Technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines

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Abstract. The article presents the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines. It was designed the classification of competence-based educational simulators for learning general technical disciplines. There are presented types of educational simulators and outlined professional competencies of general technical disciplines that provide the developed types of simulators. On the basis of passing educational simulators it is formed not only a qualitative indicator of the educational results, but also an indicator of the formation of competencies in the course and curriculum. The method was tested using experimental group and control group (total 1301 students of specialties 'Agricultural Engineering', 'Electrical Power, Electrical Engineering and Electrical Mechanics', 'Professional Education' that studying general technical disciplines) by systematically measuring achievement of professional competencies in the conditions of informational and educational environment by using educational simulators. The results show that higher education applicants in the experimental group achieve better results of acquiring professional competencies.

1. Introduction

In the context of the development of modern equipment and technologies, the question of studying general technical disciplines among future specialists in engineering specialties arises. Technological progress expands the possibilities of using modern educational environments, which requires an appropriate level of training future engineers. The future engineer must be competitive in the global labour market, which means that he must have professional competencies. Therefore, the application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines is relevant.

The use of e-learning strategies in higher education is becoming increasingly popular [1, 2]. Moreover, online higher education is an innovative way to increase the accessibility of university education [3]. Universities with the help of open education can evaluate student without attendance [4–8]. However, the important aspect in the context of learning in the informational and educational environment is feedback between tutor and students [9–14].

The findings show that about 75% of students of engineering specialties agree with the advantages of online learning [15]. The learning in the conditions of informational

and educational environment helps to develop an analytical thinking and understanding underlying issues [16]. An increasing number of higher education institutions have deployed learning management systems (LMS) to support learning and teaching processes [17–19]. But implementation learning management system in higher education institutions needs a range of special online tools [20].

Educational innovations such as the flipped classroom, game based learning, gesture based learning, along with pedagogical shifts, such as life-long learning portfolio maintenance, team teaching, and separation of learning and competency assessment are involved in the engineering learning [21–27]. There are opportunities with regard to learning in conditions of informational and educational environment such as: online teaching, supporting mechanisms, quality of education and educational efficiency [28, 29]. The researchers make remote evaluation of engineering competences using progressive competence representation model [30].

In engineering education exists strong evidence for improvement of basic competences: underlying science knowledge, knowledge of fundamental and advanced engineering, engineering reasoning and problem solving, systemic thinking [31]. The emergence of new educational environments, in which digital fabrication techniques are used to turn ideas into digital designs, and these into tangible products through 3D printing offer an opportunity for the development of engineering creativity [32–35]. The engineers have tendencies to face problems with the technical, economic, social and environmental impacts of their solutions [36].

Informational and educational environment provides a common support service for learning outcomes information exchange, referring to a student's knowledge, skills and competence [37]. So, there is a need in development competency management systems and the support of computer technologies to this field [38]. It is important not only to develop a competence model for the future engineer, but also scientifically substantiate it [39]. The data from the interviewing industrial employees, is highlighted as one of the professional skills required of a bachelor-degree-holding engineer working in the engineering industries and it can help to outline professional competencies [40].

The development of the competencies is possible during a laboratory and practical classes [41, 42] that be carried out in the conditions of informational and educational environment. General technical disciplines are designed to perform several main functions: to promote polytechnic education; provide a deeper understanding of special disciplines; to help students better understand the laws of science in their application in engineering and technology; to develop technical thinking [43, 44]. The system of engineering education in the conditions of informational and educational environment requires modernization of theoretical and methodological foundations of training, its structural and organizational restructuring through the introduction of theoretical, interactive and practical tasks, such as educational simulator.

The aim of the article is to develop the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines.

2. Methods

The set of methods used in the research process is represented by:

- theoretical methods – forecasting, formalization, categorical and logical analyses in order to determine the pedagogical characteristics of learning general technical disciplines in the conditions of informational and educational environment, generalization of the results and experience;
- empirical methods – surveys, questionnaires, self-assessment, testing, direct and indirect observation of the learning process, pedagogical experiment;

- statistical methods – quantitative processing of indicators and verification of the reliability of the obtained empirical results using the Pearson's criterion.

In order to statistically verify the equality of use of educational simulators in the informational and educational environment for learning general technical disciplines in control and experimental groups, it was applied Pearson's criterion χ^2.

The following hypotheses are formulated: H_0 – there are no significant difference in the level of application of educational simulators in the informational and educational environment for learning general technical disciplines in control and experimental groups; H_1 – there are significant difference in the level of application of educational simulators in the informational and educational environment for learning general technical disciplines in control and experimental groups.

3. The designing of competence-based educational simulators in the informational and educational environment for learning general technical disciplines

The basis of monitoring the students' results in the informational and educational environments is the assessment, the achievement of points as a result of passing courses. It is proposed to consider the informational and educational environment as system-organized set of hardware, software, organizational and methodological software that is created to meet the needs of users [45] and to focus on its improvement according to the competence-based approach [46]. It is necessary to analyse students' behaviour in online learning activities and detecting specific patterns of interaction in LMS for the purpose of giving recommendations in development educational simulators [47].

Studying in the conditions of informational and educational environment attracts a diverse range of students, but it is important for tutors to anticipate students' individual needs [48]. The system aims to improve the effectiveness of the learning process by providing features for flexible adjusting of the educational tasks [49]. The evaluation of student's results focuses on the learning the participants engaged in the thematic units and the perceived outcomes on the growth of their knowledge [50].

It is recommended that instructors design courses in a way that can promote students' self-regulated learning behaviours in online learning settings and that students in online classes, as in traditional classes, set aside a regular time to concentrate on the course [51]. Adaptive assessment enables to perceive competences of students more efficiently and correctly [52]. The findings indicate that there is significant relationship between the entry test scores and the academic achievement of engineering students [53].

Simulation-based training techniques and tools can be applied in designing structured learning experiences, as well as be used as a measurement tool linked to the competencies and learning objectives [54]. Competence is defined as the level of performance resulting from the skills that can be observed. Digital technologies have an impact on education [55], training and learning by developing modern learning environments and tools that enables obtaining these skills [56]. In this study, we focus on the creation of educational simulators to provide a competence-based approach in the training of future engineers in an informational and educational environment.

Under the term competency-based educational simulator in the informational and educational environment it is implied a set of specialized logical, analytical, visual and practical training tasks on the basis of use of informational tools of the educational environment, the result of which is the acquisition of competencies in specialty. The content of any educational simulator for general technical discipline in the informational and educational environment must be appropriate for the work program for students in the curriculum. The tasks of an educational computer interactive simulator in the conditions of informational and educational environment is not a simple set, but a system of tasks that has the composition, integrity and structure in the direction of training.

It includes tasks, rules for their use and evaluation, and recommendations for interpreting the results.

The designing of competence-based educational simulators starts from the familiarization with the peculiarities of the general technical discipline and the specificity of courses, analysis of the available software tools of the informational and educational environment in order to determine its approximate structure and content.

The next step is selection of some important terms and concepts that must be studied by students and preparation of theoretical material in the form of a presentation with audio content, multimedia interactive lectures, web pages, hypertext etc.

The final stage is linking the educational simulator tasks to the competence repository in the informational and educational environment. It is possible to use educational simulator for checking the modular and final results, performing of practical tasks and consolidation of knowledge from lectures in the informational and educational environment (figure 1).

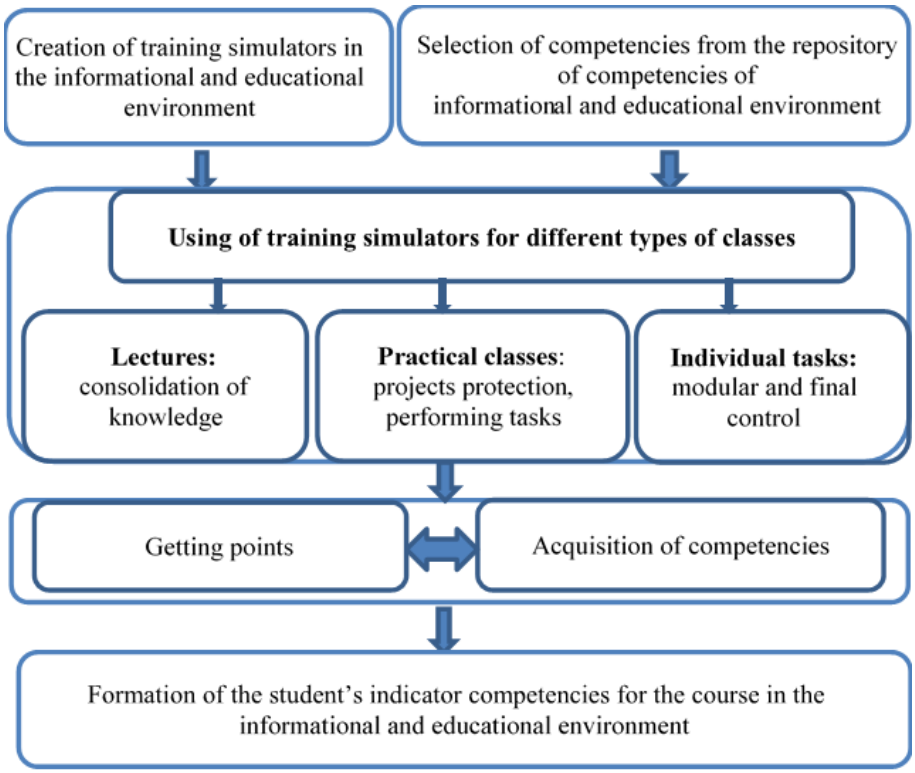

Figure 1. Technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines.

There are three main types of educational simulators for learning general technical disciplines in the conditions of informational and educational environment: educational test simulators, educational graphic simulators, educational gamified simulators.

The educational test simulator is the use of a special training task aimed at the formation of professional competencies based on test tools of the informational and educational environment, which is used to learn the laws, methods, rules, etc. It helps future engineers develop mathematical, analytical and critical thinking skills.

The main task of *the educational test simulator with multiple choice* is to choose the correct variant of the statement, based on the competencies obtained during the study of the course. The basic elements of the tasks for students with the choice of the right answer, include the

instructions for the subjects, the content of the tasks, the form, content and number of answers, as well as assessments for correctness of performance, which is the basis for the acquisition of competencies in the general technical disciplines. The answers to the tasks can be in the form of statements, numbers and graphs.

Educational test simulator with the possibility of choosing a match involves the task of establishing compliance. It needs at least two questions or statements and three answers. These can be not only text questions, but also the relevance of text and images, images and images and more. In order to perform the task correctly, it is necessary to set the information to match and connect logical pairs. Such a simulator develops logical thinking, analytical skills and visual perception when using graphic and animated objects.

Educational test simulator with a short text answer contains the answer which can be a word or a few words. With this type of educational test simulators, it is advisable to train the definition of terms, concepts, etc. In the comments it is necessary to leave explanations as to the form of input of the answer. In this type of questions for the educational test simulator it is also possible to enter images, animations to identify phenomena, physical, technical, chemical, biological or technological processes.

Educational test training simulator with choosing the numerical response provides the use and software processing of calculations. Before entering the numerical value, the future engineer must calculate, because the chance of entering the correct answer is eliminated. Such a simulator is able to develop the ability to quickly calculate, clear orientation in the mathematical, technical and theoretical space in the field of engineering.

Educational test training simulator with choosing a right or wrong statement involves identifying the correct and incorrect answer. For objective results, it is necessary to specify the test period and limit the time. During the required period, access to the simulator will automatically open. Students will only see a description of the future task and the requirements for it. Such a simulator can provide a general response to a question – a comment from the tutor, which is shown to the student after the answer. It is also possible to add tags – keywords that are needed in the future to quickly find the right questions, if there are too many.

Educational test training simulator with the ability to choose terms and keywords from the drop-down list is used when studying the methods of performing certain actions, algorithms for solving engineering problems, the sequence of drawing up the scheme. It is advisable to design such educational simulators from tasks that would meet all levels of complexity.

Simulation and manipulation play vital roles in teaching procedural knowledge in engineering education [57–60]. *The educational graphic simulator* is the use of a special training task aimed at the formation of professional competencies based on the informational and educational environment, based on the training of visual perception and work with engineering drawings, diagrams and other graphic objects. This simulator is an appendix to the theoretical study of teaching material, practical and laboratory work, and provides an opportunity to expand the understanding of individual processes and engineering systems in the complex.

Educational simulator for dragging a graphic image into a text area provides for analysis and differentiation of educational information. The task is offered a description of graphic objects, processes, complex systems, elements of engineering machines. Higher education applicant should review the proposed graphic images and objects and assemble the description and the corresponding graphic image. Such simulators are capable of training memory, visual perception, and developing analytical skills. Educational simulator focused on working with graphic markers is concentrated on the acquisition of skills of visual perception of engineering objects. Graphic marker is a tool that allows to graphically supplement the submitted image in an educational environment. Moreover, it can be a straight line, a curve, geometric images of figures and engineering objects, both in the plane and in space. Simulators that work with graphic markers are able to train the higher education applicant in the work with the elements of graphic design.

Educational simulator for dragging text to a graphic image is based on a plane or a spatial image. The visual images are selected accordingly and contain appropriate areas for explanation in an educational setting. Text explanations provide an opportunity to activate the relevant knowledge of the depicted elements of the proposed graphic image.

Educational simulator for dragging image to image focuses on the logical visualization of plane or spatial figures and the integration of their elements in the conditions of the informational and educational environment. It is advisable to study elements of deformation, diffusion and conversion of liquid materials to other aggregate states; complex components of engineering machines and processes in these machines and it is possible to drag the elements to the appropriate area of the drawing with the task of studying the components of the machine or mechanism, the design of certain details in the drawing, etc. Thus, this type of simulators enables the training of visual memory, familiarization with the practical aspects of engineering without the use of specialized equipment, develops practical skills.

Gamification can provide engaging learning experiences for students, the studies reveal four reasons for learners' enjoyment of gamification: it can foster enthusiasm; provide feedback on performance; fulfil learners' needs for recognition; promote goal setting [61–66]. *The educational gamified simulator* is the use of a special training task aimed at the formation of professional competencies in the informational and educational environment based on a task, the performance of which develops professional engineering competencies and includes acquaintance with the details and devices that are the basis of engineering, the principles of teaching the operation of complex technology; installation skills, assembly systems and repair of machinery.

Educational gamified simulators by puzzle type is used for the logical formation of engineering objects. Such objects include the results of modern technological progress.

Educational gamified simulators by crossword type presents a technique, the essence of which is to solve words according to the above definitions. Crossword simulator allows to train the skills of terminology, training the study of professional concepts. The use of a simulator-crossword contributes to the development of the ability to navigate independently and quickly in the educational material and develop creative skills.

Educational gamified quiz simulator is a cognitive task in an informational and educational environment, which consists of questions and answers from different directions of the engineering field, combined by some common topic. It develops the ingenuity and activity of students, expands their outlook, promotes mental education, development of cognitive interests and creative abilities, helps to identify modern competencies in the engineering industry.

Each task in the *educational interactive simulator* can have different complexity, duration and time to solve. The essence of such a simulator is to simulate the control of any process in the field of engineering, apparatus or vehicle. In an informational and educational environment, the simulator can give the impression of reality, reflecting some of the real phenomena and properties in the virtual environment.

Educational animated simulator is presented on the basis of GIF animation of engineering processes. GIF elements create an animation of a process, and one of the steps can be left out. From the proposed images, it is necessary to choose one and thus restore the whole process. Animated simulators can illustrate such processes of simulation of physical interaction of solids, simulations of motion of systems of particles, liquids and gases, simulation of dynamic motion and spatial animation of geometric figures. The use of animated training simulators is very useful in classes that require additional equipment. It allows to perform chemical tests without reagents, physical experiments that require special equipment and understand the principle of their action.

The types of educational simulators in the informational and educational environment for learning general technical disciplines provide acquisition of the competencies.

Educational test simulators provides the

- knowledge of the basic properties of materials and technological requirements for materials,
- ability to determine the static and dynamic loads on the working bodies and transmissions,
- ability to calculate the structures for strength, rigidity and durability,
- ability to theoretically calculate machines and mechanisms,
- ability to perform technical documentation for the product,
- ability to calculate the required capacity of machines,
- ability to make equations of motion of machines and mechanisms.

Educational graphic simulators provides the ability to

- perform drawings of non-standard parts,
- perform assembly drawings of machines on the basis of standard units,
- design connections and mechanisms of machines and equipment,
- design and research systems of maintenance of machines and equipment,
- determine the compliance of modes of operation of machines with structural features
- coordinate the parameters and modes of operation of machines.

Educational gamified simulators provides the ability to

- analyse the designs of machines and equipment and evaluate their technical level,
- predict the technical condition of machines, equipment and systems,
- to organize maintenance, diagnosis and storage of machines and equipment,
- technologically adjust complex machinery to perform technological processes,
- defect machine parts,
- choose the technical means for basic and auxiliary operations.

4. Results

It is presented the calculation of the empirical value of χ^2 based on the results of the use of educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups before the experiment.

Table 1. Calculation of the empirical value of χ^2 based on the results of the use of educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups before the experiment.

Level	EG,%	EG, n_i	CG, %	CG, n_{i1}	$(n_1 - n_{i1})^2$	$\frac{(n_1-n_{i1})^2}{n_{i1}}$
High (A)	4.95	5	5.73	6	1	0.2
Sufficient (BC)	62.37	63	58.65	61	6	0.06
Initial(CD)	32.68	33	35.57	37	16	0.48
Total	100	101	100	104		0.74

The empirical value of χ^2 is the result of the sum of the values of the levels in the last column. Therefore, the empirical value of $\chi^2 = 0.74$. The degree of freedom ν is calculated by the formula $\nu = k - 1$, where k is the number of levels. Therefore, $\nu = 2$. For this degree of freedom is defined a critical value $\chi^2_{critical}$ for the levels of statistical significance $\rho \leq 0.05$ (5.991) and $\rho \leq 0.01$ (9.210). Levels of statistical significance allow to delineate the zones of significance

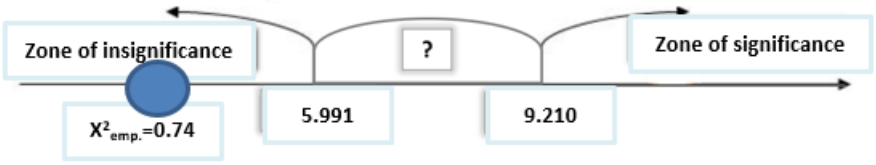

Figure 2. Empirical value in the zone of insignificance before the experiment.

and insignificance for the obtained values [67]. The axis of insignificance is presented on the figure 2.

$\chi^2_{emp} \leq \chi^2_{critical}$, which means that the deviations between the distributions are insignificant. So it is accepted hypothesis H_0 – there are no significant difference in the level of application of educational competence-based simulators in the training of future engineers in the experimental and control groups. Also it is checked the statistical verification of the equality of the use of competence-based educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups using the Pearson's criterion χ^2 at the end of the experiment (table 2).

Table 2. Calculation of the empirical value of χ^2 based on the results of the use of educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups after the experiment.

Level	EG,%	EG, n_i	CG, %	CG, n_{i1}	$(n_1 - n_{i1})^2$	$\frac{(n_1 - ni1)^2}{n_{i1}}$
High (A)	11.88	12	5.76	6	36	3
Sufficient (BC)	81.18	82	69.24	72	100	1.21
Initial(CD)	6.94	7	25.00	26	361	51.57
Total	100	101	100	104		55.79

The empirical value of $\chi^2 = 55.99$. The value for the degree of freedom $\nu = 2$ is calculated. For this degree of freedom is defined a critical value $\chi^2_{critical}$ for the levels of statistical significance $\rho \leq 0.05$ and $\rho \leq 0.01$. Levels of statistical significance allow to delineate the zones of significance and insignificance for the obtained values. The axis of significance is presented on the figure 3.

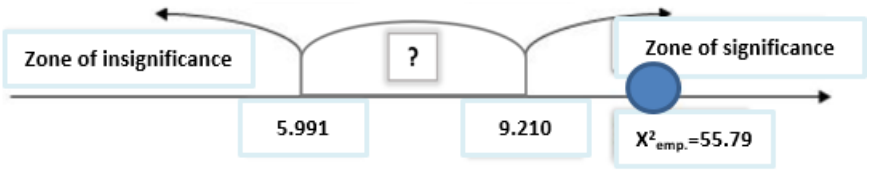

Figure 3. Empirical value in the zone of significance after the experiment.

$\chi^2 emp \geq \chi^2 crit$, which means the presence of significant deviations between distributions. So it is accepted hypothesis H_1 – there are significant difference in the level of application of educational competence-based simulators in the training of future engineers in the experimental and control groups.

5. Conclusion

It was developed the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines. It was outlined types of educational simulators, that increase the ability to provide educational services, emphasize the diversity of educational materials in the field of general technical disciplines and are able to provide quality training of students based on modern needs and relevant competencies. Educational test simulators are based on engineering test tasks that help to master the rules, techniques, laws, theorems and other content in the field of engineering. Educational graphic simulators are based on the training of visual perception and work with engineering drawings, diagrams, and other graphic objects. Educational gamified simulators consist of the task, fulfilling which develops professional engineering competencies. For designing the tasks of educational simulators in the professional training it is advisable to attach to each task the competencies that are represented in the competence repository in the conditions of informational and educational environment. Thus, the main purpose of the experiment is to check the quality of knowledge of students in the experimental and control groups at the beginning and at the end of the experiment. The reliability of the obtained results was verified using the Pearson's criterion. At the end of the experiment, it can be claimed that the using of competence-based educational simulators in the informational and educational environment for learning general technical disciplines is effective. The implementation of the outlined technology provides an opportunity to combine the educational process in the audience with the training in the informational and educational environment, forming analytical abilities and competencies for professional activity, increases the students' level of professional motivation and self-stimulation.

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