Technological features of educating specialists for digital factories of the Industry 4.0

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Abstract. The task is to improve the technology of specialist’s preparation to work in digital companies of the economy industrial sector. The main principles to form competences being studied in the education companies while the specialist’s preparation of the Industry 4.0 being conducted. It is clear that the primary disciplines and its scientific content must be determined after the technologies being used in the digital companies. They propose to implement net forms to realize educative programs in close cooperation of educative companies and industrial companies equipped with cyber and physical systems. Oriented on practice approach to organize educative process may provide a high level of specialist preparation quality for the Industry 4.0. There is a scheme how to form a set of profile disciplines and its resource base which are oriented to prepare highly qualified cadres for the Industry 4.0.

1. Introduction

The implementation of progressive informative technologies [1, 2] in the item manufacturing technological processes led to new requirements of the specialist knowledge level who are to operate cyber and physical systems (CPS) in the production [3, 4]. Traditional specific knowledge which today have people who have finished their education are insufficient to operate professionally the digital production company technological equipment [5, 6] including the exploitation of cyber and physical systems.

To task solution of the future specialist qualification improvement must be taken from creation and implementation in the educative process multi discipline education programs [7, 8] being realized in its net form of educative and production partners which have the necessary resources. Such resources today are digital technologies, cyber and physical equipment and professionally prepared scientific cadres which are capable to give their apprentices knowledge and skills which are necessary to work in the Industry 4.0 companies [9].

Multi discipline approach to form the scientific content of educative program requires oriented on practice knowledge to be developed and implemented into educative process in different fields of industry [10] which are used in item designing companies to manufacture the items. Complex way of student knowledge done by its educative organization masters and professionally prepared experienced cadres which work in industrial partner company where all forms of practices are being organized...
including student scientific research work and also the preparation of its bachelor and magister qualification works on the actual themes of the Industry 4.0 [11].

The base of practically oriented knowledge is the work programs scientific content which are being used for discipline education which together combines the study plan of highly qualified personnel preparation. So the task at hand is to define key technologies being applied in the cyber and physical digital production and necessary laboratory equipment to imitate different activity aspects of real production machines for their combine application in the educative company process to qualify the specialists with the perspective occupation of the future.

2. Specialists preparation for the Industry 4.0

To create study documentation to provide company educative activity is the most important element of educative process quality management system. Traditionally study documentation of educative company of high education contains:

- work disciplines programs which contain all type of auditory works with students;
- work study plans to make clear the necessary amounts of pass points where it is stated for each profile disciplines, forms of student frontier qualification, the discipline place in the work process chart and other;
- calendar chart of work process to give details of each year (semester) all types of study disciplines distribution;
- practice work programs and scientific research work of the student which have the short version of knowledge and formalized skills being studied;
- fund of evaluation means to describe the ways of knowledge control which student has when the educative program components are being studied and other.

In figure 1 there is a scheme how to form a set of profile disciplines oriented for high quality personnel preparation how to operate cyber and physical systems in production and its resource provision with laboratory equipment. Key field of inter disciplinary knowledge which are necessary for student to acquire the necessary skills are defined:

- informatics and calculation technics;
- technical systems control;
- information security;
- item designing and other.

Each inter disciplinary specialist preparation direction requires that the student studies the necessary set of profile disciplines which contain the description and application practical features of the digital production technology. Digital production technologies today include:

- industrial internet of things in particular and ways of wireless information transmission in general;
- cloud technologies which give the student the necessary knowledge and skills how to organize cloud services and cloud resources of different types;
- augmented reality which give the student the necessary knowledge and skills in virtualization of man and machines interface interaction which is operators and cyber and physical systems in production;
- cyber and physical systems security which is an integral component how to organize highly reliable production division specialized in item manufacturing after electronic documentation without human participation;
• additive technologies which give the student the necessary skills of new ways of items 3D printing in radio electronics, optics, machine designing industry;
• sensor technologies which give the student the necessary knowledge how to organize inter machine (inter system) interaction between industrial machines (cyber and physical systems) as a part of production workshop and other.

Each of the given technologies being studied today separately in different educative programs reflects a component how a digital production will function. To include that interdisciplinary knowledge in a single educative program will help the educative company and their industrial partner to prepare highly qualified cadres oriented to operate a cyber and physical production division.

![Diagram](image_url)

**Figure 1.** Formation scheme of profile disciplines set oriented for preparation of highly qualified cadres for the Industry 4.0.
An approximate list of profile disciplines to compose the study plan of specialist preparation in future occupation may include:

- industrial robotic technics - a discipline oriented to give the student knowledge how to create a robotized cyber and physical equipment (manipulators) of industrial purpose;
- digital automatic control system - a discipline to give the student knowledge how to control the digital processes of production machines and control variable which are being transmitted through the wireless information and communication nets;
- wireless information and telecommunication nets - a discipline which gives the student understanding how to transmit remotely production data, information exchange protocols (industrial communications) and other;
- highly productive calculation systems - a discipline which gives the student knowledge and skills how to create an integrated calculation systems of industrial purpose;
- programming - a discipline which gives the student skills how to develop a software, how to create program documentation (code documentation) for cyber and physical systems of industrial purpose;
- information security of cyber and physical systems - a discipline which makes the student aware of known and perspective technical and technological means of villains who want to violate the integrity of the information being transmitted in the company to receive authorization of unauthorized access to the cyber and physical systems resources and other;
- functional safety of cyber and physical systems - a discipline which helps the student to gain knowledge and skills in cyber and physical system self-organization, artificial intelligence and other;
- additive production - a discipline which helps the student to gain knowledge and skills item digital 3D printing and optical units, item designing, machine designing and other;
- cyber and physical systems projection - a discipline which the student takes as a part of automatized projection technologies of digital production components which helps to develop and create sets of construction and technological documentation for the item;
- numeric program control - a discipline which gives the student knowledge and skills of 3D models preparation which are being used by cyber and physical systems to manufacture the item and other.

If they want that the students gain the knowledge of profile disciplines and digital production technologies it must be done with specialized laboratory equipment which is equal in its exploitation conditions to the industrial cyber and physical systems in production. The educative process laboratory equipment to prepare the highly qualified personnel for the Industry 4.0 shall include:

- industrial robotic manipulators (cyber and physical systems) and its automatic control digital models;
- industrial programmable controllers and wireless net connection controller;
- multi-agent cyber and physical nets of industrial data safe transmission;
- 3D-printers and numeric control machines;
- license software to automatize project and production activity of designers and manufacturers being applied in digital factories and smart factories, and other.

3. Conclusion
Preparation of cadres to work in digital companies is the most important component of state science and technical politics to digitalize the economy. To develop new educative programs, they require to create the educative standards of new generation. The creation of new occupations oriented for digital production also mean that the state in their new professional standards which describes the job
descriptions and actions of potential specialists must correspond to the technologies of cyber and physical systems acquired in the educative company.

Multi discipline approach to study the profile disciplines requires that the educative companies make some structural changes which changes the existing ideology of faculties creation where the primary unit is a cathedral. This cathedral principle of educative companies was intended for specialized formation of knowledge and skills for students where the Industry 4.0 companies require the personnel which has different knowledge in the digital production technologies. Such knowledge today may grant only the artistic groups of science and educative personnel in different occupations united into educative company into a single, bigger than a cathedral, structure.

Creation of new occupations oriented to operate cyber and physical systems and technologies being implemented into the economy industrial sector in time will re-distribute the workforce market. Some occupations existing today especially occupations of «subtractive» production most probably will be replaced with new one occupations of additive production. Production companies staff will lower in time because the companies will implement paperless documentation and deeper automatizing of production processes. In this conditions the priority direction for educative companies must be the transformation of educative process to the inter disciplinary component and make stronger industrial and technological connections with partner companies which is the practical side of specialist preparation.

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