Computer-aided Training of Engineers: Challenges and Solutions

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Abstract: The paper discusses the advantages of computer technologies and augmented virtual reality in training of engineers, including the main areas of application and influence on the quality of education, and attaches an example of training of engineers for the automobile industry. It is shown that using of systemic approach to the educational process allows to improve the tuition quality of specialists for hi-tech industries. Such engineers can easily adapt in business both due to acquired fundamental knowledge and skills.

1 INTRODUCTION

Among the problem of today are not only depletion of natural resources and a critical state of ecosystems but also changing of the occupational patterns, with old trades slipping away and new ones emerging. Professional education can cope with the latter problem only in the framework of the systemic strategy. The challenge arises from inconsistency of the rapidly advancing economy, badly in need of as rapid training of personnel capable of tackling complex problems, and the inertia of the formal education system. This is especially true of the training of engineers, whose role is becoming increasingly important in the globalizing economy and advancing processes and technologies.

The contradiction can be overcome using the systemic strategy that might integrate advanced technologies and the experience in engineering education accumulated in universities worldwide. This strategy should ensure stability and continuous updating for the educational system and enable it to meet the requirements of the real economic sector. The system of engineering education in the 21st century should embrace the innovative principles, methods and teaching technologies. The curricula should also be anticipatory and re-shaped to be equal to the modern technological advances.

According to educational standards, the engineering competences are defined broader, as applied to the entire kind of industry a specialist will be engaged in. This gives rise to a contradiction between the goals of education and business demands for full-fledged engineers due to extending scope of engineering activities. Moreover, the issue of today is the necessity of "globalized" competences.

Collaboration will promote the sustainability of both educational and production systems. To rationalize it, the models of competence profiles of universities and companies should be coinciding, or proximate.

Another problem at issue is increasing unwillingness of young people to obtain engineering education, especially when it implies subsequent intellectual activity, such as designing of new machines and technologies, which combines applied research developments and research with engineering and construction operations. To enhance the motivation, it is proposed to introduce early professional orientation, revealing and developing of abilities and boost the engineering prestige.

2 COMPUTER-AIDED TECHNOLOGIES IN THE TRAINING OF ENGINEERS

2.1 Computer as a Teaching Medium

Nowadays, the educational system is expected to prepare creative and initiative persons capable of solving difficult problems by applying innovational and flexible methods. This can be achieved if we abandon the old reproductive approach and turn to a creative one both in organization of educational processes and in learning content and teaching

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techniques. The concept of lifelong learning means using the computer for self-study to obtain knowledge and skills from educational contents and distant learning systems. As considered by Daniel Araya, a well-known expert in education policies and information technologies, the global network capitalism, that has ousted the industrial capitalism, embodies a network model providing democratization for the educational process, developing globally horizontal linkage, which enhances self-organization and interaction, the features of education in the future (Araya, 2010). John Seely Brown (Brown, 1999) claims that the obligatory component of the system of education must provide only the basic competences such as reading and writing, arithmetic, and critical thinking. The rest of the education (the "open component") is to be chosen by the students proceeding from a wealth of opportunities offered (or to be offered in the future) by the so-called educational social networks – the distributed network platforms promoting the creation and transfer of knowledge and experience and accommodating the interests and motivation of participants.

Some of the contradictions can be smoothed down if a learning environment is formed using computers. We mean, first, the contradiction between the necessity of diminishing the training period and increasing requirements placed on students' competences, this under conditions of fast updating of industrial technologies. The second contradiction is that between the necessity to maintain a high level of instructors' competences and increasing teaching loads caused by having to update learning contents.

These contradictions can be solved by creating a unified informational educational environment, desirably with business participation, which will help to pool the efforts in study courses development and launch communication between all interested parties. This will improve feedback, create individual educational paths for the learners, and facilitate self-control and quality control. This will modify the entire E-learning concept 2.0 of "Motivation – goal – tools – realization".

One more contradiction consists between the young people's desire of quick results and high requirements to the graduates' competence alongside with growing rivalry on the labor market, which requires long learning. Motivation for learning can be enhanced by using the systems of revealing of learning capacities to develop them, while promoting the role of an engineer in the modern world. We mean such systems as STEM (science - technology – engineering – mathematics) and STEAM (science - technology – engineering – art - mathematics), which help to form the basis of engineering education and research activity. Moreover, difficulties arise when creating a unified system of learning management systems (LMS) for partner organizations (universities and business) (Ribón et al., 2015).

2.2 Computer as a Means of Communication

Capacity for communication is one of the most important human competences, especially for engineers; therefore virtual platforms cannot replace an actual teacher-to-student or student-to student interaction. Moreover, many of the skills and competences, needed to ensure a sustainable development, can only be formed as a result of participation in joint practical activities. It is clear that the education of the future is inconceivable without media literacy. For understanding of the great body of daily incoming information it is not enough to be able to think critically; the perception of a media-literate individual is more adequate because he\she can filter it.

So far, formal education has been unable to provide a universal media literacy, which is supposed to transform the media consumption to an active and critical process helping people to look through potential manipulation (in particular, on the part of advertizing and PR) and understand the role of the media in forming of their views of reality.

Global companies are in need of professionals prepared to operate in bilingual situations. Second language skills have become a significant personal and professional characteristic of a specialist, helping to find one's bearings in the modern information space. This requires updating of the technology of language teaching for global-level specialists.

2.3 Computer as a Virtual and Augmented Reality

It is known that analysis and decision making rely on adequately perceived information. Since engineers have to deal with complex systems, their training and further professional activities should involve systems of virtual and augmented reality.

Analysis of personal and inter-personal competences has revealed the necessity of the foreign language skills component, of predominantly English, which has spread due to markets globalization and as the language of science

(Tonkin, 2011). The issues of developing and perfecting of bilingual skills are extensively discussed in relation to training of engineers. Thus, work (Holgate, 1992) has explored the need in developing of bilingual communication skills of engineers according to their professional activities.

The process of language teaching has been essentially influenced by computer having the advantages of informational capacity, intensification of individual studies, enhancing of cognitive activity and motivation, and creating of personally meaningful communicative situations.

The authors of work (Wu et al., 2013) outline the educational possibilities of recently developed "augmented reality" (AR), alongside with the problems it has brought in its wake. Thus, in work (Kesim and Ozarslan, 2012) it is suggested that educationists should collaborate with researchers to develop extended interfaces of reality. Although the key role of producing augmented realities is played by soft- and hardware technologies and there are engineers for designing them, the educational technologies are seriously in need of specialists to design learning activities for augmented reality.

It is shown (Martín-Gutiérrez, J. et. al, 2012; Martín-Gutiérrez, J. et. al, 2015) that one of the AR advantages consists in saving of instructors' time on repeat explanations because students can use them for independent revision. Furthermore, the effect of these technologies is twofold: facilitating the teachers' control of laboratory courses and promoting the students' motivation. Work (Webel et al., 2013) describes an experiment of applying AR for training of technicians in industrial maintenance and assembling operations. The authors emphasize the importance of drilling technicians in new skills due to increasing complexity of maintenance operations and demonstrate the superior performance of AR tools compared to traditional teaching techniques.

2.4 Computer as a Tool for Solving of Professional Tasks

Informational competence, as part of professional competence, incorporates a number of specific issues corresponding to the level and content of computerization of a professional environment of which knowledge and experience a specialist must be aware and in which they must be experienced. Moreover, it is presumed that a specialist must be able to extend his/her knowledge and skills both in their professional areas and linked industries. Forming of the informational component of professional competence is achieved through a set of disciplines, case studies, and practices imitating real professional tasks.

Since employers nowadays require an IT proficiency, all study courses should be geared to give the students the skills of using both the software products and mathematical models they are likely to deal with when solving problem in their professional activity. A competent specialist must be able to sort out miscellaneous information, isolate the piece he/she needs, analyze it and arrive at a proper conclusion. Students must be given access to the software tools specific for their industry and workplace at all the stages of operating with information: collecting, processing and analysis.

2.5 Computer as a Tool of Assessing the Quality of Engineer's Training

Notwithstanding the fact that human capital is now recognized as one of the key objectives and prerequisites for successful development, the investment to education is still insufficient. National educational systems are concerned about commercialization and formalization of education. Common problems for many countries are the multiple-choice test-based control of knowledge and inferior tuition at many higher school establishments. Formal indices fail to give an idea of how successful an educational system is in shaping of a new type of individuals adapted to new conditions.

Nonetheless, students can perform self-assessing when working at the teaching complexes of existing training and assessing systems. Teachers can use computer testing systems for current control of assimilation of an educational module. Such systems afford to assess the level of students' preparation, determine his rating position in the group. Besides, the teacher can check the time spent by each student on learning a module and correct the study courses accordingly.

3 RESULTS AND DISCUSSION

3.1 Stages of Creating a System of Engineer Training for High-tech Productions

The automobile industry is faced with the necessity of enhancing the efficiency and environmental safety of transport facilities, developing of power-

efficient vehicles, and reducing the negative impact on the environment during vehicles manufacture, operation, servicing, and disposal. The automotive engineer must also possess the skills in creating of digital models of a car, its manufacture, servicing and of intelligent transportation systems.

Table 1: Questionnaire surveys of engineers from partner companies.

Groups of compe-tences	The competence	Functions of the business		
		1*	2**	3***
The technical	Fundamental knowledge	90	30	40
	Engineering knowledge	90	30	50
	Application IT for the decision of professional problems	70	50	65
	Understanding of problems of life cycle of a product	90	40	40
The personal	Creative and critical thinking	80	40	60
	The initiative	90	85	80
	Ability to constant perfection	90	90	90
	Ability to end in itself and planning of the career	95	94	90
The professional	Engineering thinking	98	50	60
	Ability to the decision of professional problems	95	95	92
	System thinking	95	40	70
	Ability to search and the information analysis	95	85	80
	Awareness in engineering tendencies	98	60	70
Interpersonal and communicative	Ability to work in collective	80	90	90
	Knowledge of methods of business communications	90	75	85
	Communications in foreign languages	90	70	70
	Ability to successful work in the organization	95	95	95

*Designing and manufacture of vehicle's and intellectual systems of the vehicle

**Management in transport and logistical systems

*** The organization of transport processes and safety of transport systems

Here we present our experience of collaboration with PTC KAMAZ on training of engineers for its Engineering and Technological Centers, and also with companies involved in logistics, servicing, managing of transport systems and transport safety. Given the scope of reasons for updating the engineering education and the multitude of instructor's manuals and technical aids for their realization, we started by putting straight the goals and means. We systematized the tasks to be solved by engineers at their workplaces. First, specialists of partner companies were interviewed to reveal the competences of university graduates most meaningful for their performance and career, and also which software and technical solutions are applied in practice. The survey findings were processed and systematized in respective categories (Table 1).

In order to harmonize the professional and educational standards, the questionnaire was split into a general technical block, offering the study courses common for engineers and ensuring all stages of the automobile life cycle, and the professional block, comprised by the study courses unique for a workplace.

At the next stage, we developed an integrated curricular of degree courses including the key competences meeting the professional standards of the automobile industry. The courses, aimed at forming the essential competences revealed, were included into the educational curricula for engineers for different companies and kinds of professional activity (Table 2). The peculiarity of this training system consists in the fact that students are gradually integrated into the professional environment, doing professional practical work in freshman classes and proceeding, if recommended by recruiting department, to work in engineer positions in different factory departments by combining work and study.

In this case they get access to informational resources of the enterprise and can use the teaching content of corporate university at professional software while doing projects. In other words, disciplines of block one are studied at university and those of block two – in real production environment, for which purpose are created university-based subdepartments. This allows to split the separate management in two LMS.

At the second stage of creating the teaching system, we developed a learning content, selected a way for effective realization of the study process, and equipped the multimedia classrooms. The third stage consisted in testing the performance of the system proposed. For this, we formed experimental study groups to be taught with the aid of the developed methods and technologies.

For instance, with students majoring in car design (automobile- and engine construction) emphasis was laid on designing of intelligent car systems, such as anti-lock braking and crash avoidance systems, active suspension, etc. These students studied 3D modeling, engineering analysis and imitation modeling using the Siemens PLM

Table 2: Learning courses in curriculum.

The name of discipline from the curriculum	Groups of competences			
	The technical	The personal	The professional	Interpersonal and communicative
Learning courses in the designing of the vehicle intelligent systems				
System of the automated designing and modeling of manufactures UG NX	■		■	
Designing and calculation of intellectual systems of the vehicle	■		■	
Microprocessors in automobile branch	■	■	■	■
Durability and safety of designs and electronic systems	■		■	
Techniques and systems of engineering calculations and the engineering analysis	■		■	
Test of vehicles. The bench equipment and techniques of tests	■	■	■	
Learning courses in the safety of transport systems				
Ecology on motor transport	■		■	
Bases of safety of transport systems	■	■	■	
Communication and information support of transport process		■	■	■
Program complexes for safety of transport systems	■		■	
Systems of satellite positioning of transport systems	■			
Bases of the theory of reliability and diagnostics	■		■	
Hardware systems of active safety of transport systems	■		■	■
Standards of safety of transport systems			■	
Learning courses in the organization of transport process				
Systems of the automated designing in the organization of transport processes	■		■	
The theory of transport processes and systems	■		■	■
Maintenance service and transport repair	■	■	■	■
Modeling of transport processes	■			
Methods of optimization of transport streams	■			
Quality maintenance on transport	■	■	■	
Geoinformation technology on transport	■	■	■	■
Automatics and telemechanics on transport	■			

software complexes. The students majoring in automobile electronic systems, were trained in developing of intelligent electronic management systems with a focus on engineering analysis and construction of functional schemes using the Siemens NX, e-Series software complexes.

As for the students of machine-building technologies intending to work in technological centers of auto-manufacturing companies, they studied the Siemens PLM programs: Plant Simulation and Tecnomatix (with Jack and Human Performance modules). These programs are used by manufacturers to perfect the technological processes on virtual mannequins. They also contain tools for solving of ergonomic tasks. Students, majoring in logistics and operation of automotive transport, studied the theory of management of transport vehicles and transportation flows, methods of logistics optimization, telematic systems, and GIS using the MiniTab, PTV Vision (VISSIM, VISUM), ArcGIS, and MapInfo software.

3.2 Examples of the System's Implementation

By participating in real projects, the students got a better idea of requirements imposed on modern vehicles and developed them by employing new design technologies.

The ITS area most in need of a use engineers in different activity lines is that of transport systems control because it is here that the greatest scope of tasks is solved. The engineers, creating programs for intelligent onboard systems, study the synthetic vision systems and pattern recognition techniques

The issues of transportation planning and simulation are dealt with in different companies. There are companies creating the infrastructure, building and reconstructing the street-road networks, determining the location of sites for public transport stops, petrol filling and service centers. Others are involved in planning of traffic along the street-road networks and of traffic control with the purpose of enhancing its safety and effectiveness.

Engineers in these companies must know how to obtain adequate information and operate with great data volumes, analyze them and make strategic and operative decisions. Training for these positions envisages instruction in the systems theory, intelligent control systems, statistical data analysis, the theory of experiment planning, and methods of optimization.

Constructing of public transport routes requires exploring the consumer demand for transportation

both within and outside the city. Engineers employed in companies dealing with passenger transportation must be aware of demand analysis techniques, principles of rational constructing of routes, methods of bus fleet management, and ecology-minded driving. This is taught at such courses as statistical data analysis, theory of experiment planning, methods of optimization, technosphere safety, systems modeling, management of passenger transportation, and of transport flows.

The engineers involved in logistics processes and cargo delivery must know the means and methods of cargo shipment planning and managing of motor vehicle fleets, methods of building logistical chains accounting for interaction of different kinds of transport.

These aspects are studied by doing such courses as statistical data analysis, methods of planning and forecasting, theory of constraint, systems analysis methods, theory of experiment planning, management in logistical systems, and the theory of transport flows.

The students solve real problems which help them to understand the problems of the industry and professional tasks already during their study time. This approach facilitates professional adaptation. Survey results of the employers after the introduction of above described method shows that the degree of satisfaction with the quality of students training increases (Figure 1).

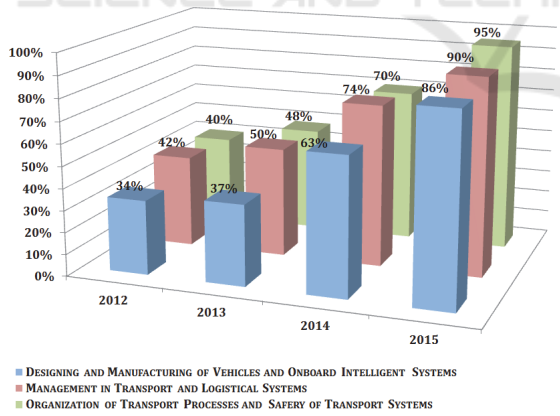

Figure 1: Dynamics of satisfaction with the quality of students training.

4 CONCLUSIONS

In our opinion, developing of a high-quality study content in the simulation environment later to be used at real workplaces will improve both the quality of engineer training and the learning process management in realization of the "life-long learning" concept.

Here are the advantages of the proposed system over the traditional methods:

- For business, it gives the advantage of shorter time spent on a graduate adaptation in real-work environment, a higher level of graduates' training, and new-coming employees with already developed business-relevant competences.
- For the student, it promises higher interest in academic disciplines, a possibility to become involved in real problem solving, and personal competitive advantages at the labor market.
- For the education system it means higher occupational prestige for engineers, a possibility of closer contact with business and higher quality of education.

Moreover, interaction with business will give an opportunity for the teachers to learn new technologies and apply them in teaching of students.

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