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PEDAGOGICAL TOOLS AND ECONOMIC AND MATHEMATICAL METHODS IN AGRICULTURAL PRODUCTION MANAGEMENT

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Abstract

Within the conditions of reforming agribusiness the task of performance improvement in agricultural production has to be solved by the latest economic and mathematical methods. Setting and solving optimization problems is a relevant management tool of agricultural production in resource poor settings and an intrinsic part of agricultural engineer professional activity. It was in studies revealing that the basic contradiction between the objective need of agricultural production for optimization task accomplishment and inability of students - future agricultural engineers to their solution. One of the ways of this contradiction resolution is development of the practice-oriented system of mathematical training providing formation of socio-technical competence of agricultural engineers expressed by abilities to use the methods of optimal decision making in professional activity. The scientific idea of engineering activity in agribusiness is concretized by the authors following the logic of scientific enquiry; the structure and criteria of component formation of socio-technical competence of agricultural engineers is presented. The offered practice-oriented system of mathematical training is based on the content providing mutually development of all components of socio-technical competence due to application of the competence-based modules reflecting specifics of engineering activity. With regard to the above mentioned the structure of modules is presented in the form of block sequence corresponding to a decision-making algorithm that creates conditions for adaptedness of graduates to special aspects of agricultural engineering activity.

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Keywords: Agricultural production, management tools, economic and mathematical methods, optimal decisions.

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1. Introduction

Implementation of the state program on reforming of agribusiness targeted at the country problem solution of food supply security requires an effective management system at any stage of production starting with technology process planning to sales of goods. At the same time dynamically changing environment conditions, natural scarcity (technical, financial, labor, etc.) cause application of appropriate management tools – economic and mathematical methods which allow implementing the solution of multidimensional multiple-choice optimization tasks by means of information technologies and correcting results promptly according to the change of internal and external conditions of production in various spheres of economy (manufacturing industry, transport, health care, etc.). Agricultural production is an industry where effective application of decision-making methods is possible as well, because it is characterized by scantiness of resources in time and space, availability of targets and performance indicators of agricultural production, freedom of economic decision choice stemming from the various level of needs and resources (Trubilin et al., 2012). It should be noted that in the conditions of the market economy when a company revenue yield depends directly on the level of its performance, economic results of decision-making which are worsened with complexity of reproduction in agricultural production, convergence of economic and biological factors; production risks connected with changes of weather conditions, natural disasters; economic uncertainty caused by fluctuation in prices, supply and demand, rate of interest on credit (Vasilieva, Reznichenko, Vasiliev, Trubilin, Iosifovich, & Bershitskiy, 2016). Hence, the problem of finding and making optimal decisions, i.e. corresponding to the purpose of the management system to the fullest extent, is updated.

2. Problem Statement

The study problem is content design, and definition of means of socio-technical competence formation of agricultural engineers expressed by the abilities to the problem solution of resources and process optimization being one of key strategies in development of modern agribusiness.

3. Research Questions

The analysis of the works (Burda, Frantsisko, Baranovskaya, Trubilin, & Loiko, 2016; Belyaeva, Ermoshkina, Sukhinina, Starikova, & Pecherskaya, 2016; Manos, Chatzinikolaou, & Kiomourtzi, 2013; Jablonsky, 2017) confirms the enormous potential of making optimal decision methods in agricultural production management. The issues of optimization were investigated: balanced ration (Kocjančič, Žgajnar, & Juvančič, 2016; Lukyanov & Lukyanov, 2015); parameters of pasture and dairy farming (Filippi, Mansini, & Stevanato, 2017; Merel & Howitt, 2014); reproduction processes of peasant farms (Burda, Burda, Zatonskaya, Kovalyova, Kosnikov, Osenni, & Frantsisko, 2016; Capitanescu, Marvuglia, Navarrete Gutierrez, & Benetto, 2017) and others. However, despite recognition of positive effect of optimization calculations, insignificant use of optimal decision making methods in practical activity of the agricultural companies is noted (Jablonsky, 2017; Trubilin et al., 2017) that is explained by complexity of information preparation, unavailability of appropriate software, but the main thing is shortage of skilled labor having a good command of decision-making methods.

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The main reasons for the created situation are to be considered. For identifying readiness of future students – agricultural engineers to put into practice methods of optimal decision taking we conducted a pilot research with application of the content analysis of final qualifying papers of the Engineering Department of the Samara State Agricultural Academy (the programs: 110301 Agricultural Engineering, 110304 Service Engineering and Machine Maintenance in Agribusiness, 110302 Electrification and Automation of Agricultural Industry) within the period of 2009-2015. As the result 619 messages (the topics of graduate theses) were analyzed, occurrence of the analysis unit (word: optimization) – 0%, i.e. performance improvement of agricultural production, its modernization and reconstruction are not connected with process optimization (Rudneva & Berishvili, 2016). The monographic, statistical, calculating and constructive and balancing methods are used for the engineering and economic analysis of the particular company performance or its division operation. While the methods of taking optimal decisions, allowing to define the strategic growth priorities of a company, an optimal variant of its resources employment, are not applied.

The application of making optimal decisions methods assumes: mathematical model-building of a task; its identification in terms of a class of optimization problems (linear programming, integer programming, dynamic programming and others); the choice of a solution method corresponding to this class of optimization problems (the simplex method, the prune method, the potential method etc.); search for an optimal solution with the use of the software (MATLAB, Mathcad, MS Exel, etc.); analysis of solution results. Thus, the solution of professional tasks including optimizing, requires an ability and readiness for application of mathematical modeling methods in professional activity of an agricultural engineer, that is reflected in Federal State Educational Standards of the higher education. However, the analysis of working documents of the Mathematics course on the Agricultural Engineering program (the educational program specialization: Engineering Systems in Agribusiness, Technical Service in Agribusiness) revealed lack of informative and methodical basis focused on forming skills of mathematical modeling. Thus, the Methods of Optimal Solutions course and its possible modifications (Optimization Methods, Operation Research Methods, Mathematical Programming, etc.) are not studied by agricultural engineers.

As a part of the study the survey of teaching staff among thesis advisors of the specialized departments: (Agricultural Machinery, Tractors and Motor Vehicles, Security of Service and Machine Maintenance, Maintenance of Machine and Tractor Fleet, Livestock Breeding Mechanization and Technology, Electrification and Automation of Agribusiness, Mechanics and Engineering Graphics) was conducted in the Samara State Agricultural Academy (the sampling made 42 people). The survey findings showed that 52% of the respondents consider the insufficient mathematical training level of students for further mastering of special courses, among them 85% find some difficulty in building mathematical models of productive processes. It should be noted, that only 9% of respondents connect dissatisfaction with mathematical training with inability to solve optimizing problems, that is, in our opinion, can be explained by insufficient awareness of teachers about the opportunities and advantages of application of optimal decision methods in professional activity optimization (Rudneva & Berishvili, 2016).

Therefore, changes in the agricultural engineering activity content, its orientation to the solution of professional tasks of process optimization and taking optimal decisions updates the problem of

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mathematical training of agricultural engineers. It is necessary to recognize that the researchers addressed a problem of students' mathematical training in agricultural higher educational institutions: the potential of the Higher Mathematics course for forming students' readiness to educational activity development in agricultural higher educational institutions was noted; integrative communications between Informatics and Mathematics in the process of training future experts in the agricultural sphere and engineers in timber complex were considered. In addition the developed system of mathematical training of agricultural engineers demands revision and specification of its content objectively, its structure on the basis of the principle of interrelation with courses of professional, humanitarian, social and economic cycles, innovative processes in the agricultural sphere that is caused by designing new professional focused courses and technologies.

Therefore, the analysis of the scientific literature and teaching training, studying the requirements of experts and managers of the agricultural companies for vocational training of experts in agricultural higher educational institutions allowed revealing the main contradiction between the growth in the need of agricultural production in achieving the objectives of resource optimization and inability of students - future agricultural engineers to their solution.

The present-day practice of vocational training of engineers in agricultural higher educational institutions needs to be reconsidered, as strict requirements are imposed on vocational training quality in connection with reforming the agribusiness. Formation of socio-technical competence as an integrative attribute of a personality, allows focusing inner personal resources on performing the main line of engineering activity – socio-technical design, provided that:

- the scientific idea of engineering activity in agribusiness is concretized;
- the essence is revealed, the structure is developed, the criteria of forming socio-technical competence of agricultural engineers are marked out;
- the adaptive system of mathematical training of agricultural engineers providing formation of socio-technical competence is designed and approved.

4. Purpose of the Study

Under the study the purpose was set, that is development of the practice-oriented system of training engineers in an agricultural higher educational institution providing formation of socio-technical competence of an agricultural engineer.

5. Research Methods

Within the framework of the study the complex of the mutually complementary methods relevant to the study object was applied: the theoretical analysis and synthesis of historical, pedagogical, psychological, methodical literature for identification of specifics of agricultural engineering activity; empirical methods (involved observation, questionnaire, testing, self-appraisal summative and formative assessments); praximetric methods (studying the experience and establishing the best practice of vocational training of engineers in agricultural higher educational institutions, content analysis of regulations, training programs, topics of graduate qualification works, course projects, mathematical

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literature); qualitative and quantitative ways of processing of the scientific information (correlation, factorial analysis).

6. Findings

Agribusiness is a priority of the Russian economy which importance is caused by the social and economic transformations taking place in Russia, need for the problem solution of the country food supply security becoming aggravated in connection with Russia accession to the WTO and imposition of economic sanctions by the European Union against Russia. The main condition for reforming and sustainable development of agricultural production on the basis of technical and technological updating is availability of highly-skilled engineering personnel. The changes in process complicated the requirements to the personality of an engineer and caused the necessity for new ways of their vocational training improvement.

The studies in the field of the theory and methodology of vocational education showed that the design of training system has to consider specifics and characteristics of their future professional activity and conditions where it is implemented. Studying the object of agricultural engineer activity revealed that agricultural production is represented as a complex dynamic multicomponent open indeterministic socio-technical system where there are two subsystems (technical and social) requiring balance. Changes in a technical subsystem of agricultural production only predetermine increase in its efficiency, and real growth is provided with management (of a social system) while making optimal decisions (technical, economic, etc.). Thus, in the context of our study, engineering activity is considered as the process of professional tasks complex solution on production optimization in agribusiness and making optimal decisions according to the socio-technical public needs.

The study found that, agricultural production efficiency depends on the competent design providing optimum conjugation of its technical and social subsystems that demands consideration of a socio-technical design being the leading type of agricultural engineering activity, the criterion of which is optimality that reflects specifics of agricultural engineering activity. The interrelation and interdependence of social and technical processes of agricultural production cause characteristics of agricultural engineering activity that is making optimal decisions in the course of socio-technical design that will be promoted by use of economic and mathematical methods, in particular, the methods of making optimal decisions.

The logic of our study involving consecutive consideration of specifics and characteristics of agricultural engineering activity confirmed legitimacy of marking mathematical training of agricultural engineer socio-technical competence, as an effective characteristic, being an integrative attribute of a personality which is expressed by abilities to apply methods of optimal decisions in future professional activity for the purpose of balancing technical and social subsystems of agricultural production. In terms of the study it was proved that the demand for socio-technical competence is caused by several prerequisites: development of engineering sciences, needs for material production, problems of agricultural engineering activity.

When developing the structure of socio-technical competence was based on the principle of identification that allowed correlating the stages of socio-technical design and the stages of making an

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optimal decision and presenting the effective characteristic in the form of the set of components (value and motivation-based, information and cognition-based, technology- based, activity – based, reflexive and regulatory-based (table 01).

Table 01. Structure of agricultural engineer socio-technical competence

Socio-technical design stages	**Analysis for the system requirements and tasks**	**Information training**	**System parameter optimization**	**Implementation**	**Findings design due diligence**
Socio-technical competence components	Value and motivation-based	Information and cognition -based	Technology-based	Activity - based	Reflexive and regulatory-based
Decision-making stages	Problem identification and analysis	Strategy determination	The best alternative selection	Implementation of made decision	Assessment of decision efficiency
Agricultural engineering readiness types	Worldview readiness	Strategic readiness	Tactical readiness	Operational readiness	Behavioural readiness

Source: Rudneva & Berishvili (2016).

The content of components in the structure of socio-technical competence is defined by the principles of integrity that allows taking into consideration the qualification profile of an agricultural engineer, the leading type of agricultural engineering activity, and optimality that enables to specify requirements to the identity of an agricultural engineer implementing the function of production optimization using the methods of making optimal decisions. The following agricultural engineering readiness types: worldview, strategic, tactical, operational, behavioral were defined, as criteria of formation of socio-technical competence components.

The search result in vocational education quality improvement in an agricultural higher education institution was presented by the practice-oriented system of engineer mathematical training being a kind of the pedagogical system which development source is resolution of conflicts between the required and existing condition of mathematical training for agricultural engineering activity. The keynote (integration of mathematical knowledge which content is defined in accordance with Federal State Education Standards (FSES) and the meta course: Methods of Making Optimal Decisions for the purpose of agricultural engineer training to solve professional tasks on optimizing production processes) is based on the analysis of the practice caused by a new educational paradigm, changes in requirements to an agricultural engineer being capable to solve economic, production and administrative problems in the conditions of natural scarcity of agricultural production on behalf of employers. The integrated nature of competences causes consideration of interdisciplinary links as a system-forming factor of socio-technical competence formation. However, the problem of content selection and structuring is solved by marking the integrator – a mathematical model that corresponds to a current trend of mathematicization of sciences. The meta course: Methods of Making Optimal Decisions is presented in the form of the set of the competence-based modules (Resources Allocation, Stock Management, Maintenance, Business Management, Enterprise Strategy Development in the Competitive Environment) which content reflects specifics of agricultural engineering activity. The structure of each module includes the block sequence

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(problem block, theoretical block, application block, compatibility block, generalization block) corresponding to the algorithm of making an optimal decision that creates conditions for graduate adaptedness to agricultural engineering activity characteristics by means of mathematics. The problem block of the module performs the function of setting a professional and applied problem which solution is in demand by the tasks of agricultural production modernization.

The theoretical block provides transfer of the theoretical knowledge necessary for building mathematical models of optimization problems and algorithm analysis of the corresponding methods of their solutions. The application block includes the system of tasks on practical use of the studied material, building mathematical models of optimization problems and finding optimal solutions with the use of the corresponding software. The compatibility block provides the solution of a professional and applied problem which was set in the problem block. The generalization block performs the function of result assessment of the made decision taking into account environmental, social norms and values-based orientations. The competence-based modules are mastered by means of active methods (a case study, a problem lecture, a visual lecture, an expert lecture, brainstorming, group work, a project method). It should be noted that the case study sources are the situations presented in special literature and true job-related problems, students face when doing an internship.

The study base is the Samara State Agricultural Academy which is the part of Agrarian and Educational Complex of the Samara Region Association including educational institutions of professional education, scientific, production and other non-profit organizations of the regional agricultural profile. The sampling made 1050 people.

The pilot testing which purpose was an approbation of means of socio-technical competence formation of agricultural engineers, showed positive dynamics according to all the diagnosed indicators of socio-technical competence that confirms effectiveness of the developed system of agricultural engineer mathematical training (table 02).

Table 02. Fundamental indicators in the structure of agricultural engineer socio-technical competence

Socio-technical competence components	**Index of average value**		**Fundamental indicator**	
	s.a.	**f.a.**	**Summative assessment (s.a.)**	**Formative assessment (f.a.)**
Value and motivation-based	-0.18	0.58	Understanding of future profession social value	Need for mastering the methods of making optimal decisions
Information and cognition -based	-0.18	0.53	Ability to collect and analyze initial data for calculation and design including the use of IT and data bases in agricultural engineering	Ability to model business processes
Technology-based	-0.57	0.46	Ability to use software	Ability to find optimal decision taking into account social, environmental norms and values-based orientations.
Activity - based	-0.11	0.55	Ability to conduct experimental studies	Ability to implement tasks on optimization of technical and social subsystems in agricultural production
Reflexive and regulatory-based	-0.32	0.54	Ability to self-assess professional activity results	Ability to project the own route of socio-technical formation
Average index	-0.27	0.53		
Gain	by a factor of 2.96			

Source: Rudneva & Berishvili (2016).

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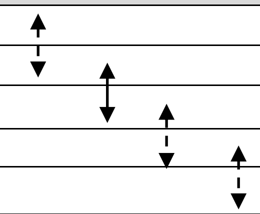
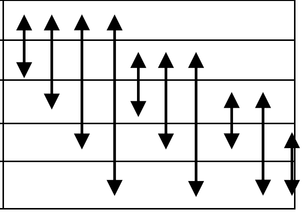
The comparative analysis of indicator matrixes by the results of the summative and formative assessments demonstrated distinction of the fundamental indicators. So, there are some changes in the formative assessment unlike the summative one: the growth for a value and motivation-based component is directed to increasing the need for mastering methods of making optimal decisions; the ability to model business processes dominates in the information and cognition –based component; the ability to find optimal decision taking into account social, environmental norms and values-based orientations is in the technology-based component; the ability to implement tasks on optimization of technical and social subsystems in agricultural production dominates in the activity - based component; traditional reflexive abilities of the self-assessment of professional activity results turn the focus toward expansion due to projecting the own route of socio-technical formation. It should be noted, that the average index of socio-technical competence can be interpreted as an integrated indicator of agricultural engineer readiness to professional activity. Thus, socio-technical competence represents the variable, dynamic value being capable to transform and improve in the course of training, self-education and gaining professional experience.

In the course of the comparative result analysis of the summative and formative assessments, significant correlation relationship between the components of agricultural engineer socio-technical competence was revealed and their compensatory role due to marking the fundamental indicators is confirmed.

Table 03. Component interrelation of agricultural engineer socio-technical competence (correlation analysis-based)

Socio-technical competence components	**Summative assessment**	**Formative assessment**
Value and motivation-based		
Information and cognition -based		
Technology- based		
Activity - based		
Reflexive and regulatory-based		
Correlation coefficient value		
R (value and motivation-based – information and cognition -based)	0.39	0.69
R(value and motivation-based- technology- based)	0.13	0.53
R(value and motivation-based – activity - based)	0.30	0.66
R value and motivation-based – reflexive and regulatory-based)	0.28	0.54
R(information and cognition -based – technology- based)	0.60	0.56
R(information and cognition -based – activity - based)	0.17	0.59
R(information and cognition -based – reflexive and regulatory-based)	0.21	0.52
R(technology- based – activity - based)	0.44	0.63
R(technology- based – reflexive and regulatory-based)	0.26	0.70
R(activity - based – reflexive and regulatory-based)	0.31	0.66

Source: Rudneva & Berishvili (2016).

The factorial analysis on the basis of the studies material of the summative and formative assessment was carried out for specifying the hidden interrelations focusing attention on the indicators demanding certain means of their development.

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Five factors influencing the formation of socio-technical competence are distinguished based on the studies materials of the formative assessment. The first factor distinguished the indicators with significant weights: ability to implement tasks on optimization of technical and social subsystems in agricultural production (0.625); ability to find the solution in the conditions of uncertainty and multicriteriality (0.570); ability to correct progress in decision implementing (0.564); ability to participate in design of technical facilities and productive processes (0.457); ability to correct decision results according to change in internal and external conditions of production (0.367). This factor is interpreted as operational readiness to agricultural engineer professional activity.

The second factor contains indicators with significant weights: ability to use software for finding an optimal solution (0.898); ability to identify mathematical model in terms of the class of optimization problems of (0.796); ability to find an optimal decision taking into account social, environmental norms and values-based orientations (0.646); ability to build mathematical models on process optimization problems in agricultural production (0.623); ability to integrate knowledge of various areas for solving professional tasks (0.527). This factor is interpreted as tactical readiness to agricultural engineer professional activity.

The third factor distinguished the indicators with significant weights: satisfaction from made decision results (0.692); ability to work in the situation of uncertainty and technical risks taking into account social, environmental norms and values-based orientations (0.545); need for mastering methods of making optimal decisions (0.547); value perception of future professional activity (0.519). This factor is interpreted as worldview readiness to agricultural engineer professional activity.

The fourth factor contains indicators with significant weights: ability to systematize and generalize information on forming and using company resources (0.820); ability to collect and analyze initial data for calculation and design including the use of IT and data bases in agricultural engineering (0.774); understanding the importance of making optimal decision methods for development of agricultural production (0.730); ability to model manufacturing situations (0.731); ability to forecast and regulate operating results (0.571); ability to analyze productive process as the object of control and management (0.535). This factor is interpreted as strategic readiness to agricultural engineer professional activity.

The fifth factor distinguished the indicators with significant weights: ability to self-assess professional activity results (0.720); ability to project the own route of socio-technical formation (0.691); ability of professional activity self-control (0.668); ability to take responsibility for made decision results (0.336). This factor is interpreted as behavioral readiness to agricultural engineer professional activity.

The factorial analysis revealed the significant indicators providing readiness to agricultural engineer professional activity within the conditions of modern agricultural production that confirms rationale of the practice-oriented system development of mathematical training.

Thus, by the results of the study it is proved that the developed contradiction between need for use of making optimal decision methods for professional activity and inability of the students - future agricultural engineers to their application is settled by development and implementation of the practice-oriented system of the agricultural engineer mathematical training providing formation of socio-technical competence.

7. Conclusion

The reconsidered problem solution on vocational training of engineers in an agricultural higher educational institution is expressed by the following things: scientific idea of engineering activity in agribusiness is concretized; the essence is revealed, the structure is developed, criteria of agricultural engineer socio-technical competence formation are marked out; the practice-oriented system of agricultural engineer mathematical training is designed. It should be noted, that the strict requirements are applied to the quality of vocational training in connection with development of modern agribusiness.

The theoretical relevance of the study is that it enables to solve the scientific problem having important social value – the problem of practice-oriented concept development of agricultural engineer vocational training providing readiness of young specialists to the solution of optimization problems in agricultural production; contribution to development of the vocational pedagogics research vocabulary is made. The concept of agricultural engineer socio-technical competence formation offered in the study allows defining new approaches and the principles of practice-oriented system development of vocational training for experts of various profiles at the theoretical level.

The practical relevance of the study consists of educational process enhancement in an agricultural higher educational institution; identification of mathematics opportunities for training the methods of making optimal decisions of agricultural engineers for the purpose of production optimization in agribusiness; yielding an economic effect in a number of the companies in the Samara region due to the use of making optimal decision methods.

The findings of the formative assessment, feedback of pedagogical community to the papers following the experiment findings allowed to be reinforced in need for further development of the mathematical model base containing problem situations in agricultural engineering activity; electronic work books, recommendations for professional development of teachers of the specialized departments in agricultural higher educational institutions in terms of using making optimal decision methods for professional competence formation of students and experts in agricultural production in the conditions of additional and online education as well; quality rating criteria for professional readiness of agricultural engineers according to the requirements of modern agribusiness.

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