2020 № 41 "On approval of methods of calculation of indicators of the Federal project "Personnel for the "digital economy" national programme "Digital economy of the Russian Federation". One of them (competence 2) is self - development in conditions of uncertainty. This competence implies the ability of a person to set educational goals for the emerging life tasks, to select solutions and means of development (including using digital tools) of other necessary competencies. Another aspect of the application and implementation of new information technologies is related to the fact that new technologies also bring new dangers to their users. Software developers insert so-called "bookmarks" into it, which can be controlled remotely. It is no accident that after the introduction of sanctions, the "import substitution" direction appeared in our country, which has not yet received wide support, but has created new challenges to the education system. This leads to the need to introduce disciplines related to information security into the educational process. For new information technologies and, accordingly, for new S-shaped cycles, it is necessary to use a systematic approach, analyze both the advantages and risks of their use.

Our country is not only characterized by technological backwardness from industrialized countries [7] and the desire to accelerate the transition to new high-tech technologies, which is enshrined in a number of government documents, but also the lack of a unified architecture, a secure national platform, and an information technology development strategy. In order to meet the requirements set out in the document “Digital economy” [8], it is necessary not only to develop the competencies necessary for graduates to work with distributed registry systems, blockchain and smart home technologies, cloud technologies, etc., but also the competencies that allow them to analyze both the advantages and risks of using them.

Good scientific and technical literature plays a very important role in obtaining fundamental education. The current requirement for the year of publication of textbooks, which prescribes the use of only new textbooks published no more than 10 years ago for classical subjects and no more than 5 years ago for new special courses, must be applied informally. For new special courses that study new processes, concepts, and technologies, of course, new textbooks are also needed. Information and communication technologies go through their entire life cycle very quickly, and textbooks in this area are rapidly aging. But for classical disciplines, there are wonderful textbooks written decades ago that have world authority and have not lost their relevance. These include "Theoretical physics" by L. D. Landau and E. M. Lifshitz, "Operations Research" by E. S. Wentzel, "Numerical methods" by A. A. Samarsky, and others. The ban on the use of well-known authoritative textbooks just because they were published earlier is unjustified. This shows a lack of confidence in teachers, who have the right to choose their own textbooks to ensure high-level education.

Another challenge to the education system is the universal introduction of distance technologies due to the virus pandemic. One of the aspects of the mass transition to distance learning technologies is to increase competition between Universities and teachers. Lectures by leading professors from leading Universities and educational materials from their own University are equally available to students on-line. This is very good, but as practical experience shows, the use of distance learning is not so much due to the desire to improve the quality of training, but rather to reduce costs and is aimed at partial, and in the future, perhaps, complete replacement of the full-time training system, and as a result, the rejection of the traditional training system, which is especially harmful for engineering education, which should be fundamental. In [9], it is pointed out that "young people are less interested in traditional forms of education", so distance education should not compete with the traditional full-time form of education, but should help it.

Traditionally, engineering training was based on basic (fundamental) mathematical and natural science education, since the engineer's activity consisted of creative scientific work, the results of which were implemented in technical practice. Currently, the curriculum is reducing the hours allocated to the study of mathematical and natural science disciplines, which affects the quality of engineer training. However, modern realities are such that information technologies belong to a rapidly developing field of knowledge, without mastering which it is impossible to train a highly qualified specialist for any, even well-established, field of knowledge. IT technologies have not only received rapid development, but also increased their knowledge intensity, and this, accordingly, requires a qualitatively new training of an engineer who is not only a user, but also a developer of this technology, who in modern conditions needs to perform not only the functions of a technical specialist, but also a scientist in solving specific knowledge-intensive tasks, and in some cases, the head of serious innovative projects. When preparing an engineer who has the necessary skills for effective work, it is necessary to focus on the mandatory repetition, and in some cases, the study of basic mathematical and natural science methods and laws within special disciplines, without knowledge of which it is impossible to study special disciplines in depth. It is necessary to provide a systematic presentation of the mathematical foundations, system analysis, probability theory, etc. from the angle of their practical use in solving specific engineering problems, and the presentation should be conducted with appropriate mathematical rigor based on the current level of science development.

Another issue that I would like to focus on is that currently there are no scientifically based recommendations on the application of sanitary standards when using modern computer equipment and various kinds of gadgets in educational activities when conducting remote classes with students of higher educational institutions, which are fixed by law. In sanitary standards there are General guidelines for the organization of labor and leisure in the use of computer technology. In conditions of self-isolation, when not only our country, but also other countries had to switch to distance learning due to the coronavirus pandemic, this issue is almost of primary importance, since it concerns both the health of the younger generation and their teachers. Students are forced to spend more time on the computer than in traditional training. Moreover, the initial interest that arises almost always when a person is faced with something new gradually fades and apathy comes, since students who are isolated, outside the team that solves the same problems, do not feel the spirit of competition.

Teachers, in turn, are forced to spend a large amount of time not on professional development in their subject area, but on getting acquainted with various technical and software tools necessary for conducting classes in remote mode, configuring and debugging them, as well as preparing for this type of classes.

4. Methodology

The development of a self-established educational standard for higher education of the North Caucasus Federal University was carried out on the basis of the Federal standard 3++, taking into account the requirements of professional standards for the following areas and areas of professional activity of graduates:

01 Education and science (in the field of education and research in the field of information systems and technologies);

06 Communications, information and communication technologies (in the field of research, development and implementation of information technologies and systems);

40 Cross-cutting professional activities in industry (in the field of organization, management and conducting research and development in the field of information systems in various fields and areas of the digital economy).

5. Results

This paper describes the results of the development of the self-established educational standard in the direction of training 09.04.02 "Information systems and technologies", taking into account modern requirements and features of training IT specialists. The self-established educational standard is developed on the basis of the Federal state standard 3++, it contains basic disciplines, variable disciplines and practices. Universal and General professional competencies of the self-established educational standard meet the requirements of the Federal standard in the direction 09.04.02 "Information systems and technologies". Professional competencies are divided into two groups: mandatory professional competencies and professional competencies determined based on the directivity (profile) of the master's program, based on professional standards that correspond to the selected type (one or more) of professional activity of graduates.

A graduate who has mastered the master's program, regardless of the directivity (profile) of the educational program, must have professional competencies (PC) that correspond to the solution of professional tasks in research activities, which are mandatory: PC-1(Able to carry out mathematical modeling and research of information processes, systems and technologies, objects, and devices of computer technology based on modern computer modeling packages), PC-2 (Able to develop and research theoretical and experimental models of objects of professional activity in various fields) и PC-3 (Able to plan and conduct experiments, process and analyze results using modern information technologies).

The basic block of master's programs included the following subjects: Mathematical support of decision support systems (4 ECTS), Methods of research and modeling of information processes and technologies (7 ECTS), System engineering (7 ECTS), Organization and management of scientific research and educational activities in the field of information systems (6 ECTS), Systems of computer modeling of business processes (4 ECTS). Thus, the study of the basic block disciplines should prepare the graduate for a broad systematic approach to the current state and prospects of the industry; decision-making in conditions of risk and uncertainty; search for innovative approaches to solving complex problems.

Three master's degree programs have been developed on the basis of the self-established educational standard: "Data Management"; "Information Systems in Science and Industry"; "Software For Robotic Systems". The features of these educational programs are reflected in the variable modules.

For the educational program "Data Management", the variable module includes the following subjects: "Application of Mathematical Logic in Control Systems", "Parallel computing", "Computational and Experimental Methods in Scientific Research"," Modern Trends of the

Information Systems Development", "Artificial intelligence Systems"," DataBases in High Performance Information Systems".

For the educational program "Information Systems in Science and Industry", the variable module includes the following subjects: "Logic and Methodology of Science", "Multimedia Technologies in Professional Activity", "Computational and experimental methods in scientific research", "Information systems in science and production", "Neurotechnologies and Artificial Intelligence", "Industrial Internet", "Web Mining".

For the educational program "Software For Robotic Systems", the variable module includes the following subjects: "Logic And Methodology of Science", "Robotic Systems", "Programming Of Robotic Systems", "Neural Networks And Deep Learning", "Educational Robotics", "Web Mining", "Industrial Robotics",”Artificial Intelligence", "Industrial Internet".

When studying the disciplines of variable modules, the focus is on: technologies for processing, storing, transmitting and protecting information, organizing and processing big data; software development, technologies of information systems; web technologies; technologies based on forecasting methods and the use of intelligent systems, data mining methods and algorithms for analyzing and processing data of complex structure, unstructured data and data in natural languages used in solving scientific and applied problems in the field of science and production.

6. Discussion

Experience in developing and using of the self-established educational standards in educational activities has shown that their main advantage is the ability to: form their own set of competencies depending on the directivity (profile) of the master's program in this area of training; vary the labor intensity of the basic and variable parts of the educational program, freedom to choose both fundamental and applied disciplines that reflect the directivity of training; use their own standards and tools for assessing the quality of training that adequately reflect the degree of competence formation among students as a result of mastering the chosen training program.

Thus, the training of masters on the basis of the self-established educational standards allows you to solve the problem of preparing a competitive, ready to innovate and self-actualize master in the field of information systems and technologies, who is able to solve professional problems and has a sense of responsibility.

7. Conclusion

When training engineering and technical personnel, it is necessary not only to take into account the practice-oriented approach and the need to develop tolerance to uncertainty, but also to prepare masters for work and life, taking into account possible technological discontinuities as an inevitable component of scientific and technological progress.

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