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Risk Based Ecological Economics to Engineering Students

Elena N. Prokofieva [1*], Klavdiya G. Erdyneyeva [2], Alexander A. Galushkin [3,4], Alexey I. Prokopyev [5], Valeriy I. Prasolov [6], Svetlana I. Ashmarina [7], Boris V. Ilkevich [8], Milan Kubiatko [9]

[1] Institute of Pedagogy, Psychology and Social Problems, Kazan, RUSSIA
[2] Transbaikal State University, Chita, RUSSIA
[3] RUDN University (Peoples' Friendship University of Russia), Moscow, RUSSIA
[4] Stolypin International Institute of Informatization and Public Administration, Moscow, RUSSIA
[5] Plekhanov Russian University of Economics, Moscow, RUSSIA
[6] Financial University under the Government of the Russian Federation, Moscow, RUSSIA
[7] Samara State University of Economics, Samara, RUSSIA
[8] Gzhel State University, Elektroizolyator, RUSSIA
[9] University of Zilina, SLOVAKIA

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ABSTRACT

Modern ecological crisis threatens the sustainability of human civilization. Awareness and education for probable disaster risk reduction give greater urgency to the issue of decreasing industrial failure rates associated with basic manufacturing activities and, consequently, improving the training in this area. The authors have highlighted the features of modern risk based approach in engineering training based on proximity of production entities to anthropogenic factors: allocation of risks and threats in professional and personal situations or tasks; critical analysis of any industrial process and considering its consequences; using professional and personal risk response strategies; risk-based thinking as the core professional activity. The paper considers the mechanism of risk-based thinking as a necessary part of engineering students training on the basis of diversionary analysis, and gives its algorithm adapted to their learning activities. A system of professional tasks and tools to be used in the students' future job has been developed to promote their readiness and willingness to work across trades within the sphere of their technical competency. The paper is intended for researchers, practitioners, managers of enterprises dealing with ecological and economic production activities, as well as for professional training of engineers.

Keywords: risk based approach, risk-based thinking, professional and personal situations, engineering students training, risk based ecological economics

INTRODUCTION

Modern ecological crisis threatens the *sustainability of human civilization*. *Further degradation of natural systems leads to destabilization of the biosphere*, loss of its integrity and ability to maintain the quality of the environment. The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework, 2016) highlights the integral importance of addressing the world community safety issues. One of the framework priorities was enhancing disaster preparedness for effective response and the phrase "Build Back Better" became the *motto* in recovery, rehabilitation and reconstruction. This approach means that there is a need to strengthen disaster preparedness for response, take action in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase, which needs to be prepared ahead of the disaster, is a critical opportunity to build back better, including through integrating disaster risk reduction into development measures,

✉ elena-kzn@list.ru **(*Correspondence)** ✉ eridan58@mail.ru ✉ alexander.galushkin@yandex.ru
✉ alexeyprokopyev@mail.ru ✉ VIPrasolov@fa.ru ✉ asisamara@mail.ru ✉ lk_bv@mail.ru
✉ mkubiatko@gmail.com

Contribution of this paper to the literature

- The stages of developing preparedness and readiness to risk management have been determined.
- The use of diversionary analysis method has been proposed to be used as the basis of risk-based ecological-and-economic training of engineering students at the university.
- Diagnostic tools to assess preparedness and readiness of university graduates for risk management have been developed to ensure pedagogical impact on the students' learning outcomes.

making nations and communities resilient to disasters. That is why another slogan "Invest Today for a Safer *Tomorrow" has a clear message:* Disaster risk reduction should be an everyday concern for everybody.

It has become possible in the modern community to claim that any human activity, any commodity or service production is accompanied by "production and risks distribution "which may be rendered in its common sense as transformation of activity objectives under uncertain conditions, the probability of hazard occurrence (Sedova, 2008, Muravyeva, 2017; Prokofieva, 2015; Cherdymova & Sorokina, 2013). Continuing increase of any power may threaten the social order; at the current moment, all social systems are becoming increasingly fragile. The most common case is the effect of industries on environment, i.e. m*ajor* environmental disasters have been caused due to industrial mishaps.

This aspect brings cognitive representation of risks, its scientific component requiring a risk analysis in the subject area to the fore; involve into discussion on risk rationale, reduction, ways and mechanisms of its stagnation. And as to the mechanism, vocational education evidently providing risk based content of the engineering courses thus prepares future professionals and managers to risk-centric industrial systems (Muravyeva & Romanovsky, 2010).

Technical university students take courses delivered by the Environment and Science departments to learn how to address environmental issues. Accredited courses in ecology provide them with a foundation in the principles of civil engineering, developing their knowledge of how to assess the environmental impact of civil engineering projects and to design environmentally friendly structures (Cherdymova, 2013; Cherdymova et al., 2017). This approach is of a great significance because of the fact that graduates of these educational institutions are "at the forefront" of the majority of the anthropogenic factors that have a particularly strong impact on ecosystems. Available multiple technologies used in training of engineering professionals is specially designed to provide understanding of risk-based thinking and the subsequent *risk* management as a component of their professional competence and contribute to maintaining harmonious relationship that exists between man and nature.

However, current understanding of a risk in terms of sociocultural factors impacting it, and admitting that risk has become an integral part of our everyday life makes modern society consider itself as a "risk society" and, thus, demands forming inevitably "reflexive" risks when faced with a global threat and danger (Ford, 2009; Gullone & Moore, 2000). This position is reflected in the international standards relating to risk management codified by the International Organization for Standardization (ISO 31000:2009, Risk management – Principles and guidelines, 2015) that provides principles, a framework and a process for managing risks and can be used by any organization regardless of its size, activity or sector. It gives a new definition of risk ('the effect of uncertainty on objectives' changing it from 'the chance of something happening that will have an impact on objectives' to 'the effect of uncertainty on objectives'). Now professionals will continue to consider the possibility of risks occurring, but they should now apply risk treatment options to ensure that the uncertainty of their enterprise meeting its objectives will be avoided, reduced, removed or modified and/or retained. Risks can have consequences in terms of economic performance and professional reputation, as well as environmental, safety and societal outcomes. Therefore, managing risk effectively helps organizations to perform well in an environment full of uncertainty.

The Sendai Framework for Disaster Risk Reduction 2015-2030 has provided disaster risk management participators with a series of new guidelines. It highlights the role and relevance of regional platforms for disaster risk reduction

To guide implementation of the priorities of action, a comprehensive framework with achievable targets, a legally-based instrument for disaster risk reduction, the use of existing training and education mechanisms to promote the incorporation of disaster risk knowledge, including disaster prevention, mitigation, preparedness, response, recovery and rehabilitation, it is recommended to use the potential of formal and non-formal education, as well as in professional education and training at all levels (Levin et al., 2012; Modarres, 2003).

The goal of this investigation was to determine the features and mechanisms for risk-based ecological-and-economic training of engineering students at the university.

The goal set is closely linked to the following objectives to be focused on:

1) the importance of a risk-based approach to engineering students at the university;
2) features of risk-based ecological and economic training courses for engineering students at the university;
3) a mechanism of risk-based ecological-and-economic training aimed at developing university graduates' preparedness and readiness for risk management;
4) a diagnostic toolkit to assess university graduates' readiness for risk management.

MATERIALS AND METHODS

Experiments for scientific research have been carried out with university students studying Chemical Technology (Kazan national research technological University), Mechanical Engineering and Technosphere Safety (Kazan national research technical University), all in all 298 students.

The Risk-Based Approach in Ecological-and-Economic Training of Engineering Students at University

Risk is most commonly interpreted as the probability of risk occurrence of under uncertainty conditions of the process or phenomenon considered (Beck, 1992).

Current understanding of risk (ISO) implies detection of the influencing uncertainties from the standpoint of negative or positive variance which is considered as a threat to the goals or probable change. A probability is the ability of an object to output which will comply with requirements to this output. Hence, it is evident that a risk may be associated with an action or inaction causing it– it all depends on the process conditions. Risk management involves the process of managing a risk with any effect possible (ISO 9001:2015) and a new term "risk-based thinking" has been introduced to ensure that risks are identified, considered and managed during the design and application of the management system in any industrial activity. Risk-based thinking is something we all do automatically and often sub-consciously to get the best result, ensures risk is considered from the beginning and throughout, makes preventive action the part of strategic and operational planning.

The risk management process is an integral part of ecologic-and-economic activities with its essential components (subject, object, environment and their interaction) in a continually changing state. Irreversible uncertainty and unpredictability come out from ever changing reality. Correspondingly, the identification of risks at production and business level leads to making balanced management decisions, i.e. use of improved methods for assessment and forecasting specific risks, introduction of analysis technology and an early warning system (Atkinson, 2008; Ayyub, 2011; Baetova, 2016).

The essence of a risk-based approach in professional training is associated with search, identification and analysis of probable industry and business risks with a view to adjusting the development strategy and management. It makes it possible to operate in high risk environments related to integration of knowledge, i.e. ecology, economy, predicting dangerous factors (risks), natural hazards, reliability of technical systems, and technogenic risks. As a result of applying this approach in university training of engineering students, their mindsets are formed on the bases of risk-assessment experience. Risk-based thinking provides a continuous simulation (pre-effect) of professional and surrounding environment, in terms of risks/probabilities. Risk-based thinking ensures that risks are identified, considered and controlled throughout the design and use of management system. Due to using risk-based thinking the consideration of risk is integral. It becomes proactive rather than reactive in preventing or reducing undesired effects through early identification and response action (Belov, 2011). Risk thinking increases the willingness and ability to achieve goals, reducing the likelihood of a negative outcome.

Modern understanding of the need to balance environmentally and economically conditions of production in the market conditions, and protection and preservation of the environment is one of the most important issues facing humankind today. It has led to creation of innovative achievements in modern science and advanced progressive technologies that, from an environmental point of view, are able to ensure the further existence and development of mankind. Training of engineering students with their concerns attached to entrepreneurial activity in the domestic and overseas markets proved to be the solution of environmental problems in any region (Kasyanenko, 2008; Krutova, 2013; Shapkin, 2010; Cai et al., 2017). These professionals must be good at solving multiple issues related to industrial activities, marketing and management for safe operation of production facilities, extending the lifetime of materials and products, using them for a new functional purpose (conversion), as well as the rational use of secondary raw materials through recycling. The question of production process analysis, introduction of industrial innovations and predictive assessment of their consequences, etc. also is related to risk-based approach and is able to provide ecologically acceptable alternative. To manage risks and thereby facilitate graduates' adaptation they must be provided with all detailed information about the forms and types of risks that are likely to emerge in their professional activities. In this regard, we believe it necessary for university students to study decision making under risk and uncertainty, and develop their competences in making optimal decisions in uncertainty and risk situations.

Features of the Risk-based Training in Engineering Education

It was established that one of the components of a civil engineer readiness to risk management is the operational component contributing to practical preparation for risk management. Due to the fact that this component is associated with the readiness to solve professional tasks in managing all types of production risk and, consequently, possessing risk management skills, it is necessary to define a system of this kind of professional tasks in the activities of an engineer and identify relevant skills (Ayyub, 2014; Bradbury, 2016).

Taking into consideration the industry field (chemical, petrochemical, mechanical engineering) we have studied:

1) stages and content of an optimal management decision as the methodological basis to systematize this type of professional tasks;
2) stages and the content of enterprise risk management as a whole, as a substantial basis of the identified professional objectives of risk management;
3) types of business risk and business risk situations as objects of risk management, which we also consider as the specific content of risk management professional objectives;
4) types of professional tasks in engineer activity.

Professional activity is a process of solving professional tasks. A task includes demands (goal), conditions (known) and the desired (unknown) which can be formulated in a question. Based on the definition of the task as a logico-psychological category, a professional task can be defined as an activity to meet requirements of a particular profession and aimed at problem solving. The professional task in production risk management is the type of an engineer-and-manager' professional activity to meet the requirements of the profession and the risk situation at an industrial enterprise.

Thus, risk-based training features of engineering students based on enterprise proximity to anthropogenic factors are:

1. allocation of risks and threats for any professional task;
2. critical analysis of professional actions and their consequences;
3. action training of future engineers in the context of possible professional and personal risks;
4. development of a risk-thinking as the essence of professional activity of the university students intending to work at an industrial enterprise.

Mechanisms of the Risk-based Training of Engineering Students at the University

Risk-based training of the university students intending to work at an industrial enterprise includes the following steps in forming their preparedness and readiness for risk management:

1) psychological basis of willingness to risk management ensuring basic personal willingness to take risks;
2) development of risk management professional basis to ensure preparedness for profession and risk management;
3) development of a special risk management professional basis to ensure a holistic preparedness for risk management in a manufacturing enterprise (according to industry fields studied).

As a pedagogical means used to form readiness for risk management we propose:

— Organization and contents of the university syllabus according to education and selected to meet the requirements of risk management functions in the field studied;

— educational task system as preliminary desobjectivated for specific tasks and jobs selected for the relevant learning content;

— a system of methods to form preparedness and readiness for risk management meeting the requirements of the field studied.

Because the methods used to stimulate creativity are close to real production activities they positively influence the course of education; and we believe that the application of diversionary analysis method will be good for developing risk-thinking skills, allowing to use a new angle to look at the object safety. Diversionary analysis is a method that enables us to predict the appearance of harmful effects (including ecological) in our system, or its failures, and prevent them before they occur, as well as identify the causes of accidents that have already happened (Romanovsky, Muravyeva & Chabanova, 2015). The method involves implementation of two main stages/phases:

Stage one: Transformation of questions "why" or "what" (what emergencies and adverse events are possible in /with this facility? why did this emergency situation happen?, how to ruin the object?, how to ensure the emergence of the greatest number the most dangerous adverse events, how to implement in this object the emergency situation that has arisen). They enable us to know "in advance" and to prevent system failures and/or harmful effects. As a result, *c*reativity techniques are used for inventive problem solving.

Stage two: Efforts to prevent the forecasted "diversionary" problems. In "Diversionary Analysis" students use special informational funds:

- standard ways of creating adverse events and their results;
- standard dangerous areas on engineering facilities;
- resources capable of harmful effects;
- typical mistakes when creating technical systems;
- ways to enhance and correct unwanted events;
- ways to prevent unwanted events and deal with the consequences.

In the context of risk-based ecological-economic training such tasks correspond to a study method of external and internal environment of the organization from ecological and economic standpoints, and analysis of all possible risks. Diversionary analysis is based on the principle of forecasting possible operation failures through modeling the maximum number of "diversions", *sabotages,* against the enterprise considered as a sociotechnical system and taking into account the impact of typical and specific risks (strategic uncertainty).

The main purpose of using diversion analysis in ecologic and economic training of a future engineer is to enable him to be competent and reveal weaknesses of the enterprise, explore external and internal risks, develop a detailed plan of measures to protect and improve the weaknesses.

Such a broad content of training material may not be provided only by one academic discipline; therefore, the selection of the content for risk-based training requires consideration of interdisciplinary connections that ensure a holistic educational process.

A meaningful framework for learning objectives may be provided by activities specific for the job of an engineer, presented in the form of risk management professional tasks at an enterprise (according to the field studied). Learning objectives, thus, have been systematized in three types:

— learning objectives of a tentative type, adequate to the activities related to student guidelines in risk situations (description, explanation, predicting, goal setting); these tasks correspond to the first phase of the optimal management decisions in a risk situation - preparation of the solution;

— learning objectives of reflective type, adequate to the activities related to decision-making in risk situations (generation of alternatives; evaluation of outcomes, or consequences, of the decision; choosing the best decision; assessment of the decision; preparation of the implementation plan); these are the tasks corresponding to the second stage, i.e. making an optimal management decisions in a risk situation;

— learning objectives of creative (transformative) type, adequate to the activities related to the impact of the risk (transformation of a risk situation); these objectives correspond to the last stage of the optimal management decisions - implementation of the decision in a risk situation.

This system of learning objectives developed and structured in its logics to optimal management decisions is able to help the teaching staff of a university develop students 'risk-thinking, their preparedness and readiness not only to the specific activities of risk management, but also to a holistic professional readiness.

Table 1. Algorithm for solving risk-based problems used by university students

STAGES	OUTCOMES
Formulation of risk	Detection (control) risk issues
Transformation of a risk task	Gathering information about risks, hazards, vulnerability in a particular situation
Study of risk system	Information display in a convenient form
Certification of risk of resources	Analysis of information on risk situation (sources, objects of risk; possible controlling actions; forecast of their effectiveness)
Search the harmful effects	Problem definition and ranking the risks of the situation
Search the harmful effects using forecast method	Defining risk management objectives of a particular situation taking into account resources available
Search of new decisions	Development of the criteria to be used in assessing risk management effectiveness in a certain situation
Study of revealed the harmful effects	Verification and assessment of options for risk-solutions
Outcomes study and general conclusion of the results	Acceptance, registration

RESULTS

An Algorithm to Solve Risk-based Tasks

A general algorithm for solving a task (situational risk management) includes the following operations that involve identifying of enterprise ecological and economic risk (**Table 1**).

Thus "the diversionary analysis" includes pre-operations performed: formulating the "diversionary goals"; the study of the known ways to create extraordinary situations, harmful and undesirable phenomena; characterization and testing the possibilities to use existing resources for "diversion", or sabotage; identification of possible unwanted, sabotage, effects on the information funds and by means of technical creativity methods; search for means to improve and "hide" undesirable effects; study of undesirable effects identified and their improvement; opportunities to eliminate unwanted effects.

Then scenario analysis method was used as the way to test various predicted proposals for the future. It includes creation of two or three plausible scenarios, an adequate strategy to develop each of them, assessment of the likelihood of scenario implementation, and assessment of the resulting strategies. All of the above said, in our opinion, will greatly contribute to the development of professional risk-based thinking, because for "well-planned sabotage" it is necessary to have professional knowledge in the field of operation of the facility, its weak points, synergistic effects of emergencies, etc. After studying strategic diversionary, or the sabotage, analysis with the use of the above-mentioned algorithm the student can determine (predict) the optimal risk events. Students work on collecting and processing the source data and methods used to enhance their accuracy, and get grounded criteria for making effective management decisions.

The system of risk management professional tasks and relevant professional skills of a graduate student is built in this context and makes the basis for the content of university training, educational and professional tasks of its dynamic training system.

A Creative Risk-based Learning Objective: A Case Study

General statement of the problem: Study of the possibilities for a major investment project - Development of oil and gas resources in region N. The following information regarding natural factors of the region, characteristics of crude oil and gas, information on raw materials recovery, differentiation of the deposits, quality of raw materials, condition of fixed assets in oil and gas sector, and technological background have been given.

To adequately assess an ecological risk (and other risks) for major investment projects related to oil and gas resources it is needed to follow the stages in risk management (**Figure 1**). The first block: assessment stages of the ecological risk (1-5) with an ultimate goal to determine quantitative risk measures that correspond to different scenarios of adverse events and protection strategies; and stages of environmental risk management (6-8) that aim at defining events and activities to reduce the level of a risk to its "acceptable level" and control its impact. The first stage establishes a list of factors which by themselves, or in a certain combination, are able to initiate an adverse, unwanted, event; and the second one forms and analyzes the system of these factors in reality.

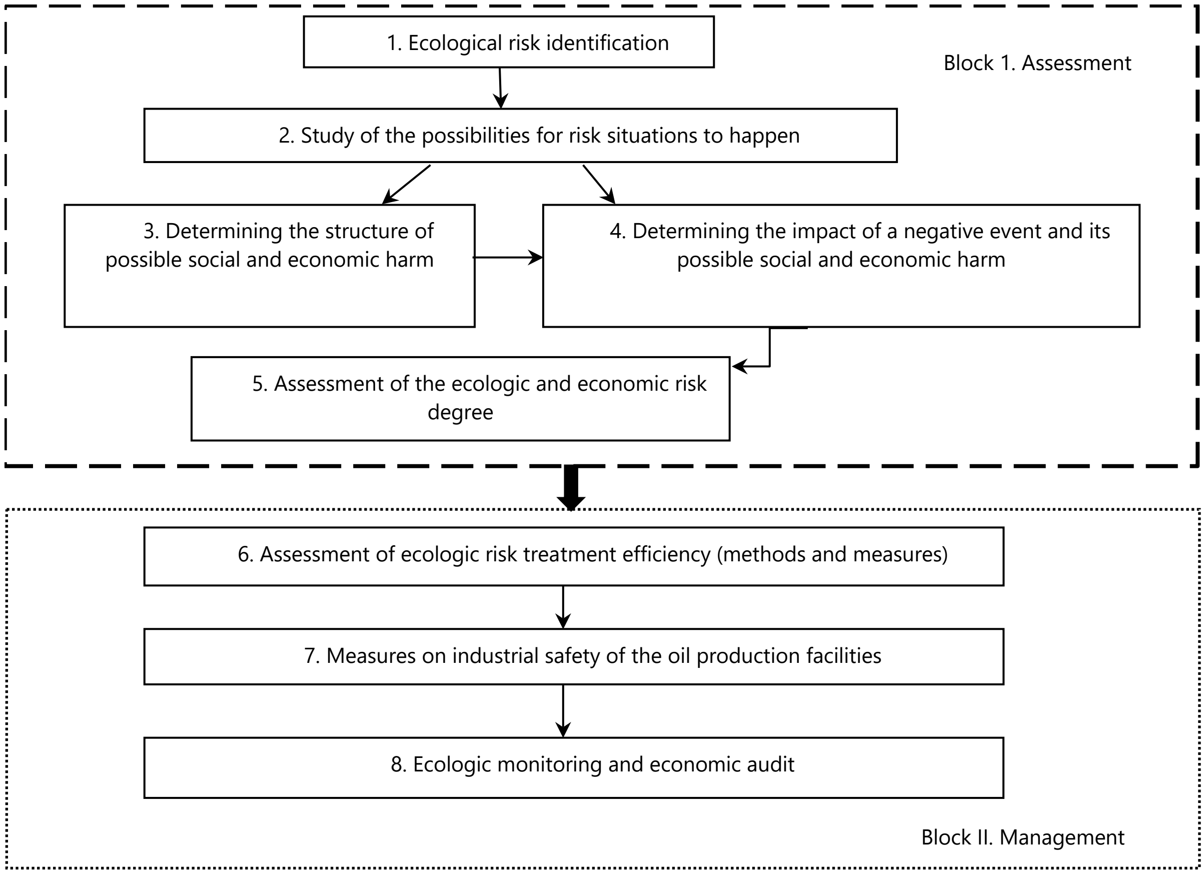

Figure 1. Block diagram of stages of risk management

An influence diagram has been used to show hazard identification. They are known as a systematic representation of the flow of events and processes that allow tracing the origin and development of conditions causing failure or the state of emergency. Such diagrams are represented as graphs, trees events, functional networks, and flow maps.

An event tree diagram has been used to identify environmental risk of the investment project. The tree is a hierarchical structure, the top level of which characterizes the consequences of adverse events (environmental pollution), and the lower level represents sets of factors and conditions under which it manifests itself. The conditions of a higher level are also represented as a tree and include factors of the lower levels.

Basically, the event tree represents an emergency scenario causing environment pollution (see **Figure 2**). A semantic model of an event tree diagram usually involves some leading events, which are connected with specific logical conditions with intermediate and initial assumptions that caused its emergence.

To build an event tree diagram for a priori quantitative estimates of environmental damage one should involve a set of iterations, and each consists of the following steps:

1) selection of oil and gas facility;
2) building models of an event tree type and their outcomes;
3) a qualitative analysis of the simulated process;
4) quantitative environmental risk assessment (average damage) expected from the analyzed accident;
5) justification of actions to decrease an ecological risk.

The process of a specific incident will be interpreted by this model as a certain signal passing from some initially assumed prerequisites that caused the signal, to the event that is considered to be its outcome. Prerequisites for the top and subsequent levels have been considered as intermediate events of the tree.

Using cause and effect models for event tree diagram that covers probable destructive outcomes it is possible to make a system of the events preceding emergency situations, place a priori estimates of the incident parameters and prevent or reduce environmental damage and environmental risk in general. The occurrence and probable preconditions for the development of the events should be systematized into project stages, as well as the types of damage and harm caused.

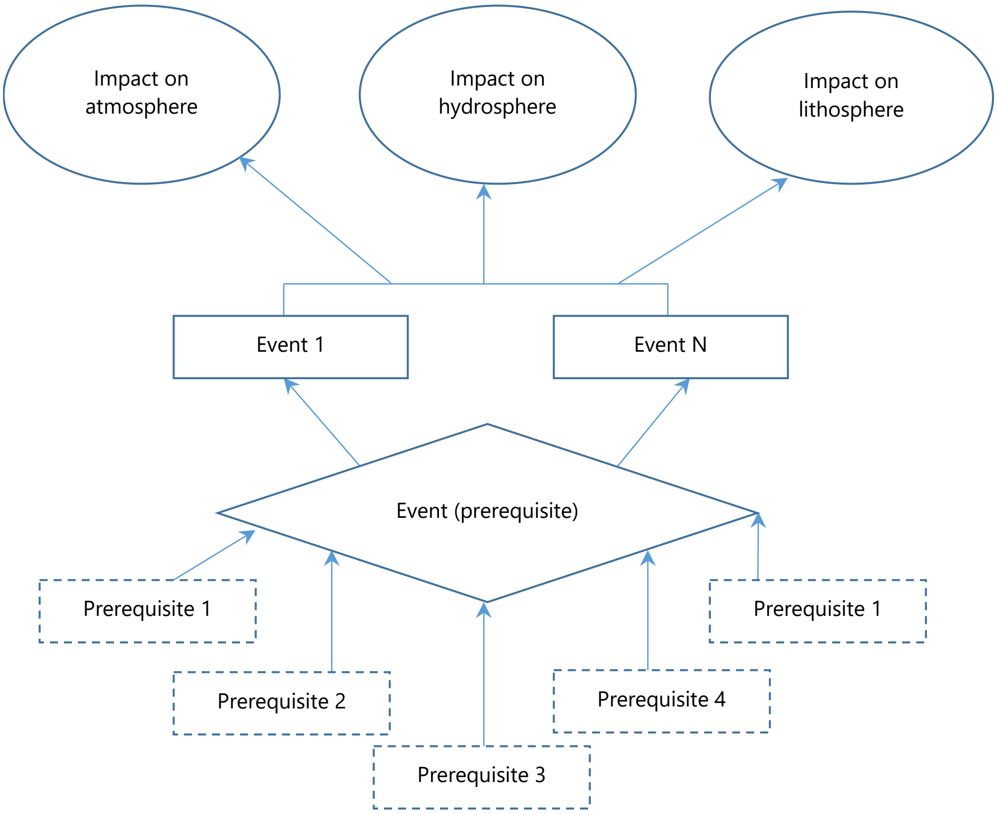

Figure 2. A common variant of an event tree for evaluating environmental risk

A generalized solution of the problem involves the formulation of environmental and economic risks, investment project risk, in the development of oil and gas resources of the region N (industrial-and-technological, ecological, geological, nature, marketing, institutional, financial), and their detailed qualitative and quantitative assessment. In the context of risk management, it is also important to assess the degree of risk acceptability (control), methods of mitigation and mitigation of consequences in the economic and environmental points of view, and in the long run analyze all the possible development alternatives for the project.

The objective achievement covers many stages and can be used as a base for a technical university course project.

Diagnostics of Engineers' Readiness to Risk-based Thinking in their Professional Activities

Thinking is a set of psychological processes, states, actions of a person to process information, such as when we form concepts, engage in problem solving, to reason and make decisions, to put forward hypotheses.

A criterion of developed risk-based thinking, in our opinion, is the ability to analyze the greatest number of possible options per unit of time and find the alternative result in the least adverse consequences. The basis of readiness to professional risk-based thinking, obviously, is professional reflection of a person incorporating the system of knowledge and practical experience analysis.

Considering the willingness to risk-based thinking as an active-and-effective state of an individual, his/her certain attitude to professional behavior, we have identified its following components:

1) *cognitive* - knowledge in the field of environment, safety, economy, engineering activities, production processes;
2) *operational* - knowledge of action sequence in emergency conditions, social, technological and environmental risks, and methods of reducing them;
3) *analytical* - ability of an analytical assessment of all probable conditions and risk causes in a manufacturing process;
4) *inductive* - ability to predict the consequences and probabilities of uncertainties;
5) *dynamic* - ability to make quick and reasoned decisions;
6) *motivational* - emotional and value understanding of risk activities.

Table 2. Preparedness and readiness for risk management, control versus experimental student group results (in % of total students)

Field of study	**Chemical Technology**						**Mechanical Engineering**						**Technosphere Safety**					
Preparedness and readiness components	**CG**			**EG**			**CG**			**EG**			**CG**			**EG**		
	l.	**m.**	**h.**	**l.**	**m.**	**h.**	**l.**	**m.**	**h.**	**l.**	**m.**	**h.**	**l.**	**m.**	**h.**	**l.**	**m.**	**h.**
cognitive	3	85	12	0	83	17	7	82	11	0	84	16	0	88	12	0	72	28
operational	5	77	18	0	74	26	4	75	21	0	77	23	0	88	12	0	76	24
analytical	16	78	6	0	89	11	11	78	11	0	84	16	8	80	12	0	68	32
inductive	22	74	4	2	79	19	18	73	9	0	82	18	4	78	18	0	68	32
dynamic	10	84	6	28	51	21	9	78	13	17	61	22	8	66	26	0	62	38
motivational	14	78	8	0	57	43	9	82	9	0	62	38	8	50	42	0	44	56

Notes: CG - control group, EG - experimental group, l. - low, m. - medium, h. - high.

Each of these component is proposed to be evaluated and *expressed* on a grading *scale* as '*high*', '*medium*' and 'low' level (0,1,2).

It is obvious that the diagnostics system adoption in the framework of professional education is more aimed at development of cognitive and operational components of risk-based thinking.

Considering a professional task system of risk-based management as a pedagogical experiment and its introduction into university training of students studying Chemical Technology (Kazan national research technological University), Mechanical Engineering, Technosphere Safety (Kazan national research technical University) revealed significant differences, in their preparedness and readiness for risk-based management between the experimental and control student groups at the level of all components (**Table 2**).

It should be noted that this table presents the results of the control measurements carried out at the end of the pedagogical experiment based on the analysis of the students' course projects (according to the results of students' course project presentations). The data obtained showed that the levels of cognitive, operational and motivational components are identical in the experimental and control groups, which proves a high level of engineering training at the university as a whole. Significant differences in other components prove that the developed system of professional tasks significantly increases students' preparedness for risk management. Future specialists in the field of Technosphere Safety achieved high level and this fact confirms the importance of their knowledge and competence in the field of life safety to develop risk-based thinking. It should be noted that a high level in all 6-risk based thinking preparedness components has been achieved only by 7 students from the experimental groups. This fact indicates the importance of personal factors and personal abilities in developing risk based thinking; experts of this level can manage a strategic risk system at the enterprise and participate its management. The study of the intermediate and control outcomes after special training shows a stable increase in the level of readiness for risk-based management of students in the experimental groups. Group results have been compared using nonparametric Mann-Whitney U test: the obtained value was less than the critical, U at $p = 0.05$ ($U = 470$) which rejected *the null* hypothesis about differences between the experimental and control groups on the level of readiness for risk management after providing them special training. Comparison of the data presented allows us to draw the following conclusion: positive dynamics of changes in the components of preparedness and readiness for risk-based management is coherent. The data obtained prove risk-based training applicability in the system of higher education.

DISCUSSIONS

There are many employers and stakeholders, representatives of large industrial enterprises, who have assessed the university graduates as insufficiently prepared for their future responsibilities and unable to make immediate solutions beyond their professional boundaries or under the extreme, *force majeure*, conditions. The modern realities of production activities where emergency situations are not rare events, as well as manmade and natural hazards and disasters, have shown how valuable is the engineer' competence in the field of prevention of technogenic accidents, social and natural hazards, how significant is a professional and moral attitude to career (Michalopoulos & Paparrizos, 2008).

The issue of relationship between knowledge-based components of human activity and technical facilities in real production has been studied previously by many researchers of this country. This issue, at the general level or aspect, was touched upon in the papers on psychology and applied psychology (Aral, 2010; Levina et al., 2016; Modarres, Kaminsky & Kristov, 2007; Murzin, 2009; Klimov, 1996; Halperin, 1998; Zeer, 2001).

The study of scientific literature (Baetova, 2016; Steinberg, 2007; Michalopoulos, & Paparrizos, 2008; Synzynys, 2015; Vaganov, 2008; Vishnyakov, 2008) showed that the preparedness and readiness for professional activity is understood as a set of special knowledge, abilities and skills to perform work in a specific field of professional activity, and ability to understand regulatory requirements to work in a certain profession. We have included a set of special components into this structure: students' positive attitude towards their *chosen career*, their ability and motivation relevant to requirements of their future job; knowledge and skills, professionally important cognitive, emotional and volitional processes (Roland & Moriarty, 1990; Tymula et al., 2012).

Professional thinking development is regarded as one of the constituent parts of higher education based on the principle of multi-factor interaction in hazards/risks –competency and safety of life system (Ayyub, 2013).

We have found that risk-based thinking development is contributed by the system of professional tasks that requires integration of knowledge in different subject areas and mobilization of personal abilities. These challenges may be solved using diversionary analysis method that allows us to prove by contradiction the existing risks and probabilities in production activities in terms of environmental and economic constraints. The diagnostic tools proposed by the authors contributes to determining the strengths of professional preparedness and readiness of engineering students at the university in general; determines their opportunities for professional development in the field of risk-based management and can be used in the framework of engineers' professional development. The outcomes obtained in the course of the experiment demonstrate positive attitude of teaching staff and students towards risk-based ecological-and-economics training of future engineers.

CONCLUSION

The study carried out to develop and implement a risk-based training at the university allowed us to make the following conclusions:

1. Objective probability of various risks in the operation of industrial enterprises determines the necessity to design special training content or courses on risk-based management at the university.
2. The effectiveness of engineers' study of risk-based ecologic economics is determined by their readiness to be involved in risk-based management and is one of their purposes in university study.
3. Diversionary analysis has been identified to be the mechanism of engineering students' training in ecologic economics in the context of their risk-based thinking development as the method to assess the effectiveness of the company's security system from the standpoint of possible risks ("sabotage"), promoting search and analysis of the real risks in engineering activities.
4. To develop holistically readiness for risk management it is recommended to provide proper study of ecological economics issues and have learning objectives corresponding to professional risks and related to *e*nterprise risk management.
5. Diagnostic tools to determine the preparedness of an engineer to risk management in their career allows to improve the process of the risk-based engineer training, and promotes pedagogical management at the university.

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