Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Digital transformation of learning processes and the development of competencies in the virtual machine-building enterprise environment

IOP Conf. Series: Journal of Physics: Conf. Series **1278** (2019) 012008 doi:10.1088/1742-6596/1278/1/012008

Digital transformation of learning processes and the development of competencies in the virtual machine-building enterprise environment

B Pozdneev[1], A Tolok[2], P Ovchinnikov[3], I Kupriyanenko[4], A Levchenko[5] and V Sharovatov[6]

[1,3,4,5,6]*Moscow State University of Technology "STANKIN"*, 3a, Vadkovsky Per., Moscow 127055, Russian Federation
[2]*ICS Academician V A Trapeznikov of RAS*, 65 Profsoyuznaya Street, Moscow 117342, Russian Federation

[1]E-mail: bmp@stankin.ru
[2]E-mail: atol@ipu.ru
[3]E-mail: p.ovchinnikov@stankin.ru
[4]E-mail: i.kupriyaneko@stankin.ru
[5]E-mail: a.levchenko@stankin.ru
[6]E-mail: viktor-sharovatov@yandex.ru

Abstract. The paper presents the results of the pilot project "Virtual Machine-Building Enterprise". It was developed for multi-level learning to meet the needs of the national digital economy and the digital industry. The profile of requirements for end-to-end learning (baccalaureate - magistracy - postgraduate) of prospective personnel in the digital development of machine-building enterprises has been substantiated. E-Portfolio model has been developed in accordance with the requirements of the standards GOST R 57720-2017 and ISO/IEC TR 20013:2015 to manage the digital competency development in the learning process and practical activities. The pilot project "Virtual Machine-Building Enterprise" was implemented at the initiative of MSUT "STANKIN". It is a corporate technological platform for the digital machine-building development with the participation of industry, IT sector and technical universities. The architecture and functional model of a virtual enterprise are developed taking into account the principles of Industry 4.0, fundamental standards in automation systems integration (ERP, MES, CRM, CAD, CAE, CAPP, PLM, etc.) and e-learning (LMS, CMS, etc.). The educational programs are developed in accordance with the requirements of the FSES 3++, Professional Standards and qualification requirements for Chief Digital Officer. In the future, the pilot project "Virtual Machine-Building Enterprise" should be the basis for the formation of a digital technological university model.

1. Digital Transformation of learning in condition of national scientific and educational environment's formation

The national strategy of the digital economy development and the implementation of the priority national projects "Digital Economy of the Russian Federation", "Education", "Science", "Labour Productivity and Employment" provide for widespread introduction of end-to-end digital technologies in key areas of economic and social sphere. In the scientific and technical sphere and industry, the application of digital technologies should become the basis for the creation of smart industries and digital factories of the future in accordance with the concept of Industry 4.0 and a new generation of standards that ensure the distributed architecture for production management and formation of end-to-end value chains [1-12]. Due to this, the competitiveness of the domestic industry and, first of all, the machine-building sector, which is the basis for the sustainable development of the country's economy, should be ensured.

The introduction of end-to-end digital technologies and the creation of smart industries and digital enterprises necessitates targeted training and retraining of personnel in digital development [13]. In accordance with this strategic objective, the national priority project “Digital Economy of the Russian Federation” (direction “Personnel for the Digital Economy”) provides for the creation of centers for accelerated training of specialists together with companies of the digital economy and the development of new digital university models, which is the basis for the formation of a digital scientific and educational environment [14].

It should be pointed out that over the past twenty years, the scientific and educational sphere of the leading world countries has evolved towards the creation of integrated information and telecommunication environments, wide use of the Internet, the use of distance learning technologies and the development of new forms of e-learning [14]. The problems of integration and interoperability of multiple learning management systems (LMS), e-libraries and content management systems (CMS) have necessitated the standardization of these emerging areas at the international and national levels in all leading and many developing countries [14].

In 1999, for the standardization of IT in the field of learning, education and training in the ISO/IEC JTC 1 was created SC 36 “Information Technology for Learning, Education and Training” (ITLET), which has now developed more than 50 international standards, which regulating the main aspects of e-learning and training [15]. In 2004, a new TC 461 “Information and Communication Technologies in Education” (ICTE) was also created in the structure of Federal Agency on Technical Regulation and Metrology (Rosstandart). TC 461 actively participates in the work of SC 36 and is developing a set of national standards on ICT in education [16]. Currently, more than 45 national (GOST R) and interstate (GOST) standards have been developed, harmonized with the fundamental international standards and form the basis of the national e-learning profile. Currently, the management of TC 461 has begun to develop the structure of a new set of national standards “Digital Scientific and Educational Environment”, which includes the standard “Digital University” [16]. On this basis, a conceptual model of the scientific and educational environment is proposed (figure 1). The model of a Virtual Machine-Building Enterprise presented in the paper is considered as a key component of a digital technological university that meets the needs of the machine-building industry.

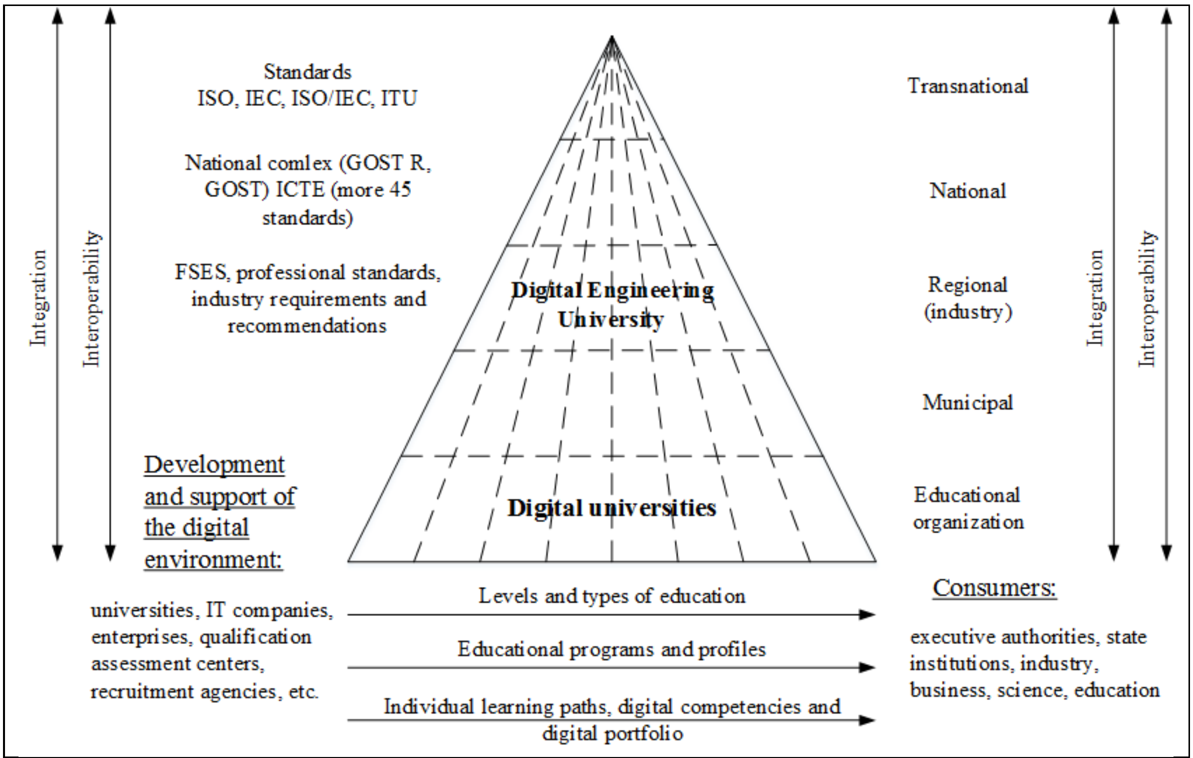

Figure 1. Conceptual model of digital scientific and educational environment.

2. Competency development in stages of learning and practical activity

In Russia, the requirements for educational programs in learning institutions are set out in Federal State Educational Standards (FSESs) and the requirements for employees of some professions are in Professional Standards. Professional Standards define 9 qualification levels (it presented within generalized labour function). In 2015, the Ministry of Education and Science of the Russian Federation issued recommendations for actualization of existing FSESs of higher education, taking into account accepted professional standards. The model of relationship between qualification and education levels is shown in figure 2 [17].

As an example of harmonization of FSESs and Professional Standards, MSUT "STANKIN" has launched magistracy educational program 09.04.01 "Informatics and Computer Engineering" by profile "Methods and Tools for Information Systems Design" under FSES 3++. This program has 34 competencies: 9 common cultural, 6 common professional and 19 professional competencies. It covers 3 Professional Standards: "Information Technology Manager", "Information System Specialist" and "Head of Software Development". 10 generalized labour functions from 11 of Professional Standards (the unselected is implemented in postgraduate) were selected in the program. The most appropriate to profile, labour functions were selected (a total of 30 out of 214 were selected) from each generalized labour functions. Labour functions contain certain labor activities (a total of 126 out of 760). Currently, MSUT "STANKIN" has new educational programs under FSES 3++. It is aimed at training Chief Digital Officer (CDO).

The interrelationship of qualification, labour functions and competencies acquired by students as a result of mastering basic educational programs, additional professional education and practical experience should be reflected in e-Portfolio. In 2015, ISO/IEC JTC 1/SC 36 published the international standard ISO/IEC TR 20013:2015 "Information technology for learning, education and training -- A reference framework of e-Portfolio information".

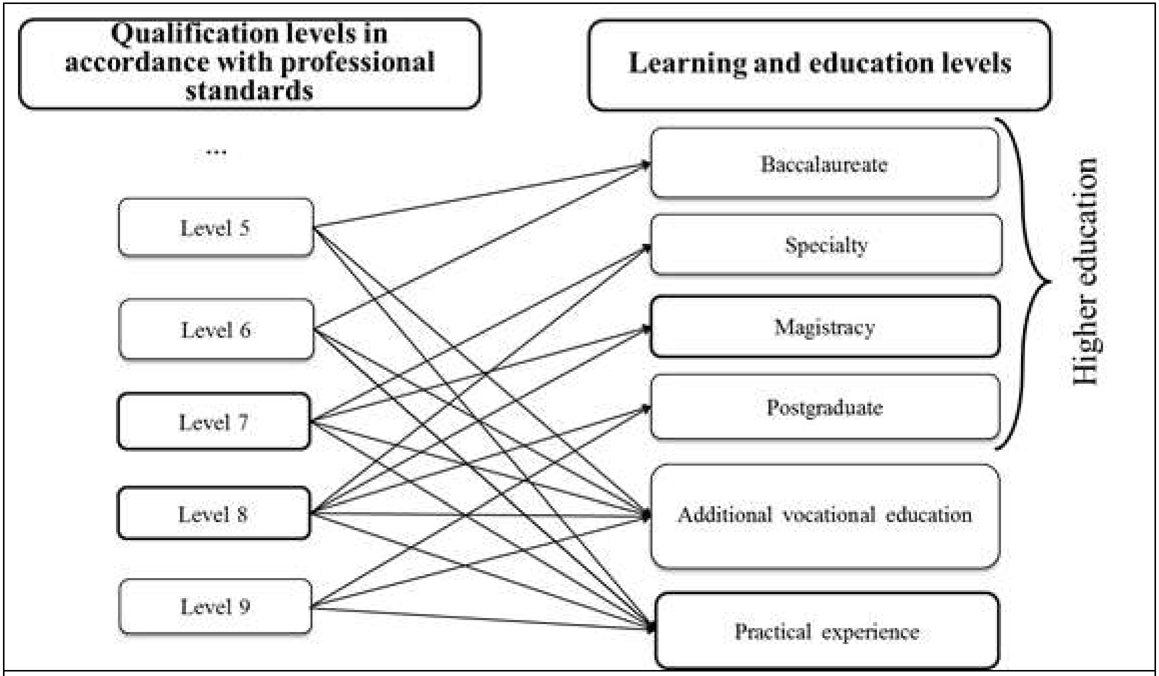

Figure 2. Relationship between qualification and education levels.

In 2017, TC 461 developed the standard GOST R 57720-2017 "Information and Communication Technologies in Education. E-Portfolio information basic structure", taking into account the specifics of the Russian education and labour market. E-Portfolio information basic structure includes information on the acquisition of knowledge, skills, competencies and qualifications as a result of learning in educational organizations of general, secondary (professional), higher and additional education, self-education outside the educational organizations, continuous professional development and also as a result of social activity. E-Portfolio should contain the information for personal data identification, levels and types of education, individual characteristics and achievements, professional opportunities and career path. E-Portfolio formation should take into account the needs of main stakeholders: students and employees, educational organizations, employers and recruitment agencies, participants of an independent qualification assessment system. The main components of e-Portfolio are presented as an abstract model in figure 3 [17].

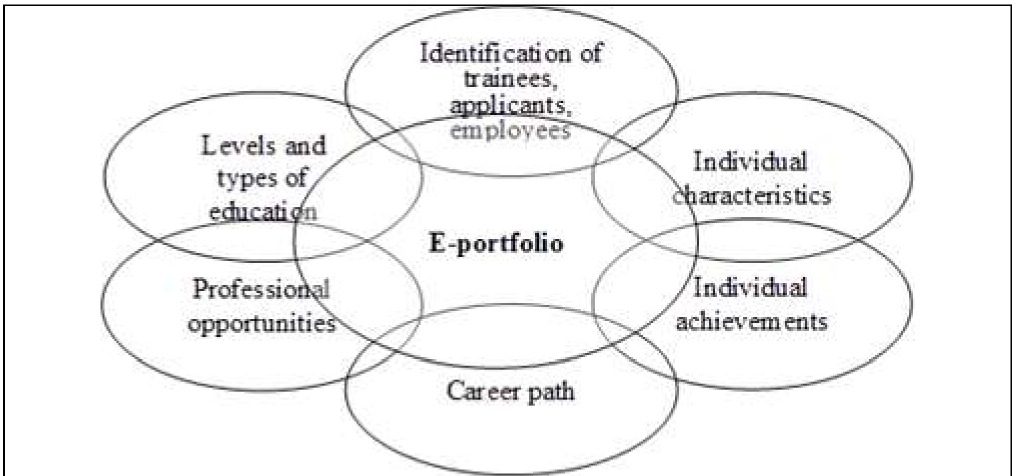

Figure 3. Abstract model of e-Portfolio components.

3. New educational programs and profiles

As a result of the reorganization, the Institute of Information Systems and Technologies was established at MSUT "STANKIN" in 2016. One of its objectives is to integrate education, science and manufacturing by using the results of scientific researches and technical advances in educational activities and by establishing mutually beneficial relationships between educational, research and development, scientific and engineering institutions, enterprises and organizations as a unified collective system for the availability and use of innovative scientific knowledge and technologies in education, economy and social sphere.

As at 2019, in view of the adoption of FSESs 3++ and market needs, education in the Institute is carried out the following educational programs and profiles:

Baccalaureate

09.03.02 Information Systems and Technologies:

- Intelligent Control Systems in Digital Economy and Industry 4.0;
- Information Communication Systems and Internet of Things;

Magistracy

09.04.01 Informatics and Computer Engineering:

- Methods and Tools for Information Systems Design;
- Integrated Control Systems of Digital Manufacturing and Enterprises;
- Imitation Modelling in Virtual Enterprise Environment;
- Software and Project Management;
- Engineering Geometry and Computer Graphics;
- Computer Modelling of Complex Technical Systems;
- Corporate Knowledge Management Systems.

Postgraduate

09.06.01 Informatics and Computer Engineering:

- 05.13.01 System analysis, Control and Information Processing (in Machine-Building);
- 05.13.06 Automation and Control of Technological Processes and Manufacturing (in Machine-Building);
- 05.25.05 Informational systems and processes;
- 05.13.18 Mathematical Modelling, Numerical Methods and Software Complexes.

These educational programs are carried out with the use of the environment of the Virtual Machine-Building Enterprise.

4. Learning and digital competency development in the environment of the Virtual Machine-Building Enterprise

Learning and training in condition of digital manufacturing has a key value. Educational and scientific processes should be ahead of the current development, focus on the practical use of knowledge and research in enterprises and organizations. The educational process should be more technological, including the transfer of knowledge, obtaining information from a variety of sources. At the same time, it is necessary to effectively develop e-learning. It has its own standards, which are vital for the creation and use of technological systems in education, and they should be developed on the basis of an education management system [18].

An in-depth study of available information with the use of knowledge management technologies is required, and traditional personnel management systems are transformed into talent management, learning and development of employees. Willingness of the company in transition to digital production, in addition to readiness for material costs and changes in business processes, requires highly qualified personnel. In the aspect of import substitution, it is necessary to motivate domestic IT companies to create research and educational testing grounds on the basis of leading universities in order to accelerate the development of promising information software and platforms in the field of digital manufacturing.

Taking into account these promising tasks, in October 2018, at the initiative of the management of MSUT STANKIN, the Association “Digital Innovations in Mechanical Engineering” (ADIME) was established, which was founded by leading industrial enterprises, IT companies and leading Russian universities. One of the aspects of the ADIME activity is related to training and retraining of personnel for the creation of digital defense enterprises based on the study of best practices, international and national standards in such key areas as information technology, interoperability, strategic management, knowledge management, risk management, quality management, etc. Without this, it is impossible to train personnel of a new formation, that capable of creating digital factories of the future and highly competitive products for the internal and external markets.

This activity should take into account existing best practices and standards. An important step towards the implementation of Industry 4.0 on a practical level is the use of the Reference Architecture Model Industry 4.0 (RAMI 4.0), which is described in DIN SPEC 91345:2016-04. It displays the main aspects of the concept of Industry 4.0 in a three-dimensional coordinate system [1, 3, 6, 19].

The first axis “Hierarchy Levels” of RAMI4.0 displays the hierarchy levels in accordance with the standards IEC 62264 (a series of international standards for the integration of computing and control systems of the company). The second axis “Life Cycle and Value Stream” of RAMI4.0 displays the life cycle of production facilities and products. This axis is constructed in accordance with standards IEC 62890, which regulates life cycle management. The third axis “Layers” of RAMI4.0 defines the display of information technology and contains digital images, for example, machines or systems, in several layers.

In the aggregate, these three axes create a comprehensive model of all major aspects of the Industry 4.0 concept. The introduction of RAMI 4.0 facilitates communication and sharing of the best practices among specialists and also simplifies cooperation between industrial enterprises. The reference model is the basis for developing standards that should ensure the integration and interoperability of all Industry 4.0 systems.

Currently, MSTU "STANKIN" together with 1C Company and ASCON are implementing the creation of the pilot project “Virtual Machine-Building Enterprise” (see figure 4), which assumes its further development in the form of a corporate environment for ADIME members and other interested parties.

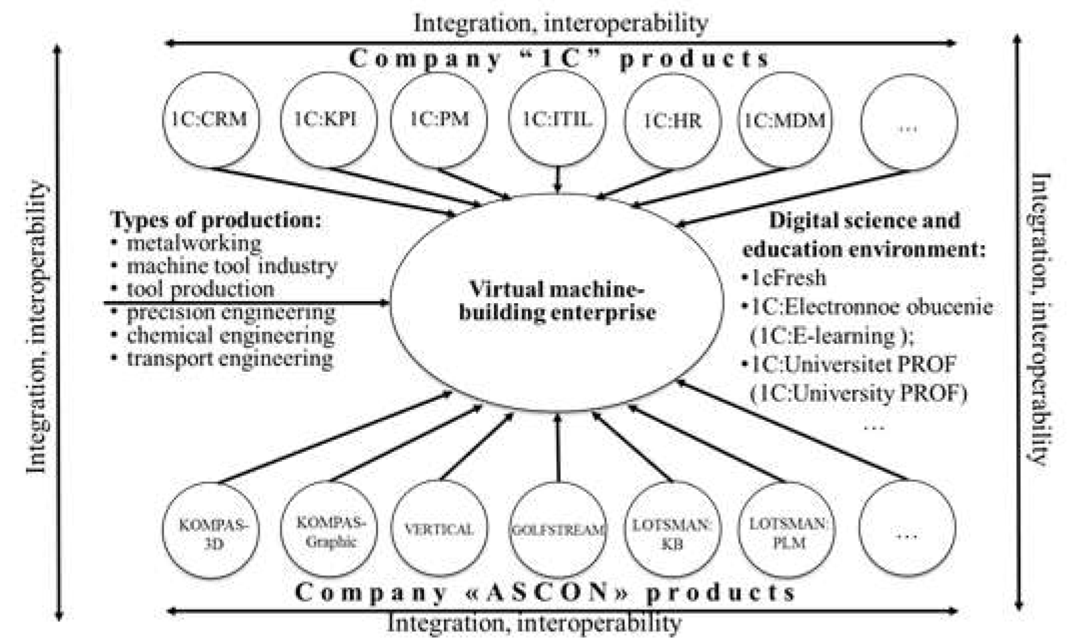

Figure 4. Digital environment of the Virtual Machine-Building Enterprise.

The corporate environment of the project “Virtual Machine-Building Enterprise” is capable of ensuring that students learn the most modern and effective ways and tools of managing enterprises. The Virtual Machine-Building Enterprise includes databases and knowledge bases in the field of digital models of production objects, technologies, equipment and digital production areas. The pilot project should ensure that students master the most modern and effective ways and tools of managing enterprises [20, 21].

Conclusions

1. New approaches to the digital transformation of learning processes have been developed and tested on the basis of the implementation of the pilot project “Virtual Machine-Building Enterprise”. These approaches aimed at personal competency development in the emerging digital scientific and educational environment.

2. The developed educational programs and profiles allow to manage the educational activities’ processes and provide targeted training and retraining of personnel for the digital development of machine-building industries, which is the basis of the national economy.

3. The implementation of a virtual university based on the best domestic software allowed to ensure the integration and interoperability of the digital learning environment, as well as solving the issues of independence in a strategically important scientific and educational sphere. The pilot project “Virtual Machine-Building Enterprise” can become the basis for the development of a digital technological university model, envisaged in the activities of the direction “Personnel for the Digital Economy” of the priority national project “Digital Economy of the Russian Federation”.

References

[1] Schwab K, Davis N and Nadella S 2018 *Shaping the Fourth Industrial Revolution* (World Economic Forum)
[2] Rogers D 2016 *The Digital Transformation Playbook: Rethink Your Business for the Digital Age* (Columbia Business School Publishing)
[3] Adolph L et al. 2018 German standartization roadmap. Industrie 4.0. Version 3. (DIN e.V.)
[4] Schuh G, Anderl R, Gausemeier J, and Hompel M 2017 *Industrie 4 Maturity Index. Managing the Digital Transformation of Companies* (acatech STUDY)
[5] Wang J M, Zhang L, Liu Y B, Mo X N, Ren G Q 2010 *Computer Integrated Manufacturing Systems* 1**6**(10) 2017-2023
[6] Böhler P, Dittmann J, Michaelis D and Middendorf P 2016 *Lightweight Design, 2016 Springer Process Simulation as Part of Industry 4.0*
[7] Borovkov A I 2017 *Digital manufacturing. Methods, ecosystems, techologies* [In Russian – Tchifrovoe proizvodstvo. Metody, ekosistemy, tekhologii] (SKOLKOVO)
[8] Lipkin E 2017 *Industry 4.0. Smart technologies.* [In Russian – Industriya 4.0. Umnye technologii – kluchevoi element v promyshlennoi konkurentchii]
[9] Mokrozub V G and Nemtinov V A 2015 *Chemical and Petroleum Engineering* **51**(7–8) 487-492
[10] Mokrozub V G, Manuilov K D, Gorshkov V V and Gorshkova T S 2016 *Chemical and Petroleum Engineering* **51**(9) 613–618
[11] Malygin E, Mokrozub V and Nemtinov V 2017 *International Conference on Modern Trends in Manufacturing Technologies and Equipment, ICMTMTE*
[12] Nemtinov V A, Borisenko A B, Nemtinova Y V, Gorelov A A and Tryufilkin S V *Scientific Visualization* **10**(3) 99-107
[13] Rudskoy A, Alexandrov A, Chubik P, Borovkov A, Romanov P 2018 *The main professional educational programs of higher education. Design and implementation mechanisms based on labor market requirements. Area of education "Engineering, technology and technical science"* [In Russian – Osnovnye professionalnye obrazovatelnye programmy vyshego obrazovaniya. Mehanizmy proektirovaniya i realizatsii na osnove trebovanii rynka truda.

IOP Conf. Series: Journal of Physics: Conf. Series **1278** (2019) 012008 doi:10.1088/1742-6596/1278/1/012008

Oblast obrazovaniya “Inzhenernoe delo, tehnologii i tehnicheskie nauki”]. (Publisher of Polytechnic University)
[14] *Pedagogics* 2018 [In Russian – Pedagogika] **V/ 4** 98-125
[15] Rubin Y, Shadrikov V, Kovalenko A, Lednev V, Rubin M, Semkina T, Soboleva E and Stepanchenko L 2016 *System for assessing the quality of education: World practice and Russian experience* [In Russian – Sistema otchenki kachestva obrazovaniya: Mirovaya praktika i rossiiskii opyt] (MUIF “Synergy”)
[16] Pozdneev B, Busina F and Ivannikov A 2016 Smart Education and e-Learning 2016 *Smart Innovation, Systems and Technologies (SIST)* **59** (Springer International Publishing) 73–82
[17] Pozdneev B, Busina F, Sutyagin M, Ovchinnikov P, Sosenushkin S, Obuhova E, Levchenko A and Sharovatov V 2017 *ICERI2017 Proceedings* 3928–3937
[18] Prokhorov A and Konik L 2018 *Digital Transformation: Analysis, trends, world experience* [In Russian – Tsifrovaya transformatsiya: analiz, trendy, mirovoy opyt] (Ridero).
[19] Roth A 2016 *Introduction and implementation of Industry 4.0* [In German – Einfuhrung und Umsetzung von Industrie 4.0] (Springer-Verlag)
[20] Pozdneev B, Ovchinnikov P, Busina F and Obuhova E 2018 *INTED2018 Proceedings* 2715-2720
[21] Andrichenko A 2016 *Stankoinstrument* **4** 54-62