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Педагогическая модель подготовки специалистов для Индустрии 4.0 в университете

Введение. Индустрия 4.0 подразумевает интеграцию информационных технологий в различные сферы жизнедеятельности людей, что приводит к значительным изменениям в производственных процессах, сельском хозяйстве, энергетике, экономике, и в образовании в том числе. Смарт технологии требуют от специалистов нестандартного гибкого мышления, творческого подхода и оперативных решений. Целью данной статьи является построение модели образовательного процесса, направленного на подготовку специалиста, соответствующего требованиям Индустрии 4.0.

Материалы и методы. Методологической базой исследования являются положения системно-синергетического, гуманно-ориентированного и интегративного подходов. Метод моделирования позволил авторам описать строение и функционирование образовательного процесса в университете, направленного на подготовку специалиста, соответствующего требованиям Индустрии 4.0.

Результаты исследования. Представлено описание структурных и функциональных компонентов педагогической модели, проанализированы педагогические условия эффективного ее функционирования. На основе методологии анализа выделена платформа SMART образования как оптимального ресурса для обеспечения студентов возможностью построения индивидуальной образовательной траектории в рамках Образования 4.0. Определены предпосылки к модернизации существующей системы высшего образования, которые лежат в основе интеграции образования, науки и производства. Выявлены качества специалиста, требуемые для Индустрии 4.0. Сформулированы критерии и показатели, позволяющие оценить эффективность функционирования модели. Обоснована целесообразность апробирования данной модели в образовательных условиях ФГАОУ ВО ЮУрГУ (НИУ).

Обсуждение и заключения. Подготовка творческого, нестандартно и оперативно мыслящего специалиста, отвечающего требованиям современного высокотехнологичного «умного» мира, может осуществляться только на основе построения индивидуальной образовательной траектории самим обучающимся. Новая парадигма образования 4.0, предполагающая «умное» образование посредством разнообразных интернет-технологий и эмпирического обучения, позволяет обучающемуся стать архитектором своего образования. Материалы статьи могут представлять интерес не только для управленческих и педагогических кадров современного университета, но и для потенциальных работодателей. Результаты исследования будут способствовать разработке конкретных решений по развитию и внедрению SMART образования в университете и на производстве.

Ключевые слова: Образование 4.0, SMART образование, индивидуальная траектория образования, высшее образование, ЮУрГУ, педагогическая модель, специалист для Индустрии 4.0

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Pedagogical model to train specialists for Industry 4.0 at University

Introduction. Industry 4.0 means the integration of information technologies into different spheres of human life. SMART technologies require creative and prompt specialists in advancing new solutions with an original and flexible mindset. The purpose of the article is to create a model of the educational process at University aimed at training Industry 4.0 specialists.

Materials and Methods. The system-synergetic, humanistic and integrative approaches have been used in the research. Modelling has enabled the authors to describe the structure and functions of the educational process aimed at training specialists, required by Industry 4.0.

Results. The authors of the article represent the pedagogical model of the educational process specially designed to train a proper specialist for Industry 4.0 at SUSU experiment platform. The article is devoted to peculiar features of Education 4.0 as an optimal educational environment to train specialists for Industry 4.0. The paper also concentrates on personalization of learning as a cornerstone of Education 4.0. Education 4.0 is considered as a background for SMART education which is highly flexible, variable and adaptive to students' individual educational needs.

Discussion and Conclusions. To train an Industry 4.0-ready specialist with problem-solving skills, creativity and analytical thinking abilities required by the modern high-tech "smart" world can only be possible due to personalization of learning. The new paradigm of Education 4.0 enables the learner to become an architect of his own education via dynamic technologies and experiential learning as its "smart" principles. The result can be used for implementation SMART education into the University educational environment along with industrial setting.

Key words: Education 4.0, SMART education, personalized education, higher education, SUSU, pedagogical model, a specialist for Industry 4.0

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Introduction

Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing. Industry 4.0 is commonly referred to as the fourth industrial revolution (4IR). The term "Industry 4.0" originates from a project in the high-tech strategy of the German government, which promotes the computerization of manufacturing. Industry 4.0 creates what has been called a "smart factory". Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. In this fourth revolution we are facing a range of new technologies that combine the physical, digital and biological worlds. These new technologies will impact all disciplines, economies and industries, and even challenge our ideas about what it means to be human [1].

That is the reason why in the last few years there has been a growing interest in new technologies within the system of education at all levels. The concept of Education 4.0 has been evolving in response to the needs of Industry 4.0, the main feature of which is a man being a creator of his own educational path.

Flexible learning paths, focus on imparting life skills, student centric learning methods and use of technology are bringing in the concept of "Education 4.0". Education 4.0 empowers learners to structure their learning paths. It is characterized by personalization of the learning experience, where the learner has complete flexibility to be the architect of his or her own future and has the freedom to aspire, approach and achieve personal goals by choice. The "traditional" profile of the learner has been changing and he or she is no more a student right from high school, enrolled in a full-time course to complete a degree; the new majority demands greater deal of flexibility and customization [2-6].

A new generation – Generation Z – who will live in the 4IR world, is growing up in a time revolutionized by technology. Learners today are digital natives who are at ease with the mobile and computing devices and look for information on the internet. One of the most important features of the youth today is ability to use different means of communication at a time. They are able to chat with a number of people, and at the same time to read some abstract texts on a website, to follow news on Twitter and various blogs, etc. Internet, video streaming, smartphones and any other technologies have made a young man mobile and independent [7]. This has an impact on the temper and behavior of the learner. They hardly resemble their previous generations and have immensely changed in terms of their basic learning habits. Most of them prefer learning in different spheres of science and technology. They are proved to be highly educable, versatile and adaptive. Their educational needs are short-term courses of retraining or extension learning so that they could save the time which they highly appreciate. Virtual interaction is getting more popular [7-10]. So the majority of generation Z prefers obtaining professions connected with IT and communications. They are eager to conquer the spheres where the competition is still not high [11].

However, it is crucial to put a question whether the current system of higher education is able to satisfy educational needs of the new generation and train the proper specialist for Industry 4.0. The purpose of the article is to create a model of the modernized educational process aimed at training specialists required by Industry 4.0. The educational process comprising education (cognitive development) and training (performance in a specific skill)

is modernized due to the integration of curriculum, research and experiential learning with the help of dynamic technology provided at University.

Literature review

The literature on higher education shows a variety of prerequisites for creating a model of training specialists for Industry 4.0 at University. Several publications have appeared in recent years documenting the urgent need to change the system of training specialists for Industry 4.0 [12-15]. SMART education is considered to be a new educational paradigm as reported by the researches [16-21]. Basic principles of SMART education to be the part of Education 4.0 such as project-based learning, digitization and informatization of education, personalization of learning, skills acquisition through the integration of education, research, business and high-tech industry have been proposed by recent studies [13; 22; 23]. Komleva N.V., Loshkareva E., Luksha P., Ninenko I., Smagin I., Sudakov D. [24] studied professional skills for specialists required by Industry 4.0. They argue that there must be a shift from traditional education to personalized learning because of new challenges towards specialists for Industry 4.0. The authors believe that it is the learner who has to estimate his importance for society. Hence, the learner must focus on self-improvement and self-development. According to the research the relevant components of specialists' professional development process within the framework of smart-society are evaluation of their competence, importance of professional development and education modernized by SMART technologies.

The results offered by Khutorskoy A.V. [25], Surtayeva N.N. [26], FitzGerald E., Jones A., Kucirkova N., Scanlon E. [27], Iatrellis, O., Kameas, A., Fitsilis, P. [28] suggest that personalization of learning may be an effective tool for self-development. The idea of personalization of learning and self-development abilities are to be the consequence of social demand for proper specialists, psychological study in the field of cognitive development and the implementation of the humanistic approach in education.

In our research we stick to the term "personalization of learning" which was coined by Khutorskoy A.V. [25]. He considers it to be an individual path to realize a learner's potential in education. A learner's potential integrates cognitive, creative, organizational and other abilities.

An integral part of our research was investigation of the psychological makeup of modern students as digital generation representatives [9; 11; 13; 29]. This proves that the psychological makeup of digital natives must be taken into account while introducing new methods of instruction at University [7; 13; 30-34].

Like A.M. Aleksankov [12], we believe that the process of training Industry 4.0 specialists is dawning. Due to scarce research on empirical data about brand new mechanisms of a complex interaction between man, machine and information system, there is a mismatch between qualifications of a specialist or the required skills a specialist must have and the system of education which is able to master them. Having analyzed related references, we assume that the real challenge to implement the model of training specialists for Industry 4.0 is University being static due to fixed programs and limited flexibility of curriculum. Moreover, it is difficult to align curriculum with individual educational needs of learners within the traditional educational framework. One can observe little curriculum integration with industrial plants, hence experiential learning is still lacking. However, to the authors' best knowledge, very few publications are available in the literature that discuss the issue

of making up a model to train proper specialists for Industry 4.0 at University taking into the account individual peculiarities of the generation Z.

Materials and Methods

The purpose of the article is to model the educational process which aims at training the new type of a specialist for Industry 4.0. Modelling means that any model is an abstract manifestation of the phenomenon under research [35-37].

The Industry 4.0 specialists' training model is of a structural-functional type. The modelling includes the structure and content of the Industry 4.0 specialists' training model (see Table 1).

As for the theoretical and methodological approaches, the Industry 4.0 specialists' training model is based on the system-synergetic, integrative and humanistic ones. All these approaches allow us to justify basic theoretical principles for modelling the smart educational process in question.

According to the system approach, which considers the object (the Industry 4.0 specialists' training model) as a system [38; 39; 40], the model presented in the article is a system of interactive and interdependent components: structural (objective, content, methods and forms, and result) and functional (informative, organizational, constructive) ones.

Structural components of the devised model correspond to the internal organization of the educational process aimed to train specialists for Industry 4.0 and support the constant interaction of its elements.

Functional components stipulate development, changing and enhancement of the educational process. The informative function of the model is to inform the user about the specifics of the educational process aimed at training Industry 4.0 specialist in general. The organizational function of the model helps to establish the structure and order of the components to operate in a pre-arranged way. The constructive function of the model stipulates the operation of the system aimed at achieving the result, i.e. to train a specialist for Industry 4.0.

The synergetic method is based on the theory of self-organizing systems and the effects of real objects interaction [41-43]. It could be applied as a methodological setting to explain the process of Industry 4.0 specialist nurturing which is self-organizing and self-developing. If we consider the personality of an Industry 4.0 specialist as a not ordered and chaotic system, so it should become self-organized via the education process. The synergy (which is interaction or combined action) of Education 4.0 curriculum delivered through dynamic technologies and experiential learning would extend the learning space where a student may feel free and active in satisfying his individual educational needs and expectations. Being constantly involved in the process of learning a student is getting self-developed and self-perfected. The synergetic approach justifies the adaptability of the educational process to the personalized needs of a learner, i.e. proves to be SMART.

The humanistic approach is an effective way to improve the core traits of a learner. Being focused on his interests and inner qualities, a student takes a chance to build his own learning path and to manifest own core traits in personalized learning based on his achieved results [40]. Social interaction and personal experience as a feature of the humanistic approach could be nurtured by the process of experiential learning where communication is less formal and more trustful. One of the big advantages of the humanistic approach is that

it reveals the learner's inner resources which help develop creative and problem-solving skills [44-47].

Figure 1 The pedagogical model to train specialist for Industry 4.0 at University
Рисунок 1 Педагогическая модель подготовки специалистов для Индустрии 4.0 в университете

The educational process is considered to be the unity comprising curriculum, research and real world experience (experiential learning). The integrative approach presupposes the integration of curriculum delivered through a large pool of education programs with research excellence [48-50]. Research is accomplished by the University being a center of innovation and creation of knowledge. Moreover, blended learning models, MOOCs, integration with real world stakeholders promote experiential learning and real life skills acquisition. The integration of the three aspects of the education process at University provides students with various opportunities for self-realization and self-development in a creative way.

Results

This section describes the components of the model and the way it works under the certain pedagogical conditions, as it is shown in Figure 1.

According to the requirements of the FSES 3+ [51], stakeholders, employers and Industry 4.0 economic situation in Russia, the objective of the model is to train a proper specialist with problem-solving skills, creativity and analytical thinking abilities for Industry 4.0.

We consider the learning facilities of South Ural State University (SUSU) to be the optimal educational platform for bachelors and masters to become Industry 4.0 specialists. South Ural State University is a SMART University which is among the 21 Russian universities participating in Project 5-100. Project 5-100 or the Russian Academic Excellence Project is a Russian government program launched in May 2013. The project's aim is to increase the role of the leading Russian universities in the global educational and research context and successfully compete with the world's most prestigious universities by 2020.

In 2018 South Ural State University entered QS World University Rankings for the first time. As the rector of SUSU Alexander Shestakov says: "The fact that South Ural State University has entered QS World University Rankings is a great achievement. It proves our high academic and research reputation and ensures that we are capable of meeting the global challenges" [52].

The main target is to transform SUSU into SMART University which is a platform for sustainable development of the region, and an important contributor to major advances in human knowledge, education, and research. SUSU as a SMART education provider is on its way to allow learners the genuine opportunity to be an architect of their learning path. To do that a student would experience a great variety of diverse types of e-learning which are under the process of being tested. They are LMS programs (a software application for the administration, documentation, tracking, reporting and delivery of educational courses or training programs), on-line courses through Moodle learning platform, being realized due to Strategic Initiative (SI) 8.1 for Implementation of the Competitiveness Enhancement Program for the Period 2018-2020 by Institute of Open and Distance Education (ODE) and many others.

Moreover, the smart educational policy of SUSU comprises elite-education system with the introduction of individual educational programs for students with high educational results. Project-based learning, advance language training program, dual-degree programs, and research work help students to become competitive at the world labor market, as they possess knowledge and skills necessary for Industry 4.0.

The content component of the model is represented in the Education 4.0 unit which is innovative in creating personalized way of learning [19; 53; 54]. Taking into the consideration

the urgent demand to meet the requirements of the contemporary environment, it has been quite evident that universities need to break away from the traditional teacher-centered learning process to a new way of education that appreciates the new educational setting through personalization of learning. On the one hand, present day technology has made personalized learning both approachable and dynamic. Without educational technology ranging from digital content to adaptive learning software, it would be extremely difficult and resource-intensive to implement personalized learning. In SUSU the content of Education 4.0 is to be delivered through such dynamic technology as Internet, LMS, MOOCs, mobile applications, educational computer games, e-learning platforms, etc.

On the other hand, personalization of learning is achievable due to experiential learning, i.e. the direct connection of the learner with his personal first-hand experience via internship, work experience or real-world learning, as shown in Figure 2.

To foster the necessary skills for industry-ready specialists, project-based learning is being launched in SUSU. All the projects meet the modern world requirements in the spheres of technology, business, economics and industry and are approved by the leading companies in Russia and abroad. The projects are interdisciplinary and consist of a number of courses. Each project team has a head instructor and there are up to 5 members in it. In two years' period of time the project team is to present the result – a device, a system or a software product. Some projects in the Humanities are in progress now [52].

Project-based learning is an innovative creative, personal and adaptable method in Russia which is also able to foster personalized learning. The higher education system in Education 4.0 will focus on the learner, supported by technology, in-person guidance and industry relevant content to meet the learner's individual learning needs. Increased innovation in teaching methods, demand for an improved higher education experience and availability of better learning opportunities supported by technology have been the major impetus for this shift toward personalization [6].

Figure 2 SMART education to satisfy students' needs for personalized learning
Рисунок 2 СМАРТ образование для обеспечения индивидуальных образовательных потребностей студентов

So, we do stand for the idea that personalization of learning is the basic principle of SMART education. The education is “SMART” because it is able to be adapted to any changes in economics, politics, society and other spheres of human life. The new concept of SMART education is based on new IT and communication technologies and various ideas of experiential learning to gain a high level of effectiveness in education settings as it is highly adaptive and independent to build an individual learning path [14; 27; 28]. In SMART education the process of learning is connected to the learner, focused on the learner, demonstrated by the learner and led by the learner. It is the learner who is in charge of defining the various trajectories of his own education, i.e. what, where, when, how and why to climb up the learning ladder. [6; 55; 56] In other words, we strongly believe that the cornerstone of the SMART Education 4.0 is personalized learning where a learner is an architect of his own individual educational path, supported by dynamic technology and experiential learning [5; 22]. Furthermore, we think that a new type of specialist for Industry 4.0 with a certain number of skills and abilities could be trained through personalized learning which would be best realized with the help of SMART education framework of SUSU.

Not to speak more of personalization of learning, we would like to mention other basic principles of SMART education 4.0. SMART education at SUSU has the following certain specific features:

- innovations – SMART University trains industrialists and introduces new ideas, methods and approaches to the system of education,
- research and practical experience – 40 laboratories in the University are the powerful foundation for scientific research and real life skills acquisition,
- flexibility and variability – the curricular is to be adapted according to the educational needs of a learner due to a range of optional courses provided at University,
- integration with the industry – the University promotes collaboration with global corporations,
- interdisciplinarity – University projects focus on world’s leading interdisciplinary researches in the field of the Internet of things while SMART education applies modern world innovative educational trends into the existing curriculum and introduces new interdisciplinary programs,
- affordable alternatives – the opportunity for a learner to use online resources instead of taking a traditional course at the University classroom or some other educational institutions.

SMART Education 4.0 is realized at SUSU through a number of interactive and innovative methods and forms of SMART education content delivering. They are blended learning (an educational approach that combines online digital media with traditional classroom methods) which is implemented in some groups for bachelors, flipped learning (an instructional strategy which reverses the traditional learning environment by delivering instructional content, often online, outside of the classroom), MOOCs (an online course aimed at unlimited participation and open access via the web), project work (a learning experience which aims at providing students with the opportunity to synthesize knowledge from various areas of learning, and critically and creatively apply it to real life situations), training workshops (a type of interactive training where participants carry out a number of training activities rather than passively listen to a lecture or presentation), digital or smart classroom (the “technology-enabled” classroom where student learning and interaction with the instructor and peers is fully supported through strategic use of information and communication technologies (ICTs), virtual laboratory (an interactive environment for

creating and conducting simulated experiments), internship (work experience offered by an organization for a limited period of time), master classes (a class given to students of a particular discipline by an expert of that discipline), educational platforms (Moodle).

The next component of the model is goal assessment criteria which allow us to evaluate the correlation between the goal of the educational process set by Industry 4.0 stakeholders and FSES 3+ and the final result we will have – Industry-ready specialist with problem-solving skills, creativity and analytical thinking abilities. The following criteria which demonstrate the readiness of a specialist to work for Industry 4.0 are abilities to resolve issues logically and systematically, to identify causation of the problem, to anticipate unexpected results, to use imagination or original ideas to find solution to a complex issue, to draw on own experience and knowledge and to call on other resources if necessary, to work in an extraordinary situation, to work in a team, inventiveness and quick reaction.

The authors' attention was concentrated not only on the content, forms and methods of the educational process, but also on pedagogical conditions it runs under. We consider pedagogical conditions to be specific circumstances which influence the effective functioning of the model. The pedagogical model in question will operate if:

- IT environment (equipment and software) is provided and totally available,
- interaction between the SUSU faculty and students is based upon the parity and equality among all the members of the educational community,
- continuing professional development of the faculty is paid attention to,
- constant industry monitoring takes place.

IT environment provides the necessary conditions for internet access and other educational facilities to make learning adaptive, variable and easy. SUSU offers a lot of distance learning technologies via Institute of Open and Distance Education (ODE).

Moreover, one of the basic strategies of SUSU is digitization and digital industry. Hence, IT environment provides the accessible learning settings for students to work and create. Working and creating are only possible in the atmosphere of peace and calm, positive emotions, trust, support and friendship. This could be achievable through establishing good interpersonal relationship with peers and building rapport between the faculty and students on a parity basis.

In order to correspond to the ever changing educational needs of students, professors should raise their professional skills to be able to update their courses regularly and adopt new methods of teaching. And, finally, to avoid the mismatch between university education and industry needs, educational institutions must constantly monitor industrial changes to offer professional courses with a focus on producing industry-ready graduates.

Discussion and Conclusions

From the outcome of our investigation it is possible to conclude that the best educational setting to provide the Industry 4.0 domain with ready specialists having a number of specified personal and professional skills and abilities should be a complex system of Education 4.0. Education 4.0 system is a new disruptive educational trend which matches the pace with modern technologies and industry innovations. It is a SMART educational model which echoes the new generation of students' lifestyle and their learning manner as well as develops and enhances the concept of individualized education. SUSU as a SMART University that offers SMART education does its best to allow students the opportunities

for self-realization and self-development through personalized learning. Personalized learning can be successfully achievable via dynamic technology and experiential learning that are all at SUSU students' disposal. Project-based learning, blended learning, LMS, etc. are the effective tools to help students of SUSU adapt the curricular and build the individual educational path. In order to draft an educational process aimed at training the Industry 4.0-ready specialist with problem-solving skills, creativity and analytical thinking abilities we have designed the structural-functional model. The pedagogical model simulates the process, functions, constituents and conditions of training specialists for Industry 4.0 at SUSU.

The next stage of our research will be experimental confirmation of our model. It is quite clear that further research will be needed to approve the model and make some amendments if necessary to achieve the goal.

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