THE USE OF EDUCATIONAL TECHNOLOGIES FOR TRAINING ENGINEERING GRADUATES

O USO DE TECNOLOGIAS EDUCACIONAIS PARA FORMAÇÃO DE GRADUADOS EM ENGENHARIA

EL USO DE TECNOLOGÍAS EDUCATIVAS PARA LA FORMACIÓN DE GRADUADOS EN INGENIERÍA

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ABSTRACT: This article substantiates the need to train mine rescuers in a professional immersive environment with the use of cognitive technologies. It describes the elements of this environment and suggests a four-module model for implementation of cognitive technologies in the training of mine rescue engineers. Special attention is paid to the need for a harmonious addition to the methods of building an educational and practical situation with the techniques of creating an internal learning immersive environment. Cognitive technologies comply with many provisions of the conceive-design-implement-operate (CDIO) standard adopted by the international community and contain a huge field of activity for the development of both traditional and innovative educational technologies. The knowledge gained in the process of theoretical training, coupled with practical experience gained in an immersive educational environment, provide better training of engineering personnel adapted to the performance of their professional tasks and the needs of production.

KEYWORDS: Cognitive technologies. Engineering education. Mining engineer.

RESUMO*: Este artigo fundamenta a necessidade de treinar socorristas de minas em um ambiente imersivo profissional com o uso de tecnologias cognitivas. Ele descreve os elementos deste ambiente e sugere um modelo de quatro módulos para a implementação de tecnologias cognitivas no treinamento de engenheiros de resgate de minas. É dada atenção especial à necessidade de uma adição harmoniosa aos métodos de construção de uma situação educacional e prática com as técnicas de criação de um ambiente imersivo de aprendizagem interna. As tecnologias cognitivas obedecem a muitas disposições da norma conceber-desenhar-implantar-operar (CDIO) adotada pela comunidade internacional e contêm um enorme campo de atividade para o desenvolvimento tanto de tecnologias educacionais tradicionais quanto inovadoras. Os conhecimentos adquiridos no processo de treinamento teórico, aliados à experiência prática adquirida em um ambiente educacional*

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imersivo, proporcionam um melhor treinamento do pessoal de engenharia adaptado ao desempenho de suas tarefas profissionais e às necessidades de produção.

PALAVRAS-CHAVE: *Tecnologias cognitivas. Educação em engenharia. Engenheiro de mineração.*

RESUMEN: *Este artículo corrobora la necesidad de formar a los socorristas de minas en un entorno profesional inmersivo con el uso de tecnologías cognitivas. Describe los elementos de este entorno y sugiere un modelo de cuatro módulos para la aplicación de las tecnologías cognitivas en la formación de los ingenieros de rescate de minas. Se presta especial atención a la necesidad de complementar armónicamente los métodos de construcción de una situación educativa y práctica con las técnicas de creación de un entorno inmersivo de aprendizaje interno. Las tecnologías cognitivas cumplen con muchas disposiciones de la norma concebir-diseñar-implementar-operar (CDIO) adoptada por la comunidad internacional y contienen un enorme campo de actividad para el desarrollo de tecnologías educativas tradicionales e innovadoras. Los conocimientos adquiridos en la formación teórica y la experiencia práctica adquirida en un entorno educativo inmersivo proporcionan mejor formación del personal de ingeniería adaptado al desempeño de sus tareas profesionales y a las necesidades de la producción.*

PALABRAS CLAVE: *Tecnologías cognitivas. Educación en Ingeniería. Ingeniero de minas.*

Introduction

Engineering personnel is a kind of bridge between two sides of industrial production: science and industry. The development of engineering personnel potential that meets the requirements of modern science and economics requires the development of an innovative approach to the training of engineering personnel and the use of new educational technologies. In order to solve this complex problem, in October 2000, the Massachusetts Institute of Technology launched a major international project to reform basic engineering education: Conceive-design-implement-operate (CDIO), which combined the ideas of leading scientists, teachers and industry representatives about ways and means of modernizing university education. The initial goal of the project for the transformation of engineering training is to bring the content and effectiveness of engineering educational programs in line with the level of development of modern equipment and technologies and expectations of employers, namely, to get a ready-made specialist who has no work experience, but is ready to immediately perform his/her professional duties. The work on the project led to the emergence of certain requirements for educational training programs, which grown into the CDIO standard, which is constantly being improved in accordance with the requirements of potential employers (DAVYDOVA, 2017; VOROBYOVA, 2015). Many of the world's leading technical universities appreciated the prospects of this standard and, taking into account the positive results and experience of its application, to some extent they began to introduce new educational technologies in the educational process when preparing students for engineering specialties.

Methods

Technical universities in Russia also drew attention to this experience. Over the past two decades, the approach to the educational initiative has significantly transformed. Cognitive technologies that were previously successfully implemented in the humanities and were hardly implemented in engineering programs, where the classical approach to the educational process still prevails, began to be used.

Literature review

Cognitive technologies as an independent branch of knowledge in modern science is the result of applied research in the field of psychology, psycholinguistics, knowledge engineering, pedagogical design, etc. The interdisciplinary nature of cognitive technologies (at the intersection of several sciences) makes it difficult to define them. Many authors apply an extended interpretation to these technologies, where each section, in fact, represents a whole pedagogical direction worthy of deep studies (ADLER, 2000; BAKIN, 2020; DUBROVSKAYA; PIKHKONEN, 2019; DUBROVSKAYA; PIKHKONEN; RUDENKO, 2020; GONCHAROVA; MOMOT, 2019; KORNILOV, 2019; KRAYUSHKIN, 2021; POTANINA, 2009; SERGEEV, 2010, 2013; TVKINORADIO, n.d.; ZAIR-BEK, 2018). The formation of ideas about the nature and purpose of cognitive technologies took place in several stages, formed from scientific messages and the progressive development of cognitive pedagogy. Each stage developed its own application *branches* and system modules.

The modern interpretation of cognitive technologies, taking into account the role of the immersive educational environment, is most clearly presented in the works of Sergeev (2010, 2013) and Kornilov (2019). From a variety of perspectives, cognitive technologies are considered in the collective monograph of Sergeev, Bershadsky, Chorosova, Solomonova, Zhohikov, Gerasimova, Zakharova, Nikulina and Savkin (2016). A deep analysis of the prospects for the introduction of immersive technologies in the learning process was presented by Zair-Bek (2018). These authors developed the main provisions of the theory of immersive and professional environments, justified the basic meaning of models and proposed a commonly used terminology. The psychological side of cognitive technologies is reflected in the works of Adler (2000) and Andersen (2002).

The structure and content of the competencies expected as a result of the educational process, and the essence of practical engineering training are disclosed in the works of Vorobyova (2015), Veshneva and Singatulin (2015), Potanina (2009) and others (CUMMINGS; BAILENSON, 2016; LI; FENG; CHENG; LU, 2018; POTKONJAK; GARDNER; CALLAGHAN; MATTILA; GUETL; PETROVIĆ; JOVANOVIĆ, 2016; RADIONOVSKAYA; BAEVA, 2014; SCHEXNAYDER; ANDERSON, 2011; TEJEDOR; SEGALÀS; ROSAS-CASALS, 2018). In this paper, cognitive technologies are understood as technologies for improving the cognitive abilities of students, allowing them to individualize the educational process.

Results

The normative documents regulating the educational process in higher education oblige to work in close contact with production, to focus on professional standards and requirements of employers. Higher educational institutions of Russia that train specialists for the objects of the mineral resource complex should be most interested in the fastest possible adaptation of graduates to work in the real conditions of mining enterprises. Cognitive technologies allow us to achieve this goal: they develop cause-and-effect relationships that arise in the external environment, help to develop skills for making independent management decisions, and work out an algorithm of actions for performing professional tasks.

When forming an educational program for engineering specialties of the mining profile, there are more and more complex and multifaceted tasks. Let's highlight the three most significant of them. The first is gaining a competitive advantage: growing competition in the higher education sector is forcing universities to look for advantages in their programs to attract students to engineering majors.

The second task is to increase the motivation of learning and retain those students who were attracted. The approach to learning can be defined in three blocks: i) "What is being studied", to show the value of what is being studied; ii) "Why it is being studied", to provide motivation for learning; and iii) "How it is being studied", to build a learning strategy. In this task, we can distinguish two main approaches of students to learning: a superficial and a deep approach. The superficial approach is typical for students who do not see the value in the learning material, and their motivation is simply to reproduce the information to meet the requirements of the course and be certified by the results of the session. A student who is motivated understands the value of knowledge, finds a practical application of the information received, applies a deep approach to learning.

The third task is to meet the needs of the employer. Employers encourage certified engineers to show their knowledge of theory and abilities and immediately get involved in the production process.

How to solve these problems? Existing teaching methods are often limited by many factors, including time, resources, and the administrative will of the university. The training of students in engineering should be provided by methods that encourage students to do something. Many approaches to learning are based on the philosophy of *action*, which concerns active learning, blended learning, project-based learning, problem-based learning, discovery-based learning, and experience-based learning. All of these approaches are focused on helping students to accumulate knowledge, find meaning between their knowledge, experience, their ideas, and set tasks.

For a mine rescuer, coordination and reflex ability are manifested in the ability to accurately perform complex procedures to rescue the victim in a minimum period of time. In particular, in a smoky and partially unbreathable atmosphere, an unconscious person should be connected to an artificial respiration device, if possible, in the shortest possible time, secure the victim and the breathing apparatus and prepare the person for transportation. Such actions are achieved only through long-term training to bring all operations to save people in an extreme situation to automatism, when conditional reflecting muscle memory should be activated. The specifics of the training of mine rescue engineers include special physical and psychological training. Thus, the efforts and funds spent on the creation and effective functioning of training mines and training areas, the development of new training technologies and the training of all categories of rescue units of paramilitary mountain rescue teams (full-time employees, junior and middle managerial personnel) become clear.

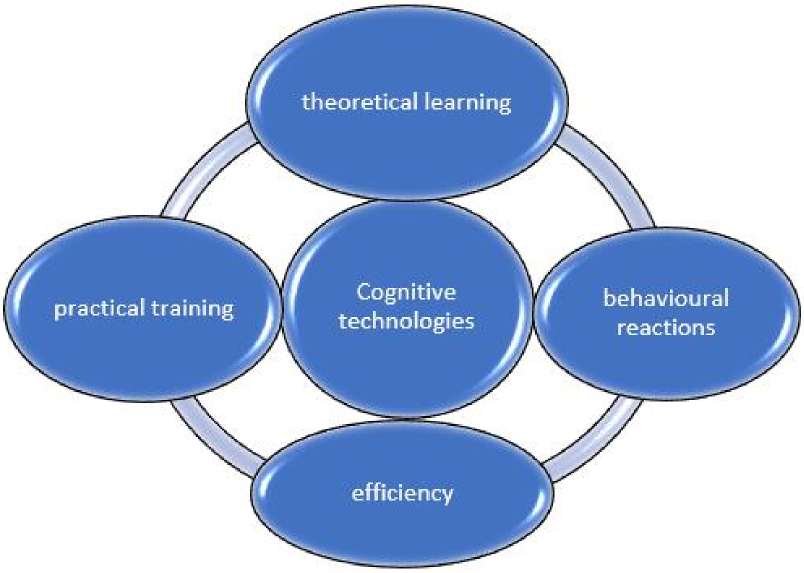
The quality of training of graduates in this specialty directly depends on the quality of the formed skills and abilities. Therefore, specialists, who are ready to work in a mode of constant stress, risk to their own lives, who are able to solve complex problems in the field of industrial safety, need to form practical skills in the conditions of existing mining enterprises. No simulators will be able to provide sensations, skills and abilities to work in a respirator, in a heat chamber, in a smoke-filled space. They will not be able to recreate stressful situations, to convey all the horror and fear of moving in cramped conditions, under simulated obstructions, in complete darkness.

Only the immersion of students in the professional environment of mine rescuers and miners in the conditions of a training mine or landfill increases motivation and interest in the chosen profession, allows to understand the meaning and scope of practical application of the theoretical knowledge gained. It helps to work out exercises to overcome fear of confined spaces, darkness and heights, overestimation or underestimation of self-esteem.

The experience of training rescue miners in Russian educational organizations has revealed a significant gap that hinders the active introduction of cognitive information and communication technologies into the educational process: the lack of specialized software that allows to identify and evaluate the characteristics of each student. Cognitive psychology and pedagogy in the context of training graduates in the specialty "Mining" are related to each other by common tasks and objects of research. In our case, this is the personality of the student, the future main rescuer engineer.

In the course of training according to the developed methods and programs, students showed the ability to adapt to the realities of production, flexibility of thinking, able to find and make decisions in nonstandard situations and demonstrate stable psychophysiological reactions necessary during rescue operations. Let's summarize the experience of the practical application of cognitive technologies in the practice-oriented training of mine rescue engineers, presenting it as a model consisting of four implemented modules: the module of theoretical training, which is responsible for the acquisition of knowledge in the process of mastering the educational program; the module of practical training, which forms practical skills and abilities necessary in professional activity; the module of behavior, which is responsible for observation, the study of interpersonal relationships; the effective model—a module that develops psychological stability, adaptation of the individual to complex, non-standard situations (Figure 1).

Figure 1 – Cognitive technology educational modules that form an immersive environment in practice-oriented learning



Source: Prepared by the authors

The immersive environment is a part of the surrounding external environment that affects the psychological state of the student, stimulating the perception of the educational material in connection with its practical application. All four modules have an impact on the student's personality, strengthening the connection between theoretical and practical learning through personal participation in the learning process. At the same time, cognitive educational technologies take into account the behavioral reactions of the student and the ability to respond to complex, nonstandard situations. In classical education, the last two modules were considered insignificant and, as a rule, were not taken into account when drawing up practical training programs.

In practice, a professional immersive environment for mine engineers is understood as the acquisition of professional skills by immersion in the reality of production. In a particular case, immersion in the external environment for mine engineers specializing in "Technological safety and mine rescue work" is training in a training mine, on training areas and working in mining—in coal and ore mines, surface coal mines, mining plants and other objects of the mineral resources sector—according to special programs that provide for students' behavioral reactions, their ability to make independent decisions in nonstandard, emergency and stressful situations.

Cognitive technologies in this model encourage students to actively participate in the educational process. They involve finding problems in the subject under study and solving them independently, stimulate interaction and comparison of one's own and other people's experiences, as a result of which a new individual experience is acquired. In the training of mine engineers specializing in "Technological safety and mine rescue work"—future managers of emergency services, where people's lives depend on the quality and speed of decision-making, often nonstandard decisions, it is cognitive educational technologies that have a perspective and advantage in the training of such specialists.

The task of teachers is to create and provide conditions for the development of individual cognitive abilities of the student, shown in the structure of cognitive models. The specialization "Technological safety and mine rescue work" is mostly in need of the use of cognitive technologies. When conducting rescue operations in difficult conditions, eliminating the consequences of accidents and catastrophes, rescuers need stable psychological training, formed personal and volitional qualities, and the ability to make managerial (team) decisions based on the acquired individual experience as a result of training and participation in rescue operations.

In-depth practical training in training centers at paramilitary mountain rescue teams, on training areas and in training mines is designed to develop personal psychophysiological qualities and skills, to make decisions in extreme conditions. The specifics of the work of rescuers involves significant physical exercises, being in psychologically unfavorable conditions, often in emergency situations that cause stress, unfavorable physiological reactions of the body: being in complete darkness, in an enclosed space, in an atmosphere unsuitable for breathing, with the threat of an explosion, fire, collapse, watching the victims, the need to provide them with first aid. Therefore, training and practice are aimed at the formation and development of the necessary physical qualities and resistance to psychological stresses.

The result of exhausting and physically challenging training using cognitive psychology methods is the development of strong-willed qualities of the graduate: from the ability to manage themselves in stressful situations and withstand heavy psychological loads to the ability to perform their official duties in an unfriendly environment, in extreme conditions.

Psychophysiological exercises help to identify the potential of the trainee's personality and gain new experience in finding effective action in various professional work situations.

Thus, through the reaction to external stress, the teacher develops a certain model of behavior to get out of the current circumstances.

The *immersiveness* (immersion, presence effect) supplement the cognitive technologies. Immersivity implies the transformation of the subject into a system of relations (educational and/or professional), in our case of a student transforming in a mine rescuer engineer, acting in the proposed circumstances of the training. Students feel the reality of everything that is happening around them, perceive it through all available channels: through sight, hearing, smell, touch, taste, perception, body.

Conditional immersive environment can be divided into external and internal. External is passive, simulated learning environment. It includes virtual reality technologies—situational simulators, landfills with special equipment—a simulated world constructed by technical devices, transmitted to the student through their senses. Virtual reality is based on the concept of using a human-machine interface to create the effect of a three-dimensional environment, in which the user interacts with virtual objects, and not with images of these objects (VESHNEVA; SINGATULIN, 2015).

The external immersive environment provides the student with the effect of immersion, a sense of presence, but does not take into account the thinking, behavior, habits, skills and abilities of the student, their psychoemotional and psychophysical state. The latter leads to inconsistency and sensory conflicts, when immersion in virtual reality causes, for example, dizziness and nausea.

The internal (active, real, information and communication) environment provides the formation and development of practical skills and abilities necessary for a mine rescue engineer. A real production environment and a training mine provide training for a mine engineer of a qualitatively different level.

The immersive environment in combination with cognitive learning technologies provides the development of psychophysiological skills, as well as sociopsychological skills of interaction in a team. When conducting rescue operations in extreme conditions, a requirement is the well-coordinated work of each member of the team, who understands the tasks almost intuitively.

Immersiveness in practice-oriented learning provides the learner with a psychological state in which they, as a person, see themselves to be included and interacting with this environment. This involvement provides the student with the development of skills, gaining experience, and the formation of situational behavior.

The practical experience acquired in an immersive environment becomes the basis for the student to individualize behavior in various complex nonstandard situations, helps to overcome various fears to which a person is predisposed. The immersive environment forms qualities necessary to perform the professional tasks of a mine rescue engineer: to be ready for conditions of deadly danger, to perform emergency rescue operations, to be psychologically ready to perform tasks in conditions of deadly danger.

Final considerations

Professional immersive environment, in our opinion, allows to form qualities necessary for a mine rescue engineer to work, it algorithmizes their actions, providing psychological readiness to find a way out of difficult situations. The experience of graduates training in the specialty "Mining" (specialization "Technological safety and mine rescue work") shown an obvious advantage of the internal (active, real, communication) immersive environment over the external (passive, simulated, training). Conducting educational and industrial practices with the use of cognitive technologies with immersion in a professional external immersive environment allowed to ensure the formation of professional skills and abilities of students at a high level, which was confirmed by both employers, teachers involved in the training of specialists, and graduates. The effect of the introduction of cognitive technologies, further scientific research, a good methodological base and a reasonable approach to their use will ensure their application in the educational process in the training of mine engineers.

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