Information Systems and Technologies in Agronomy and Business: Employers' Requirements-Oriented Study in Agricultural Universities

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ABSTRACT

This paper describes innovative approaches to the development of an academic course in information technologies in agronomy. The results of an effective combination of teaching methods through solving crosscutting situational tasks created by a group of teachers. The authors demonstrate efficiency of introduction of modern information systems into the educational process due to the use of discipline software provided by stakeholders with the examples of interactive tasks in the environment of the IS for real-time production process management. Program results are corresponds to standards of higher education in Ukraine, to the European framework of e-competences and were discussed with employers, which are the heads of agricultural enterprises, representatives of agribusiness and IT companies.

The article shows examples of motivational measures during training and summarizes the results of cooperation between universities and business. The relevance of the work is considering in the context of Agriculture 4.0's current trends and studying the needs of employers and software developers.

Keywords: e-competences, Agriculture 4.0, information technologies in agronomy, electronic sales, educational proses, curriculum design

1. INTRODUCTION

The agricultural sector worldwide, as well as in Ukraine, is an extremely scientifically capacious field, requires an introduction and development of new modern technologies, especially digital, information and communication, and finally, the inclusion of artificial intelligence systems in acquisition and processing of data [1]. Universities carry out significant work in the training of specialists on the basis of scientific research, studying the needs of the labor market, the use of information technologies and communication networks.

In his paper through the prism of the needs of the modern labor market in the field of agricultural production and IT, the results of the development and implementation of an innovative training course in the discipline "Information Technology in Agronomy" are shown. The program of the discipline is based on the study of information systems, which are actively used today in various areas of the agricultural sector of the economy in solving a wide range of tasks of this industry. The results of the effective learning organization through the solution of crosscutting situational problems created by a group of teachers that are specialists in various fields of agricultural sciences and information technology were presented. The software of the discipline was provided by stakeholders in the framework of mutually beneficial cooperation between universities and enterprises - University-Industry Cooperation (UIC). The list of topics of the discipline allows providing the necessary learning outcomes, which were also discussed with the participation of employers: managers of agricultural enterprises, representatives of agribusiness and IT companies.

Learning objectives were achieved through well-thought-out cases and crosscutting situational tasks, which are built based on a description of real technological processes. The materials for the creation of situational tasks were selected in cooperation with representatives of agricultural enterprises. They are based on real documents used by agronomists.

The work consists of the analysis of the latest research of development directions in agro-industry, description of methods and approaches in the organization of training, and presentation of the results of development and implementation of a course «Information technologies in agronomy" at Poltava State Agrarian University.

2. ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Since the middle of the 20th century, futurologists, researchers of socio-economic change have been actively discussing and explaining the essence of the processes associated with the formation of the information society because of the third industrial revolution. The technological and technical basis of this period were computerization and automation of most production processes in industry, flexible production, the rapid development of computer networks, the Internet, the recognition of information as a new unique production resource.

Today we are participants in the processes of the fourth wave of industrial revolutions (Industry 4.0) through the development of information and communication technologies (ICT). The technological basis is an intelligent automation using cyber-physical systems (CPS) and the Industrial Internet of Things (IoT), decentralization of management. One of the important consequences for industrial production systems is the reorganization of classical hierarchical automation systems into a self-organizing system of cyber-physical production, which allows flexible mass production to order and achieve flexibility for production. [2].

The basis for active implementation of Industry 4.0 is that currently most opportunities to increase profitability are almost exhausted; there is a need to look for new opportunities and resources. These trends are also observed in agricultural production. The World Government Summit has published a report that is named as "Agriculture 4.0 - The Future of Farming Technology". This report notes in particular, "farms and agricultural operations will have to be run very differently, primarily due to advancements in technology such as sensors, devices, machines, and information technology. Future agriculture will use sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advanced devices and precise agriculture and robotic systems will allow farms to be more profitable, efficient, safe, and environmentally friendly" [3].

In the agricultural sector, the prospects for the introduction of Industry 4.0 relate to the introduction of precise farming systems and the connection of intelligent systems. Since traditional automation tools in this area have not been widely represented, the construction of intelligent agriculture usually considers from the initial level. Specific features of agricultural production field in the context of introduction of intelligent systems increasingly consider through the paradigm of Agriculture 4.0 [4].

With the digitalization of all spheres of life, the world of work and the requirements for the skills of professionals are radically changing. In addition to equipment and IT systems, human resources considered among the main factors that have an impact and ensure the readiness of companies for Industry 4.0 in many countries [2, 5]. The training and emphasis on of e-competencies in the study of specialists in various fields are now mandatory for the mass implementation of the latest principles of production process management.

As follows, at the present stage, content of university education at all levels is increasingly viewed from the point of view of not only gaining specialized professional knowledge and skills, but also computer, information competencies, located in the interdisciplinary planes. Training programs are developed in collaboration with employers, business representatives (stakeholders) according to the needs of the modern labor market to reduce the adaptation time of young professionals and make them more competitive [6]. There are many interesting publications about establishing successful cooperation between universities and IT companies or industrial companies [7]. However, the issues of the combination of current trends in the development of IST and the training of agronomists in agricultural universities were insufficiently covered and require research that are more detailed.

The purpose of this work was to show the elements of construction and teaching methods, to reveal the reasons of the success of the original master's course in the discipline "Information Technology in Agronomy", which combines competencies in agronomy, entrepreneurship and information technology. The course is based on the study of modern information systems (IS) that are implemented in agricultural enterprises with integrated management of production and business processes.

3. THE METHODOLOGY USED

Taking into account the latest trends in the labor market, transition of leading agricultural enterprises to a higher level of technology using precise farming systems, a group of teachers - specialists in agronomy and information technology - analyzed existing information systems on the software market and used in the agricultural sector. The selection criteria for such systems was considered from several points of view (different viewpoints). The first was that the systems should be used in real agricultural enterprises and meet the needs of production process management [4]. On the other hand, we must be able not only to study the interface, the functionality of such a system, but also to implement a number of tasks of an educational nature, as close as possible to very professional conditions. The software must be licensed or freely available. All stakeholders were involved in the cooperation, a large number of seminars, scientific and practical conferences, negotiations with the authorities, surveys of senior students with work experience [8]. As a result of establishing contacts and signing bilateral agreements with IT companies and the university, Soft.Farm and Agroxy, which are based on cloud technologies, have free access to some modules and are ready to start working from any workplace, were selected for study.

The Soft.Farm IS has a full functionality and an appropriate interface for the management of production processes in crop production and stockbreeding [9], a large number of completed directories, generates all reporting documents in accordance with current laws. The system provides users with the following online services: SaaS (fields monitoring, data analysis, data interoperability, financial analysis), PaaS (data storage, authentication, resource management, databases, and access to the executive program), and IaaS [4, 8].

Agroxy system was designed for conducting of legal protected sales of large and medium batches of agricultural products, implements auction technology by type of the Dutch auction (reduction), connected to the registers of Ukrainian enterprises, registers the certificates of volume and quality of batches of elevators. System has the most complete elevator maps with full description and calculation of logistics, uses block chain technology, generates the entire package of supporting documents for the completion of the sale transactions of products, and has bank guarantees [10]. IT companies, which are the developers of these software products, have shown interest

in long-term collaboration with universities, developed additional training modules (such as test bidding), provided free access to individual paid geoformation applications of companies or promo codes to simulate paid transactions.
The creation of a new training course "Information Systems in Agronomy" and the first successful realization took place in the 2017-2018 academic years. At that time, there were no other analogues of such a program. The most important steps in choosing the content and teaching methods are considered in the next section.
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4. EDUCATIONAL ASPECT OF IMPLEMENTATION OF INFORMATION SYSTEMS IN AGRONOMY

When developing the curriculum in the discipline "Information Technology in Agronomy", the topics of individual modules and software were selected taking into account the recommendations of stakeholders (heads of agricultural enterprises, representatives of IT companies, academic community) and expected learning outcomes. When detailing the programmed skills at the end of the course, the developers of the program took into account the standards of higher education in the specialty "Agronomy" of a master's level, which operate in Ukraine, as well as some examples of e-competences described in the European Electronic Competence System (e-CF) 3.0 [11]. European e-Competence Framework (EQF), e-CF was created for use by ICT in all places of application by users and operating companies, for managers and personnel management departments, for educational institutions of all levels of education, as well as other organizations in the public and private sectors. Out of the 40 competencies currently used in ICT in the workplace, using common language to describe competencies, skills and ability levels, there were selected those that best reflect the requirements of the modern specialist in the context of Agriculture 4.0. The list of e-competencies selected from 5 directions of electronic competence, derived from the ICT business processes PLAN - BUILD - RUN - ENABLE - MANAGE, is given in table 1.

Table 1. List of e-competencies of e-CF, which are included in the program of the discipline "Information systems in agronomy"

e-Competence areas	Knowledge examples (Knows/aware of/ familiar with)	Skills examples (Is able to)
A.9. Innovating	K1 existing and emerging technologies and market applications K2 business, society and/or research habits, trends and needs K3 innovation processes techniques	S1 identify business advantages and improvements of adopting emerging technologies S2 create a proof of concept S3 think out of the box S4 identify appropriate resources
B.5. Documentation Production	K1 tools for production, editing and distribution of professional documents K2 tools for multimedia presentation creation K3 different technical documents required for designing, developing and deploying products, applications and services K4 version control of documentation production	S1 observe and deploy effective use of corporate standards for publications S2 prepare templates for shared publications S3 organize and control content management workflow S4 keep publications aligned to the solution during the entire lifecycle
D.10. Information and Knowledge Management:	K1 methods to analyse information and business processes K2 ICT devices and tools applicable for the storage and retrieval of data K3 challenges related to the size of data sets (e.g. big data) K4 challenges related to unstructured data (e.g. data analytics)	S1 gather internal and external knowledge and information needs S2 formalize customer requirements S3 translate /reflect business behavior into structured information S4 make information available S5 ensure that IPR and privacy issues are respected S6 capture, storage, analysis, data sets, that are complex and large, not structured and in different formats
E.5. Process Improvement	K1 research methods, benchmarks and measurements methods K2 evaluation, design and implementation methodologies K3 existing internal processes K4 relevant developments in ICT (e.g. virtualization, open data, etc.), and the potential impact on processes K5 web, cloud and mobile.technologies K6 resource optimisation and waste reduction	S1 compose, document and catalogue essential processes and procedures S2 propose process changes to facilitate and rationalize improvements S3 implement process changes

Prerequisites for studying the program are the possession of master's students most of the professional competencies that were obtained from the required agronomic disciplines by specialty "Agronomy" (agrometeorology, agrochemistry, soil science, agriculture, entomology and phytopathology, land reclamation, mechanization of crop production, selection and seed production, technology of processing of crop products, etc.) and include:

- This stage of work considered extremely important and Knowledge and understanding of basic biological and agro-technological concepts, rules and theories related to the cultivation of agricultural and other plants.
- Ability to coordinate, integrate and improve the organization of production processes in agricultural production.
- Ability to use modern scientific and technical, cultural achievements of world civilization.

The second criterion for the quality of the course according to the TUNING project is the concept of the project - it is a guaranteed "adherence to goals", namely the ability to achieve the stated goals through the course. The available resources determine this capability, while the quality of the resources directly affects the quality of the program. In this regard, it is important to note the following. Teachers of the Department of Information Systems and Technologies (2 PhD), the Faculty of Agrotechnology and Ecology (2 PhD), as well as the Departments of Entrepreneurship and Marketing of Poltava State Agrarian University worked on the development and implementation of the program. A specialized educational and scientific laboratory "Soft.Farm IS User Training Center" has been established, which is equipped with modern computers with free access to the high-speed Internet via a wired connection and Wi-Fi, designed for the simultaneous study of 15 students. During four academic years, the discipline has been evolving, enriching with new ideas as well as information systems have been modernized.

5. CONTENT OF ACADEMIC COURSE AND THE OUTCOMES OF THE WORK

The initial program, which is presenting now, allowed realizing the whole learning outcomes due to the well-thought-out structure of the course and topics. The course is designed for 4 ECTS credits, consists of two modules - theoretical and practical. Module 1 by name includes the following list of topics (the original wording is given).

Topic 1. Introduction. The concept of information. Data as a source of information. Properties of information. Forms of information presentation.

Topic 2. Information technologies in agriculture.

Topic 3. Documenting the professional activities of an agronomist. Preparation and execution of the main types of documents. Electronic document. Electronic office.

Topic 4. Computer networks in ensuring the production and commercial activities of agricultural enterprises.

Topic 5. Information systems and technologies for agricultural services.

Topic 6. Information systems are based on "cloud technologies" for the needs of automation of production activities.

Topic 7. Planning, implementation and development of information systems in the activities of an agronomist.

Topic 8. Perspective directions of development of information systems in agricultural production. The concept of Agronomy 4.0 in Ukraine and in the world.

The topics of module 1 are the basis of the lecture course, covered by university lecturers. At the same time, specific issues and ways of using information systems were developed in cooperation with representatives of IT companies and employers. Public lectures leading specialists of agricultural enterprises, who are introduced to the innovations of the information technologies for the agricultural sector in the context of S2B relations (science-to-business).

Module 2 is a practical part, which is implemented by performing a laboratory workshop. The workshop includes several thematic sections. The first part is devoted to the development of e-competencies related to the use of general-purpose office software and is implemented in the following topics.

1. Tools for creating electronic document management databases of an agricultural enterprise: business letters, templates of official documentation, formsetc. (related to e-CF competences B.5).
2. Carrying out economic and financial calculations when performing the functions of analysis (related to e-CF competencies B.5, D.10, E.5).
3. Research of search, storage and publication of the information for needs of the enterprise by means of the Internet. Conducting market research, analytics (related to competences D.10, E.5).
4. Determining the efficiency of work and setting up a computer network (related to e-CF competences E.5).

The second, larger part of the workshop is based on the study of capabilities, work in the Soft.Farm IS, which is directly used to manage typical production processes in agricultural enterprises. The system can be classified as Manufacturing Execution System (MES), which is on the second level of the traditional automation pyramid. Soft.Farm IS supports reporting on production, planning, scheduling, product tracking, operations with maintenance, analyzes performance, manpower tracking, resource utilization and so on. The system is integrated with other levels of production automation; its implementation in the agricultural enterprise is an objective prerequisite for the transition to the following elements of Agriculture 4.0.

The system database includes a lot of valuable information about all types of soils, fertilizers and plant protection products, agricultural and energy machinery in the form of dictionaries. All dictionaries can be supplemented with new data related to a specific enterprise by the users themselves.

Examples of application of adjustment operations and work in the environment of information system in the course

From the university, teachers have developed guidelines for conducting classes in a system environment using the case method. During 12-14 hours of laboratory classes, students consider a crosscutting situational task, which includes all elements of professional application of IS in real conditions. Due to free access to the main modules of the IS Soft.Farm, students have the opportunity to enter all information about the agricultural enterprise in the program environment. They can also to conduct planning of work calendar and crop rotation, to calculate a fertilizer application in fields with different conditions and in different climatic zones, and much more. One of the main operations after entering all the data about the company is to work on drawing clear contours of the fields (Fig 1)..

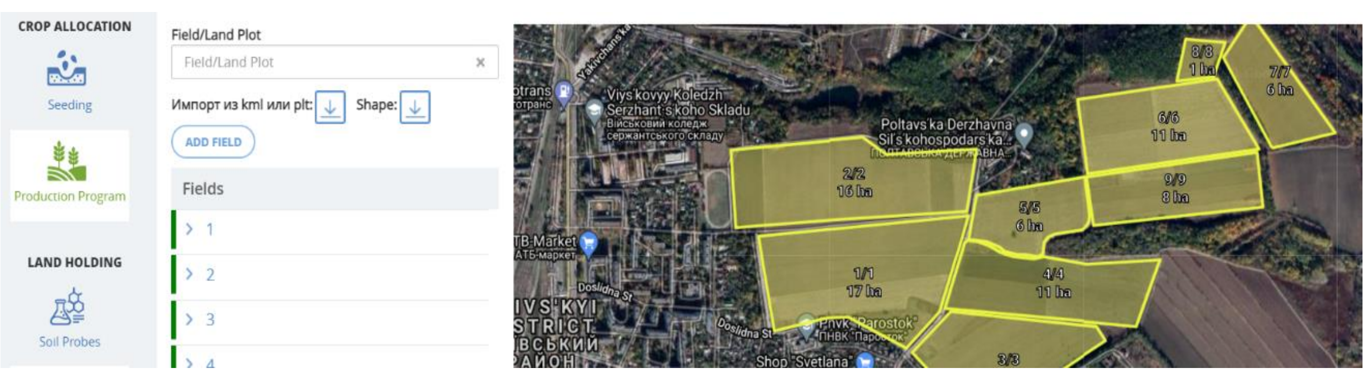

Fig.1. View of fields with the resulted contours in IS Soft.Farm [designed by authors]

Fig. 1 shows the outlines of fields overlapped on a map of the area in Google, as they do in practical classes. Each field automatically has its number from the database and an accurate calculation of the area. You can perform additional calculations, such as measuring the distance to the nearest facilities - elevator, farm, etc. Most of the functional modules of the system are objectively related to the control and management of the state of land, as well as the planning of a full cycle of technological operations for growing crop production. Due to the use of self-entered data and those that are available in the database of the system, students had the opportunity to make calculations and observations at many stages of agricultural production. We can consider a few examples that was studied and analyzed in class.

Field works control module: according to the materials of digital recording of works in one of the experimental farms provided by the system developers, the solution of practical problems is demonstrated in class and the criteria of the control of field work by field equipment is shown (Fig. 2). The module provides opportunities receive quickly an information on the performance of works and fuel consumption in the context of agricultural operations, fields, equipment and machine operators..

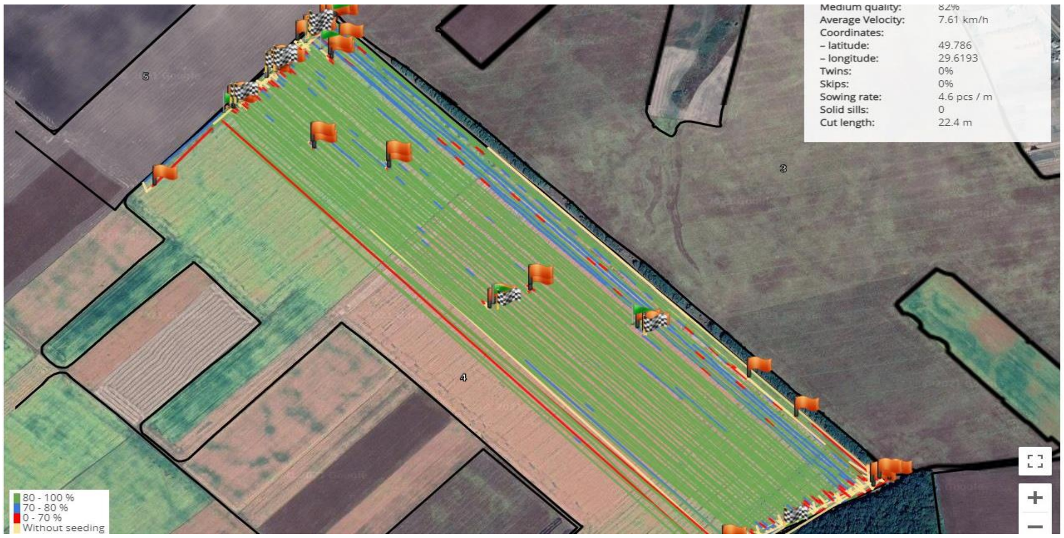

Fig. 2. Control over the quality and process of fieldwork to track the employment of equipment units in real time [designed by authors]

The map of passes when applying seed material with marks on actions of concrete units of transport and the consolidated data on a site presents in detail (Fig. 2). The flags are special labels for quality control of seed application and technological actions of vehicles to eliminate the identified shortcomings. Mode of operation of transport: stop - elimination of shortcomings (appication of seeds where missed) - continuation of work. The legend of drawing on colors (from norm of 100% to a blue and red zone in which sowing materials are insufficiently brought).

In Fig. 3 the principle of using the data of chemical analysis of the field's soil on the concentration of minerals necessary for crop growth is shown. Based on the measurements of chemical analysis of the soil of the field, a map is created. On the right - the technical task for the technological device for application of the corresponding fertilizers. The colors indicate the levels of soil saturation: from the lowest level (10 kg / ha, green color) to the highest level (30 kg / ha, red color). The technical task downloads to the computer of the machine for differentiated application of fertilizers, minerals to line-up the overall saturation of the site. The efficiency of using differentiated application of fertilizers compared to the application of the norms is on average 15%. The task is easily reduced to economic calculations for specific types of fertilizers. Students demonstrably trace not only the agronomic aspect of the application of the information system, but also environmental, economical results. .

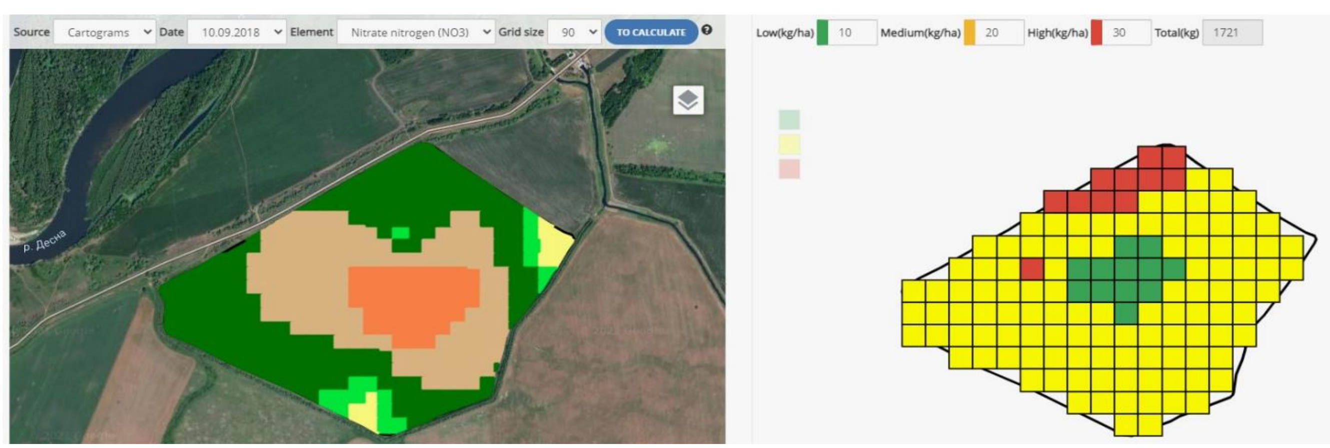

Fig. 3. The results of chemical analysis of the field (left) on the concentration of nutrients and the technical task on the differentiated fertilizer application (right) in the IS Soft.Farm [designed by authors]

In order to increase motivation for training, professors in cooperation with employers have introduced a system of knowledge testing and certification at the end of the study of the discipline, which provide benefits for future employment. All lists of certified users are in the news section of the IP site [9].

The last part of the laboratory workshop was working with the Agroxy agricultural trade system, which allows studying the benefits and mechanism of online sales of medium and large batches of agricultural products on the technology of Dutch auction (reduction). This block chain ecosystem provides a regional information and trading platform that not only supports the sale of crop products, but also aims to optimize logistics processes, document processing, reduce risks in commercial transactions, and expand the geography of supply and demand [12]. Agroxy system's programmers have developed a training auction specifically for the training process, which allows you to model the process of selling products online, just during training. This aspect is final in the sequence of processing of information flows from the field to the sale to the final consumer.

Accordingly, the program of discipline and application of combined teaching methods presented in this paper demonstrated the best opportunities for students to achieve all the planned both professional and e-competencies, as well as additional marketing and business skills. During four academic years, more than 150 students studied e-commerce in the Agroxy system; worked online in the Soft.Farm IS and received certificates. Some students have chosen a topic to write a master's thesis related to the implementation of information systems on specific materials of agricultural enterprises. The authors of the course wrote a manual on the subject "Information Technology in Agronomy", which together with teaching methods and well-selected software is now used in many other agricultural universities in Ukraine.

6. CONCLUSIONS

The active introduction of the latest general-purpose information technologies and those designed specifically for use in the agricultural sector is an integral attribute and prerequisite for achieving a qualitatively new level of agricultural development.

Cooperation with leading companies in the IT industry is expanding every year is mutually beneficial for all parties: universities, businesses, enterprises, government agencies, and local communities. However, due to the inconsistency of certain legal, educational, motivational aspects in the activities of universities and business, there are factors that restrain the pace of innovations introduction.

Among the main problems that arise when creating such training courses are lack of sufficient business motivation for more active cooperation with universities; unwillingness of a certain part of teachers to introduce new ideas and methods into teaching; absence of educational standards, which respond to industry requirements, best practices of national education.

The authors demonstrate how all these factors can be systematized to build a corresponded list of professional competencies to support agricultural producers through the higher education system. Further research should be aimed at the accumulation, systematization, and dissemination of experience among other universities, where the similar results would be obtained, in both Ukraine and other countries.

7. REFERENCES

[1] Slyusar V.I., "Artificial intelligence as the basis of future control networks", *Coordination problems of military technical and defensive industrial policy in Ukraine. Weapons and military equipment development perspectives.* VII International Scientific and Practical Conference. Abstracts of reports. October 8–10, 2019, Kyiv. DOI: 10.13140/RG.2.2.30247.50087

[2] Rojko A. "Industry 4.0 concept: Background and overview", **International Journal of Interactive Mobile Technologies**, 11(5), 2017, pp. 77-90. doi: 10.3991/ijim.v11i5.7072

[3] "Agriculture 4.0 – The Future of Farming Technology". Obtained from: https://www.oliverwyman.com/our-expertise/insights/2018/feb/agriculture-4-0--the-future-of-farming-technology.html

[4] O. Kopishynska, Y. Utkin, O. Galych, M. Marenych and I. Sliusar, "Main Aspects of the Creation of Managing Information System at the Implementation of Precision Farming", *2020 IEEE 11th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2020, pp. 404-410, doi: 10.1109/DESSERT50317.2020.9125072

[5] Ismail, F., Abdul Kadir, A., Asad Khan, M., Pei Yih, Y., & Ali Hassen Humeed Al Hosaini, A., „The Challenges and Role Played among Workers of Department Human Resources Management towards Industry 4.0 in SMEs. KnE Social Sciences", 3(22), pp.90–107. " Obtained from https://doi.org/10.18502/kss.v3i22.5

[6] Turkin and Y. Vykhodets, "Software engineering master's program and Green IT: The design of the software Engineering Sustainability course," *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2018, pp. 662-666, doi: 10.1109/DESSERT.2018.8409215.

[7] A. Boyarchuk, V. Kharchenko and V. Sklyar, "Models and cases for sustainable university-industry cooperation in IT sector," *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2018, pp. 667-671, doi: 10.1109/DESSERT.2018.8409216.

[8] O. P. Kopishynska, Y. V. Utkin, S. V. Voloshko, I. I. Sliusar and O. G. Kartashova, "Algorithm of creating of an efficient cooperation between universities, business companies and agriculture enterprises during studying and implementation of information systems," *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2018, pp. 682-686, doi: 10.1109/DESSERT.2018.8409219.

[9] "Soft.Farm - is a free software for organization and management of agricultural activities". Obtained from https://www.soft.farm/en

[10] O. Kopishynska, Y. Utkin, I. Sliusar, V. Slyusar, N. Protas, and O. Barabolia, "Professional-oriented Training of Specialists under Implementation of Cloud Computing Information Systems in Cooperation Between Universities and IT companies", Proceedings of The 14th International Multi-Conference on Society, Cybernetics and Informatics (IMSCI 2020), 2020, pp.17-22.

[11] "European e-Competence Framework (e-CF). e-CF 3.0". Obtained from http://www.ecompetences.eu/e-cf-3-0-download/.

[12] Official syte Agroxy. Obtained from https://www.agroxy.com/