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Information Technologies and University Education in Digital Economy Context

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Abstract. **Knowledge-based innovations have emerged as a major driver of economic growth in the 21st century. Universities have been one of the leading drivers of new knowledge for many centuries. The study aims to analyze the transformation of universities into innovation actors in digital economy building and using digital and information technologies in this process.**

For analyzing this problem, the system approach is used. The university is seen as a complex system of production and dissemination of knowledge, interacting with other systems of creation, distribution and use of knowledge in society.

The article concentrates on designing and redesigning concepts on knowledge production and innovation. The key points are the Triple Helix, Quadruple Helix, and Quintuple Helix for innovation, Mode 1 and Mode 2 for knowledge production and digital university as a component of digital economy.

These concepts are all published and thus publicly accessible.

The article based on a literature review on these concepts. Authors propose the concept of the Digital Quintuple Helix Model as Quintuple Helix analytically applied to the socio-economic issue of digital economy.

Keywords. Information technologies, university, digital economy, distance learning

I. INTRODUCTION

The beginning of the third millennium has confirmed the fact that science and technical progress have turned into a main source of economic growth. Permanent innovation activity and information technologies have become a basis of economic progress. Technological, economic and social changes have been accelerating and obviously leading to new type of economic development. Of course, the role of new knowledge producers has been increasing on this stage.

Universities are historically regarded as knowledge producers and distributors. Objective of this research is to analyze the transformation of universities into innovation actors in digital economy building and using digital and information technologies in this process. The article concentrates on designing and redesigning concepts on knowledge production and innovation. The key points are the Triple Helix, Quadruple Helix, and Quintuple Helix for innovation, Mode 1 and Mode 2 for knowledge production and digital university as a component of digital economy.

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II. MATERIALS AND METHODS. THEORY AND METHODOLOGY

For analyzing this problem, the system approach is used. The university is seen as a complex system of production and dissemination of knowledge, interacting with other systems of creation, distribution and use of knowledge in society. The key points are the Triple Helix, Quadruple Helix, and Quintuple Helix for innovation, Mode 1 and Mode 2 for knowledge production and digital university as a component of digital economy.

The beginning of the XXI century is characterized by the breakthrough development of digital technologies, a revolution in the information space and acceleration of the globalization of the economy. The increasing complexity of social structures and relations, which are increasingly based on modern digital technologies that cause exponential growth in data flows, highlights the need for a new type of economy, the main tool of which is digital (information) technologies. An economy of this type is accepted to designate such a concept as “digital economy” in modern literature. [1, p. 9]

Many scholars are involved in the study of this concept, including F. Weber and D. Bode, A.Rees, A.Toffler, X. Hanamaru and D. Wade, K.Arrow [2], D. Bell [3], F. Machlup [4]. American computer scientist Nicholas Negroponte at the University of Massachusetts firstly used the concept of “digital economy” in 1995. However, Negroponte did not give a clear

definition, using this concept more as a figurative expression, but not a scientific definition. [2]

Currently, scientists have not come to a consensus regarding the definition of a digital economy. Russian scientists often use such synonyms of the digital economy as “electronic economy”, “new technological world order”, “API economics”, “application economics” and “creative economics”.

Decree of the President of the Russian Federation of 05.09.2017 N 203 "On the Strategy for the Development of the Information Society in the Russian Federation for 2017 - 2030" declares that the priority direction for the Russia’s development is the creation of favorable conditions for the formation of a knowledge society in Russia. As well as in this document a national interest stands as the development of the digital economy. [5].

Government bodies are making significant efforts to digitalize all spheres of social life. This topic is actively considered at many discussions, large-scale government programs are devoted to it. Now important directions of digitalization are:

1. Reforming educational infrastructure. The production processes automation led to the complete or partial disappearance of a number of specialties. As well as there is a massive shortage of specialists who have digital knowledge skills. In this context, there is a need to adapt the educational infrastructure to new requirements. In the education system, it is necessary to develop and introduce fundamentally new approaches to learning, which will ensure a high level of basic digital literacy of the population [1].

2. Financing for applied research and digital entrepreneurship. Today, the development of research centers for basic research is important. The digital era implies the constant adaptation of the educational infrastructure to new conditions of R&D in the field of computer science and digital business models.

3. Retraining and further education. According to analysis by the McKinsey Global Institute, by 2036 up to 50% of all work processes will be automate in the world, which will lead to a significant release of labor, a reduction in the number of medium skilled jobs. Centers for continuing education and mass retraining of personnel play a special role in providing the economy with personnel with the necessary qualifications, they will give new skills to specialists of companies that cannot organize the process of learning, developing and testing of new digital technologies. [6]

4. The solution of the priority tasks of the digital development of industries. In order to make decisions promptly on key issues of industries digital development, it is advisable to create permanent platforms for dialogue between the government and industry. This interaction will be more effective if it is performed with the participation of educational and research institutions. [1]

5. The development of digital infrastructure. Modern society need activities that will address on bridging the digital divide, providing equal access to basic infrastructure services and a wider range of digital services, for example, such as distance learning, providing educational opportunities for residents anywhere in the country.

6. Promotion of innovation. Digital literacy, desire and willingness to use new methods to solve problems, take risks and experiment will become increasingly important in the future, determining the success of an individual and business.

Scientists, using the term "digital economy", sometimes regarded it as a response to the transition of the economy to the new technologic paradigm, when the trend of intellectual processes "automation" with using ICT became the leading. In other words, the business models create a digital economy and technologies play a role of instrument. [1]

In modern society, information technologies are used in almost all areas of social life, and education is not an exception. ICT in education have become an essential component of modern educational systems at all levels, as well as the condition for successful informatization of society. The "National Doctrine of Education in the Russian Federation" states that education should be aimed at training highly educated people and highly qualified specialists who are capable of professional growth and mobility in the context of informatization of society and the development of new information and communication technologies. [7]

The following pedagogical goals for the using ICT in education are distinguished:

1. Increasing the intensity of the educational process through using ICT. In other words, increasing an efficiency and quality of the learning process and the cognitive activity, deepening of interdisciplinary connections have place. It is important to note the increase of the volume of information, the optimization of its search. [8]

2. Developing learners' personalities, preparing the individual to live comfortably in the new type of society. Developing different kinds of thinking and communication skills is implemented through using ICT in education. Esthetic training is also carried out through the using computer graphics, multimedia technology. In the context of the digital economy, the formation of an information culture, skills in big data processing and situational modeling is very important. [21]

3. Implementing the social contract. The formation of new technical and economic paradigm determines the changes in demand for personnel. Using ICT in the educational process contributes to the preparation of an informationally literate person, advanced computer user.

4. Improving the information and methodological support of pedagogical activity. ICTs can significantly expand the information and methodological support of teachers and students, as well as the possibility of communication and cooperation based on computer communication tools.

5. Enhanced ability to present an educational information. The use of color, graphics, sound, all modern tools of computer technology allows to recreate the real situation in the educational process.

6. Increased motivation of students to learning. The modern generation is in the digitalization of many areas of life from an early age. Using various gadgets is everyday life for them. Therefore, the availability of ICT tools in education is an

additional motivation for students. ICT involve students in the teaching process, contributing to the widest disclosure of their abilities, enhancing mental activity. [8]

7. Increasing control over the students' activity. ICTs allow a qualitative change in the control of student activities, while ensuring the flexibility of managing the teaching process.

Thus, we can conclude that the ICT involvement in the educational process has a positive effect on the students, and also creates more comfortable conditions for the teacher to work.

The digitalization of many social, economic, production and educational processes has becoming the main line of development over last decade. It led to new model of university – "University 4.0.", "digital university".

"The most common misconception of the "digital university" is that it is simply a university that offers online learning and courses. But it is much more than that. A true digital university is one that embraces the digital age from back to front, inside out, and beginning to end. A digital university is one in which lecturers teach students about the latest digital trends whilst using that very technology to deliver the most up-to-date insights. It is one in which PhD students openly seek out digital technology to support new, unknown, and untested ideas and innovations. It is a university in which students play with the latest technology and imagine working in the most digital workplaces" (Hoare, 2016) [9].

A digital university is a way of organizing education in modern era. It is the sum of methodological approaches, infrastructure and digital technologies, which transforms the form and content of the educational process and will be able to support education, scientific and administrative activities in accordance with the frame of the electronic economy. Unlike a traditional university, digital university operates on the base of "big data", with total automation of economic, financial and administrative activities, the introduction of electronic services and digital resources that allow joint research projects with scientists from other organizations and countries.

The educational process using digital technologies provides not only the direct transfer of information, for example, during online lectures, but also controls its understanding. Therefore, for example, through the analysis of various data, a teaching plan for each student can be formed.

The new role of universities in the knowledge society and digital economy is manifested in the fact that:

the contribution of modern universities to the innovative development of the country is increasingly determined by the university intellectual property;

modern universities are the social institutions that best solve the problem of transferring knowledge into intellectual capital through the using resources of globality, openness, dynamism, a constant influx of active youth;

modern universities are not only R&D executors, but actively creators of technologies and technology companies;

universities are becoming leaders and centers for the creation of new hi-tech industries.

At the same time, number of experts note many universities cannot use the advantages of digitalization effectively. In British Public Research Center Report, common reasons of this situation are identified [10]:

• Understanding that universities have a new breed of customers that they need to engage with, and competitors that they need to compete with, in new and different ways

• An inability to simultaneously evolve existing ways of working whilst adding new techniques, tools and capabilities

• A culture that inhibits the rapid development and release of new technology

• A lack of trust in digital services and cloud technologies, or concerns about their reliability, security and resilience.

Another major inhibitor to digital uptake in universities is digital literacy.

In addition, university IT departments who need to support digital initiatives are not always well equipped to do so. Inflexible policies, aging infrastructure and inexperience working with digital agencies can delay or prevent new digital initiatives from taking shape.

However, digitalization of higher education and development of «University 4.0." model go fast.

"University 4.0" is a public institute that implements the function of a providing knowledge about the future. University 4.0 is becoming a leader in the development of high-tech industries. Thus, "University 4.0" is able to display effectively the function of capitalizing its own knowledge. When modern universities are moving to "University 4.0", more and more value is produced on the university campus, and is not transferred to the economy in the form of "semi-finished products": specialists and general knowledge.

III. RESULTS AND DISCUSSION. CONCEPTUAL ISSUES

The analysis of research on the universities transformation into the new University 4.0 model demonstrates that the main attention in this issue is paid primarily to technological and organizational aspects, that is, the active use of digital technologies in university education and related changes in the teaching process organization and university structure. However, recently, during the global COVID-19 pandemic, the practice has shown limitations of this approach.

In connection with the COVID-19 pandemic in the first half of 2020, the scale of information technologies using has sharply increased worldwide, in all spheres of life, including the education. Influenced by a pandemic, schools, colleges and universities have been moved to distance learning. This is also true for Russia. According to Higher School of Economics experts [11], only 3% of the population of the Russian Federation used the Internet for distance learning in 2018-2019, but in March-June 2020 all educational institutions in country, that is, millions of people, have switched to online technologies. Now it is already possible to try to generalize very short but real experience of mass distance learning and highlight its advantages and disadvantages.

Most of authors considered this problem (D. Kumar [12], Y. Yutkina [13], A. Zakharova [14], V. Kanavo [15] and many teachers-practitioners) define the opportunity of individual

learning, freedom and flexibility, accessibility, mobility, social equality as the main advantages of distance learning. However, in addition to these undoubted advantages, distance education has quite serious shortcomings, among which are not only technological and organizational-economic problems (low-tech equipment, lack of financing for new equipment and software), but also psychological, cultural, social aspects. These are:

the lack of personal communication between students and the teacher, that is, a lack of individual approach in education, the emotional aspects in learning process;

the need for appropriate individual psychological conditions, especially strict self-discipline, independence and consciousness of the student;

a lack of real practice, it is impossible to fully master many professions without practical experience (for example, in medicine, art, a number of technical sciences, where not only theoretical knowledge, but also practical skills are necessary). In general, this is a lack of real social contacts, of socialization of students and the formation of communication and management skills in groups, as well as the lack of a psychological atmosphere for joint mastery of knowledge, social skills, and self-learning experience. Therefore, as life has shown, distance education can be a powerful tool for the development of an experienced specialist who wants to improve their knowledge and skills or acquire new ones, but this education format is not suitable for young people and children who do not yet have the skills of self-education and self-improvement.

These shortcomings are effectively eliminated in the process of traditional university offline education. Therefore, in our opinion, the concept of the University 4.0. it is possible to integrate into the system of Helix-concepts that have been developed abroad since the mid-1990s and analyze the development of universities in conjunction with other areas of socio-economic activity - the concepts of the Triple Helix, Quadruple Helix and Quintuple Helix [16, 17].

Relevant theories of knowledge production can be classified conventionally into two main groups: those arguing that there has been a shift in knowledge production to greater university contribution to industry and social needs, and those portraying necessity of changing “Mode 1” and “social contract” between academic researchers and the state. However, all scholars agreed in recognizing main socio-economic and technological changes that have become the drivers in transformation of university role. In western countries, these changes are as follows: globalization; the growing role of knowledge and information in socio-economic development when knowledge becomes one of the major factors of well-being and competitiveness; changes on labor market when knowledge-intensive technologies require new high-skilled workers, which causes mass demand on professional higher education; increasing pressure on universities to meet societal needs, particularly those of industry and government [16, 17]

One of the most arguable models of knowledge production was Triple Helix model (H. Etzkowitz et al.) [18, 19]. This model developed the hypothesis of the ‘third mission of university”, which was the consequence of two factors: first, societal needs of knowledge-based society, and, second, lack of public funding of the universities, (although, in fact, the latter is the former). This theory presumed the transformation of traditional university into “entrepreneurial university”. The entrepreneurial university encompasses a `third-mission' of economic development in addition to research and teaching (Etzkowitz and Leydesdorff, 1999, 2000; Etzkowitz, Ranga et al., 2008, 2012) [20, 21]. Some authors argue that such shift arises from both internal development of the university and external influences on academic structures associated with emergence of `knowledge-based' innovation.

The triple helix model attempts to account for a new configuration of institutional forces emerging within innovation systems. In a knowledge-based economy, the university becomes a key element of the innovation system both as human capital provider and as seedbed of new firms. Three institutional spheres (public, private and academic), that formerly operated at arm’s length in laissez-faire societies, are increasingly interwoven with a spiral pattern of linkages emerging at various stages of the innovation and industrial policy-making processes.

The main idea of Etzkowitz *et al*. is that Triple Helix theory implies an enhanced role of the university in technological innovations in increasingly knowledge-based societies. It seems to us, these changes in university role and activities are especially important during the transition to new economic order. We agree with Etzkowitz and Ranga (2012) [21], Rodrigues and Melo (2012) [22] on practical implementation of Triple Helix concept, which can be successfully utilized to motivate regional actors to collaborate across institutional and organizational boundaries, to legitimize policy efforts and to improve coherence among different sectors influencing innovation.

As Carayannis and Campbell (Carayannis and Campbell, 2009, 2012, 2013) [23, 24, 25] stated, the innovative Triple Helix model was followed by the Quadruple Helix. This model added the “fourth helix” of “media-based and culture-based public and civil society” as integrative part for innovations; by doing this, that model involves the society and its cultural background in the process of knowledge creation and production.

As the fifth helix in the enhanced model of innovation represents the “natural environment,” currently ongoing transformation from the “Quadruple Helix” to the “Quintuple Helix” makes it clear that a sustainable development will be a definite part of the creation and production of innovations and knowledge (Carayannis and Campbell 2010, 2012) [24, 26]. It extends and expands substantially the triple helix model of innovation economics as the framework introduces civil society and the environment as pillars and focal points of policy and practice. In particular, civil society emphasizes the role of bottom-up initiatives complementing top-down government, university and industry policies and practices, and the environment emphasizes the sustainability priorities and exigencies that need to inform and moderate top-down policies and practices as well as bottom-up initiatives. The quintuple helix views the natural environments of society and the economy as drivers for knowledge production and innovation, thus defining opportunities for the knowledge society and

knowledge economy. The quintuple helix can be described in terms of the models of knowledge that it extends, the five subsystems (helices) it incorporates, and the steps involved in the circulation of knowledge [26].

In addition, the "Quintuple Helix" as improved model of innovation shows, that in the twenty-first century, the creation and production of knowledge and innovation must be "transdisciplinary" and "interdisciplinary" at the same time. This is especially needed to work against the dangers resulting from the climate change and destruction of the environment. The described complex changes in the models, and the development of innovative models, should make clear that currently given complexity in the areas of work and research requires an academic entrepreneur. [E.G. Carayannis (ed.), 2013] [24].

In our opinion, it is logical to integrate the concept of the "digital university" and, moreover, the concept of the digital economy with the Quintuple Helix model (figure 1). This means that digital technologies permeate and unite almost all spheres of modern life, including education, science, business, government, social processes, and also partially natural processes to the extent that people can observe [monitor], control and influence nature through digital technologies. For example, the application of IT in the production processes using the forces of nature: energy systems -hydroelectric power plants, wind power plants, solar power plants, etc., the construction and monitoring of engineering structures that counteract negative natural phenomena (dams, earthquake-resistant buildings), mining, etc.

Confirmation of our point of view is that the Internet of things has been actively introduced into environmental technologies in recent decades. In 2017, the IoT Week participants in Geneva developed the international declaration "The Internet of Things for Sustainable Development". According to experts' opinion, IoT is necessary:

• to combat climate change;

• for conservation of biological diversity and environmental monitoring;

• to solve problems with hunger, water supply and food security;

• to create more "smart" and "sustainable" cities, villages and other communities. [27]

The following IoT technologies are currently most widely used in the environmental field:

- sensors for monitoring and forecasting the environment;
- smart collection and recycling of municipal waste;
- IoT in agriculture as a tool for improving environmental safety and food product quality;
- Smart home / city / factory helps protect nature by reducing energy consumption.

In 2019, the French IT company Schneider Electric conducted an audit of the technological solutions that it installed in production, and noted that the industrial IoT has reduced energy consumption by 24%. [27]

Therefore, nowadays digital technologies cover almost all technological and socio-economic processes, and partially natural ones. Scientists, including university ones, are actively involved in solving social problems and developing all kinds of new technologies. For this reason, the integration of the concepts of the digital economy and Quintuple Helix seems reasonable. This model can be called Digital Quintuple Helix (figure 1).

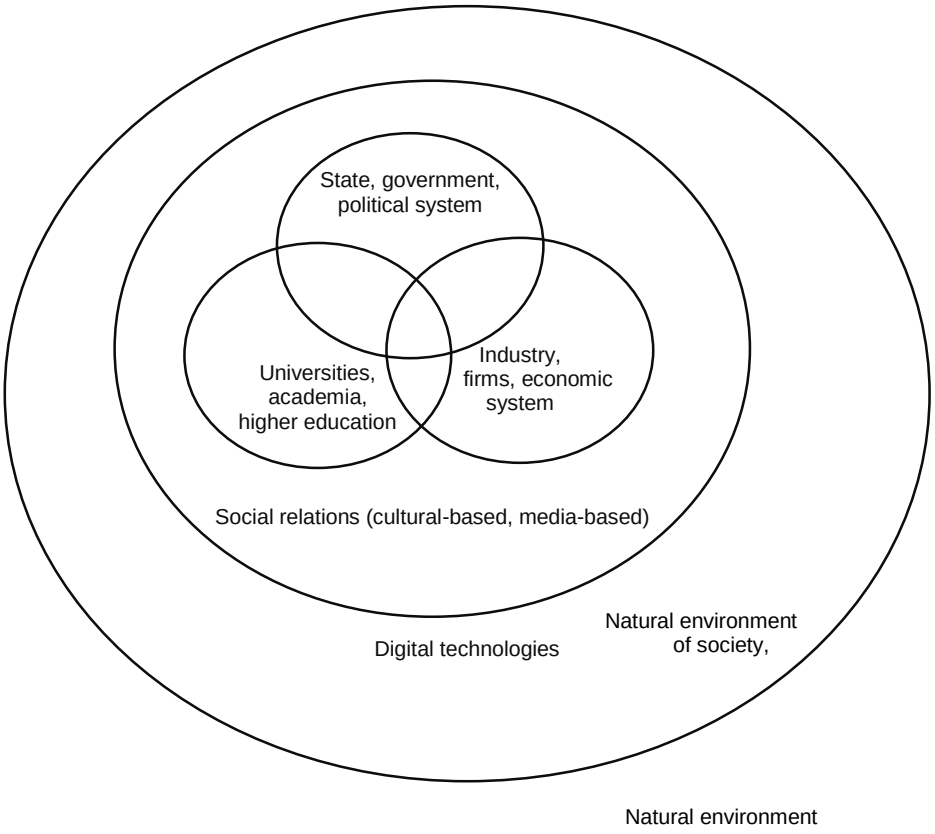

Fig. 1. The spheres of Digital Quintuple Helix Model (Source: Authors' own conceptualization based on Etzkowitz, H. & Leydesdorff L. (2000, p. 111) and on Carayannis E.G., Campbell D.F.J. (2010, p. 62)

IV. CONCLUSION

The transformation of universities to digital university and University 4.0, using actively IT, has a positive impact on increasing their contribution to the economic and social development. This impact is achieved through improving the quality of education, matching the competencies of graduates with the requirements of business structures, increasing competitiveness in the international educational market, the formation of sustainable income flows and less dependence from budget financing.

Thus, the digital space has become an integral part of the economic interaction of people in the modern world. It forms a dynamic market through information technologies, information services, databases, applications and system programs. The process of strengthening the information component in education, culture, politics and economics is taking place in the world. Therefore, the need for a deep and systematic study of this process arises. The digital economy is not only the basis for creating new models of education, management and business, qualitative changes in the models and nature of human activities, but it affects the fundamental basis of civilization.

The article concentrates on designing and redesigning concepts on knowledge production and innovation. The key points are the Triple Helix, Quadruple Helix, and Quintuple Helix for innovation, Mode 1 and Mode 2 for knowledge production and digital university as a component of digital economy.

The article based on a literature review on these concepts. Authors propose the concept of the Digital Quintuple Helix Model as Quintuple Helix analytically applied to the socio-economic issue of digital economy. Nowadays digital technologies cover almost all technological and socio-economic processes, and partially natural ones. Scientists, including university ones, are actively involved in solving social problems and developing all kinds of new technologies. For this reason, the integration of the concepts of the digital economy and Quintuple Helix seems reasonable.

References

1. Babkin A.V. Formation of the digital economy in Russia: essence, features, technical normalization, development problems // Scientific and technical statements of St. Petersburg State Polytechnic University. Economic sciences. - 2017. No. 3. P.9-16. (Babkin A.V. Formirovanie cifrovoj ekonomiki v Rossii: sushchnost', osobennosti, tekhnicheskaya normalizaciya, problemy razvitiya // Nauchno-tekhnicheskie vedomosti Sankt-Peterburgskogo gosudarstvennogo politekhnicheskogo universiteta. Ekonomicheskie nauki.- 2017. №3. 9-16)

2. Information portal "NewsRU". (Informacionnyj portal «NewsRU») URL: http://www.newsru.com/russia/30jun2017/plankudrina.html

3. Bell D. The Coming of Post-Industrial Society. A Venture in Social Forecasting. N.Y., 1976.

4. Machlup F. The Production and Distribution of Knowledge in the United States. 1962 – in Russian (Mahlup F. Proizvodstvo i rasprostranenie znanij v SSHA. - M.: Progress, 1966. - 462 s.)

5. Decree of the President of the Russian Federation of 05.09.2017 N 203 "On the Strategy for the Development of the Information Society in the Russian Federation for 2017 - 2030" (Ukaz Prezidenta RF ot 09.05.2017 N 203 "O Strategii razvitiya informacionnogo obshchestva v Rossijskoj Federacii na 2017 - 2030 gody")

6. McKinsey & Company: Official website. URL: https://www.mckinsey.com

7. National Doctrine of Education in the Russian Federation. (Nacional'naya doktrina obrazovaniya v Rossijskoj Federacii). URL: http://sinncom.ru/content/reforma/index5.htm

8. Development of the information and educational environment in organizations of secondary vocational education: Theory and practice: Materials of the II International scientific and practical conference "Secondary vocational education in the information society" (Chelyabinsk, January 26, 2017) - Chelyabinsk: 2017 —206 p. (Razvitie informacionno-obrazovatel'noj sredy v organizaciyah srednego professional'nogo obrazovaniya: Teoriya i praktika : materialy II Mezhdunarodnaya nauchno-prakticheskaya konferencii «Srednee professional'noe obrazovanie v informacionnom obshchestve» (CHelyabinsk, 26.01.2017). — CHelyabinsk: CHIRPO, 2017 — 206 s.)

9. Hoare, K. The Digital University. *Digitalist Magazine*. 7-November-2016. URL: https://www.digitalistmag.com/customer-experience/2016/11/07/digital-university-04635765

10. The 2018 Digital University; Staying relevant in the digital age, PWC, 2016. URL: https://www.pwc.co.uk/assets/pdf/the-2018-digital-university-staying-relevant-in-the-digital-age.pdf

11. Digital Economy 2020. (Cifrovaya ekonomika 2020) URL: https://issek.hse.ru/digec2020

12. Online education [pros and cons of distance learning]. (Onlajn obrazovanie [plyusy i minusy distancionnogo obucheniya]) URL: https://brammels.com/career/online-education/

13. Yutkina Yu. Distance education: pros and cons. (Yutkina Yu. Distancionnoe obrazovanie: plyusy i minusy) URL: http://www.distance-learning.ru/db/el/0DD78502474DC002C3256F5C002C1C68/doc.html

14. Zakharova A. Pros and cons of distance learning. (Zaharova A. Plyusy i minusy distancionnogo obucheniya) URL: https://sites.google.com/site/zaharovaanna31/proekt/plusy-i-minusy-distancionnogo-obucenia

15. Kanavo V. Advantages and disadvantages of distance learning via the Internet. Vladimir Kanavo. (Kanavo V. Dostoinstva i nedostatki distancionnogo obucheniya cherez Internet. Vladimir Kanavo) URL: http://www.curator.ru/e-learning/publications/do_minus.html

16. Kazakova N., Sysoyeva O. Innovation Entrepreneurship at Universities in the Emerging Innovation Systems // Journal of Entrepreneurship and Innovation Management. Volume 4,

Issue 1, June 2015. Pp. 83-106. Ankara, Turkey.

17. Kazakova Nina, Slavnetskova Lyudmila, Kulikova Maria and Serdiukova Larisa. Evolution of universities in innovation digitalizing economy / E3S Web of Conferences 135, 01091 (2019). DOI: 10.1051/e3sconf/201913501091

18. Etzkowitz, Henry. "University-Industry-Government: The Triple Helix Model of Innovation" (2011). Newcastle University Business School. URL: https://pdfs.semanticscholar.org/c737/7b7a3c21d78caff9357560da79064ea197b5.pdf

19. Smitha, Helen Lawton* & Leydesdorff Loet. The Triple Helix in the context of global change: dynamics and challenges. (2012). URL: https://www.leydesdorff.net/th11/th11.pdf

20. Etzkowitz, H. & Leydesdorff L. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. Research Policy **29** (February 2000) 109-123.

Frodeman, R.; Briggle, A. (2016). Socrates Tenured: the institutions of 21st Century Philosophy. Roman & Littlefield. URL: https://en.wikipedia.org/wiki/Robert_Frodeman.

21. Ranga M. & Etzkowitz H. (2012): Great Expectations: An Innovation Solution to the Contemporary Economic Crisis. European Planning Studies, **20:9**, 1429-1438.

22. Rodrigues and Melo. The Triple Helix Model as an instrument of local response to the economic crisis". European Planning Studies, **20:9**. 2012.

23. Carayannis E.G. (ed.), *Encyclopedia of Creativity, Invention, Innovation, and Entrepreneurship*, Springer Science+Business Media LLC 2013.

24. Carayannis E.G., Barth T.D. and Campbell D.F.J. The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. Journal of Innovation and Entrepreneurship 2012, **1:2**. URL: http://www.innovation-entrepreneurship.com/content/1/1/2

25. Arnkil, R.; Järvensivu, A.; Koski, P.; Piirainen, T. (2010). Exploring Quadruple Helix Outlining user-oriented innovation models. URL: https://trepo.tuni.fi/handle/10024/65758

26. Carayannis E.G., Campbell D.F.J. (2010) Triple helix, Quadruple helix and Quintuple helix and how do Knowledge, Innovation and the Environment relate To Each other? a Proposed Framework for a Trans-disciplinary analysis of Sustainable development and Social Ecology. International Journal of Social Ecology and Sustainable Development, 1(1), 41-69, January-March 2010.

27. Environmental Front: How the Internet of Things will Help Protect the Environment. November 25, 2019. (Ekologicheskij front: kak internet veshchej pomozhet v zashchite okruzhayushchej sredy. 25.11.2019.) URL: https://habr.com/en/company/kauri_iot/blog/477320/