THE ROLE AND IMPORTANCE OF DETERMINISTIC COMPUTER SIMULATIONS IN THE DEVELOPMENT OF TECHNICAL CREATIVITY

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Abstract. *The deterministic computer simulations (abbr. DSK) are a group of simulation software most often used in the process of technical education. Innovative education based on the introduction of this group of software into the online and offline learning process creates a new work environment conducive to creativity and creativity in humans. This article presents theoretical discussions as well as the place and role of DSK among modern teaching aids.*
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Design and modeling in polytechnic education

There are various definitions of the concept of simulation in the pedagogical literature. They relate to both the teaching method and the technique, e.g. computer simulation in engineering. In pedagogy, the concept of simulation methods that derive from didactic games is mentioned, and the concept of simulation is combined with the concept of simulation and didactic games. The simulation method belongs to the group of problematic teaching methods, which W. Okoń described in the framework of the so-called didactic games.

The lack of winners and losers is what distinguishes simulations from simulation games - recalls W. Furmanek. Computer simulation is a special type of simulation. *Due to the currently popular environment for the implementation of simulation experiments, which is a computer, the name computer or digital simulation has been adopted. Computer simulation is a simulation with the use of a mathematical model, saved in the form of a computer program. Simulation techniques are particularly useful where analytical determination of the solution would be too laborious, and sometimes even impossible - which is often the case in complex systems.* (Furmanek, 2010, pp.19–22). In *simulations* and *simulation computer games*, real models are created thanks to mathematical algorithms contained in computer programs. The pedagogical literature also includes the following terms: *computer simulation experiments, computer teaching games, virtual laboratory, computer simulation programs, computer techniques or computer simulation systems.* They indicate participation in the simulation method of the dominant role of the computer together with the simulation

software. Computer simulation is one of the types of *simulation learning* that has become the object of great interest among educators in recent years (Ibid., pp. 23-33).

Deterministic Computer Simulations (abbr. DSK) in terms of information technology can be defined as a system of techniques, numerical methods used to carry out experiments on specific types of mathematical models, which are characterized by the use of a digital machine. Computer simulation is a simulation with the use of a mathematical model, saved in the form of a computer program. The *deterministic* term also brings additional information about its type, so the simulation result repeats and depends only on the input data and interaction with the external (virtual) environment. Since computer simulations are carried out with the use of computers that could not function without specialized software, the concept of *deterministic computer simulations* can also be defined by a group of simulation software. The constructed algorithm of the program operation combines both the modeling process and the performance of deterministic simulations based on the model made. In the further part of the work, examples of technical projects made in the DSK environment will be presented. On the other hand, computer simulation, as a simulation method, is a system of purposefully selected research activities, i.e. a structure of phased activities aimed at achieving the research goal. These activities include: problem formulation, creating a mathematical model, formulating a program for a computer, checking the correctness of the model, planning simulation experiments, performing simulation runs and analyzing the results (Łatuszyńska, 2011). Its effect is, therefore, the acquisition of certain skills and knowledge, in terms of didactic effectiveness. Simulation modeling is a field of knowledge that serves to deepen the level of understanding of the interactions occurring in the system and the system as a whole. In terms of methodology, simulation is a method of active learning in which reality is imitated in order to gain experiences similar to those we do in the real world. In the process of education and research, computer simulation is irreplaceable wherever research is needed on systems that are so complex and tedious in calculations that their analysis in real conditions would be difficult, time-consuming or even impossible. Computer simulations, especially those based on the deterministic foundations of their operation, perfectly reflect the current assumptions of constructivism and cognitivism. Computer simulation is one of the forms of simulating the system visualization using a symbolic (graphic) model, which can be easily operated, and the result of which is numerical data (Łatuszyńska, 2011, pp.162-163).

Computer simulation shows the complex process of device operation or the course of the phenomenon from the moment of designing the project in the program (modeling) to the end of the calculations. This process is repeatable, so it is possible to introduce innovative solutions based on its preliminary results and in reference to the basics of theoretical knowledge. In the cognitive process, we

can observe the feedback phenomenon, in which the student (or student), obtaining the initial results of the simulation, compares them with the expected values, undergoes a preliminary assessment, on the basis of which he makes further changes in the model. The cycle may end when the results are significant enough to meet the expected requirements compared to the project assumptions. Their acceptance is therefore based on the knowledge enriched as a result of the simulation tests carried out. The student compares the results, draws preliminary conclusions, which, as a result of incorrect work effects, mobilize to search for new ways of solutions and study the literature. This process can be repeated systematically, so each time there is an increase in the level of knowledge through new perceptions and beliefs, thus stimulating to further active work. This process ends when the final simulation results are considered to be in line with the assumed goals, and thus leads to a deep interpretation of the content, evaluation and creation of new questions and associations. The advantage of the simulation method over laboratory tests deserves attention in terms of the consequences of making wrong decisions and the possibility of correcting them. If the selected didactic tools support the teacher in practical activities that allow students to present knowledge, develop their interests and cognitive abilities, and implement them into self-education, then their legitimacy should be considered as the success of the teacher's work. As an example, the principle of science can be cited, so the teaching aids to be accessible to the student should correspond to the appropriate level of previously acquired knowledge. It should be borne in mind that they are only an element supporting the cognitive process, and not only the goal of learning in itself. The above remarks should be considered as universal observations concerning a broad classification of teaching aids in various fields of science and levels of education. However, with regard to deterministic computer simulations, the above remark needs to be supplemented. Deterministic simulation programs can be an example of commercial software, developed not only for educational purposes, but also aimed at a narrow audience. So they combine both features - didactic and commercial. Their usefulness in the didactic process is not determined by the fact that they were created with a selected user in mind. The analysis of the computer software market shows that software authors offer their product on the basis of various licenses, and thus, related to a specific group of recipients. There is a group of software in the so-called educational version, which can be an example of free software, intended for people starting their education. Of course, they have their limitations in functionality, but they are an interesting alternative not only for pupils or students, but also for educational institutions. Due to the high purchase costs of the full versions, they are often used in secondary and higher schools with a technical and IT profile. The principle of pictoriality (concreteness) is also important here, i.e. the simulation model should reflect through symbolism (graphics) the elements of the system understandable to the student and the relations between them. What is more, the possibility of own interpretation of the model by changing its appearance and symbolism, as

imagined by the student, facilitates its interpretation and analysis of the complexity of the launched project. The principle of systematicity (systematic), in turn, indicates the correctness of the effectiveness of the teaching-learning process, related to the organization of didactic material according to the adopted logical structure, dividing the material into smaller units and mastering them in relation to the whole.

Compliance with the principle of systemic nature should lead to the development in students' minds of understanding the world as a whole, as a certain system, a structure based, inter alia, on temporal, spatial, quantitative and cause-effect relationships. Another is the principle of independence, i.e. respecting all individual actions of the student leading to the solution of the problem situation (also in cooperation with the group). Of course, these are only selected teaching principles, but as you can see, the discussed group of software perfectly identifies with them and finds its place. An important role of computer simulations is not only the very fact of understanding the operation of the modeled system, but most of all shaping the ability to make decisions about the functioning of a given model. It is important to use the knowledge of a computer program to develop additional skills in solving other problems within a given field of science. In this way, we transform a passive attitude into an active one, but most of all we make it scientific.

In terms of the effectiveness of education, the usefulness of computer technology will be a derivative of several factors, i.e. primarily the input knowledge before starting the simulation (substantive knowledge), the ability to use IT[1], the quality of knowledge acquired during the simulation (individual creative work) and interaction with peers and the teacher.

The computer software discussed in the work enables simulation with the following feature:

- deterministic, because it meets the event predictability criterion - the result is repeatable and depends only on the input data;
- with discrete time (time elapsed criterion - the time increases with constant increments, and the time step is selected optimally with regard to the system performance load);
- static and / or dynamic - the result is a data set, a static image or the result is a process running over time, e.g. animation (output data criterion);
- local and / or dispersed (criterion of location and complexity of the computer system).

Computer simulation is a method of conducting experiments on dynamic models describing existing or designed systems (Fig. 1). The research objective of the simulation method is to obtain knowledge about the behavior of the

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[1] Abbrev. IT- information technology

examined mechanism in time. The computer program is therefore a tool for the implementation of the research goal, which is a formal representation of the model of the tested system (Łatuszyńska, 2011, p.162).
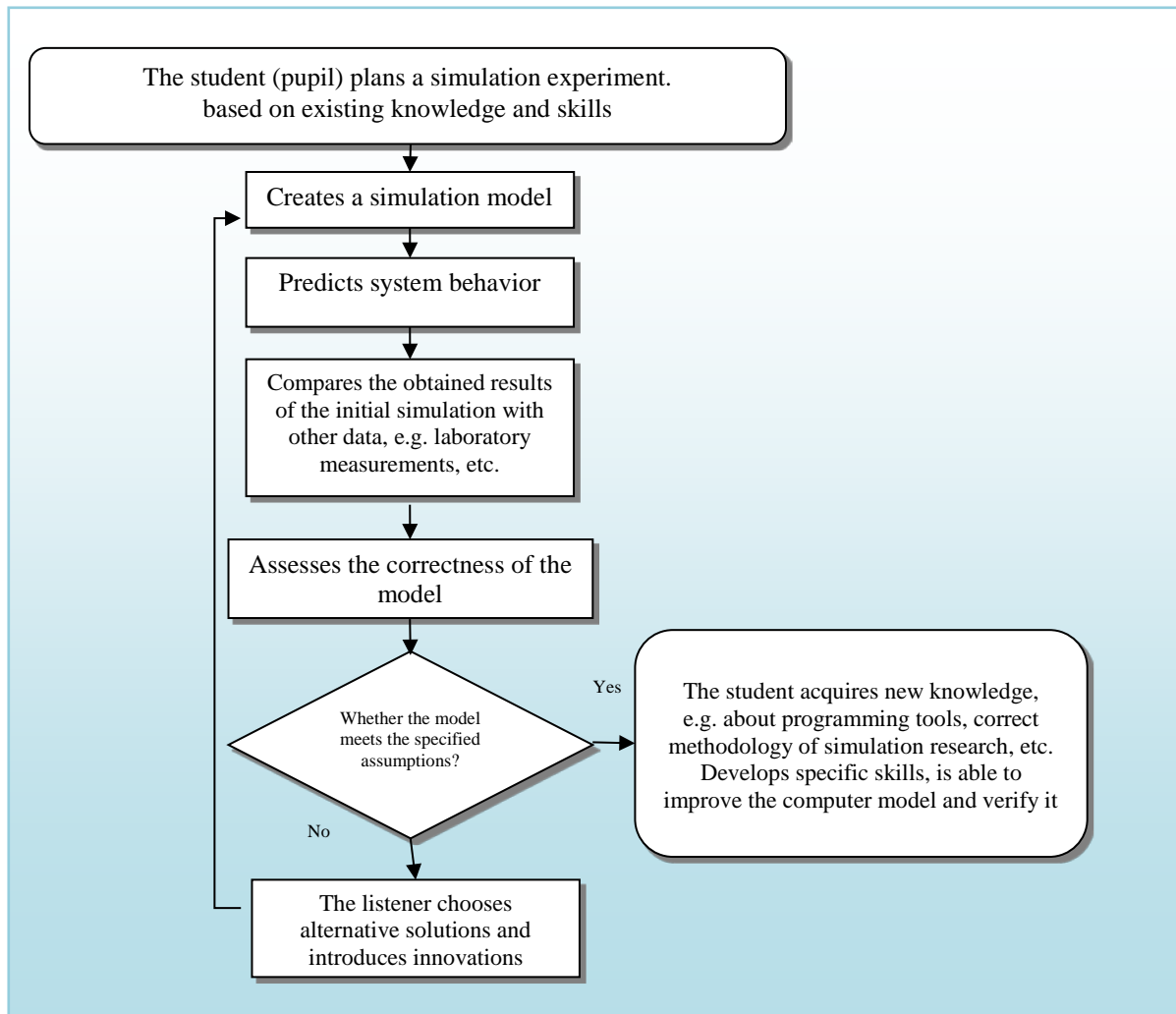

*Figure 1 **Algorithm of the real model design process** (own source)*

Deterministic simulation software is easy to use and relatively easy to handling. Using it while working does not require the student to have additional programming skills (writing algorithms), because these programs offer ready-made basic instructions that meet the expectations of the learner. Of course, they do not limit their capabilities to basic tasks and allow the introduction of additional, complex algorithms, but such a function is not used in simpler modeling operations. The program itself is a supporting tool, a means of cognition, not an end in itself. This is an extremely important feature, because thanks to its intuitiveness in use, it relieves the student from additional work, which is not his main goal. The tool used should not, therefore, force knowledge of keywords, commas, colons, and parameters in the appropriate columns, but rather propose a ready-made solution to the problem related to the model software. In addition, the software should be distinguished by the ease of writing and

reading the computer model. The menu should be dominated by graphic icons corresponding to their purpose, and the components of the model should be displayed both in a simplified[2] and very detailed form (realistic view).

The construction of the model is a basic activity, but what would it be like to develop a model without observing its operation and analyzing the results? Legible reports with the option of any modification or visualization as well as archiving in the most popular, compatible recording formats also seem important. Practically unlimited possibilities of their analysis, including the statistical one, should apply here. In addition, the program should ensure the correctness of the individual stages of the student's work through automated communication and identification of errors when they occur. Of course, the most common cause of their formation are errors resulting from modeling errors, i.e. wrong assumptions in the logical structure of the model, imperfections of the computer software algorithm or incorrectly entered data. Ease of experimentation can be a subjective concept. These programs, however, are characterized by the possibility of repeated repetition of the experiment as a result of interference and modification at each stage of the work, which in relation to the learner's ability allows the use of an individual pace.

The simulation package should also enable two main strategies for running a simulation experiment - ending simulations and continuous running simulations. It is also desirable that the statistical analysis of the replicates be performed automatically, for example calculating the mean and variation from multiple replications, determining the length of the confidence interval and others (Mielczarek, 2003, pp.137-138). Figure 2 shows a block diagram classifying computer simulations according to the adopted division criterion (Łatuszyńska, op. Cit.). As you can see, the classification is quite complex, because it corresponds to different types of simulations.

For the purposes of this study, the discussion of programming parameters resulting from algorithmics was omitted, and only the values resulting from the practice of using individual programs for didactic purposes were focused. It should be mentioned that the presented diagram does not take into account mixed simulations, which at the same time present different division criteria.

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[2] Graphical User Interface - an IT tool enabling the construction of a computer model using graphic icons and dialog boxes
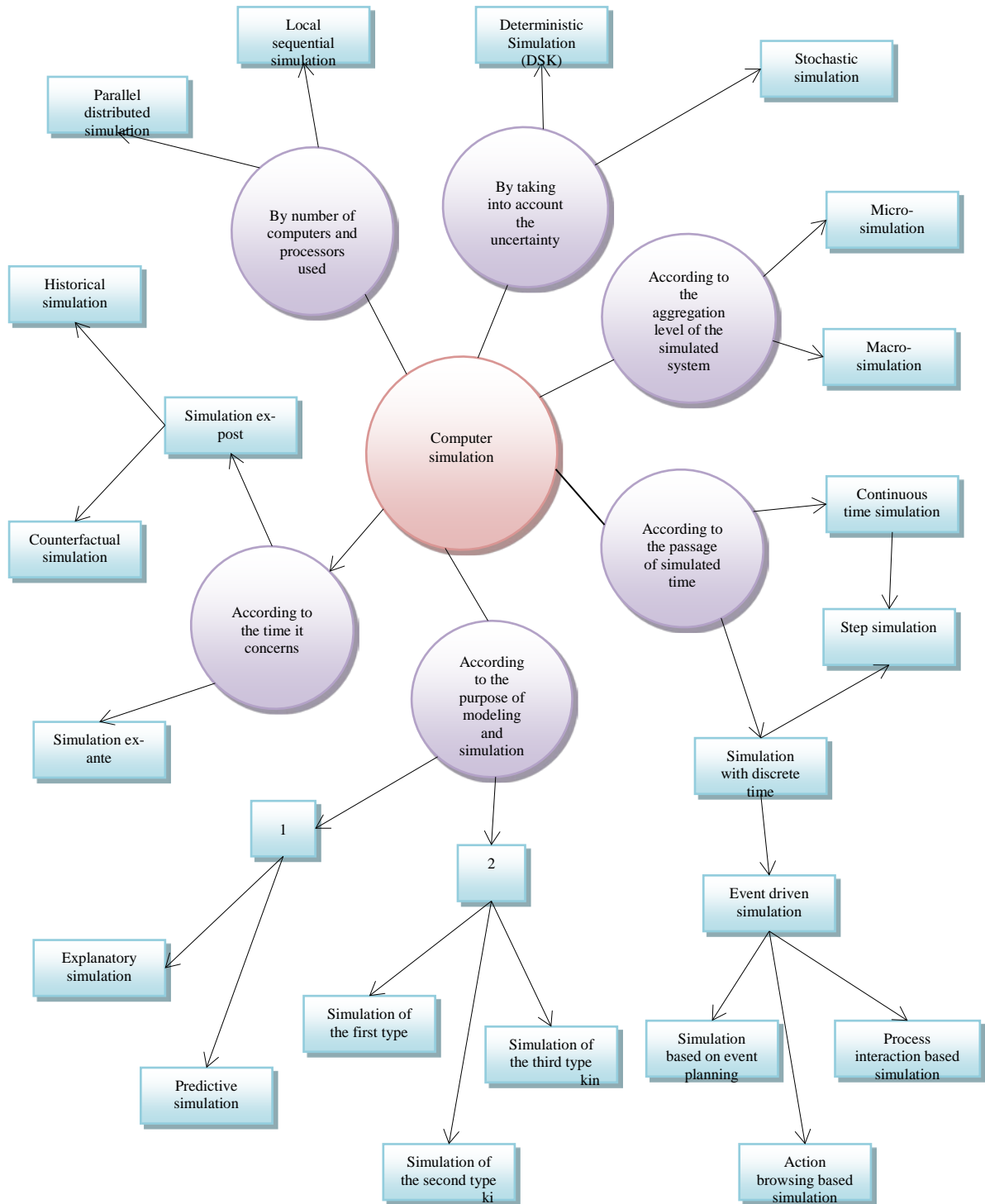
Figure 2 **Extended scheme of logical classification of computer simulation methods**
(source: Łatuszyńska, 2011)

The simulation programs belonging to DSK present the assumptions of the constructivist idea and give it an extremely practical meaning. The concept of constructivist software was very accurately defined by Z. Meger: *Constructivist software offers problem situations for independent reflection and development. It differs from objectivist programs which, from the teacher's perspective, offer*

explanation of dependencies and relationships and presentation of how to perform tasks or exercises. They allow the learner to independently determine which information he needs and is necessary for solving further stages of the work, solutions are not given, but asked, and the learner has to achieve the final result on his own. Computer simulation in this case is an interesting solution (Meger, 2006).

Classic and didactic simulation model

As already mentioned, the variety of computer simulation techniques proves the rich offer of software, aimed at a wide range of users. The literature on the subject also distinguishes the division of computer simulations into a classic and didactic simulation model[3]. The classic simulation model is identified with a group of simulation software of wide versatility, enabling solving problems with a complex structure. This group also includes deterministic simulation software. These are professional programs that are most often used by engineers and scientists. They were created as advanced tools, characterized by an extensive algorithm that allows high accuracy of mapping the model of the real object. It is a group of programs that require considerable technical knowledge, often professional, with a narrow specialization. By design, their operation requires considerable skill. The second group of programs are didactic simulation models, the purpose of which is designed in advance for educational purposes. These programs are easier to use and do not require a lot of knowledge commitment. Unfortunately, the simpler, and therefore generalizing, results - here, the accuracy of calculations with the use of simulations takes a back seat. Their main goal is to show narrowly thematic dependencies, often limited to presenting the general principle of the model's operation. Thus, a question arises about the didactic usefulness of each of the groups in relation to the constructivist philosophy of building knowledge. Which of these programs will be most useful for solving technically complex problems?

According to the author, programs that enable deterministic computer simulations, belonging to the group of traditional software, will find wider application in technical education at the level of secondary and higher education. It should also be remembered that the constructive nature of the cognition process is characterized by order and sequence related to combining facts and conclusions resulting from cyclical phases of experience. Typical (simpler) teaching programs, in turn, should be applied at the level of basic knowledge, i.e. at the stage of familiarizing the student with the basics of the widely understood technique.

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[3] Publications of the Faculty of Electronics, Telecommunications and Informatics, Gdańsk University of Technology on *Evaluation of the implementation of simulation programs supporting ICT teaching*, http://eti.pg.edu.pl/ 20[1]6.

Many years of teaching practice and as lecturers suggest that young people choosing technical schools have some experience and basic technical skills. The choice of the school profile is therefore based on the conviction that the choice of the course in line with one's own interests is right. A certain regularity of the functioning educational system is also the thematic repetition of classes, e.g. in technical secondary schools and technical universities. Therefore, simpler didactic models are not widely used at the higher education level, but will be the domain of lower education levels. The nature of problem classes at the university level requires a basic thematic knowledge of the problem, without the need to explain its basics. Also at the technical secondary school level, especially in the senior ticket offices, young people show great interest and knowledge of the chosen specialization. Choosing a school with a targeted educational profile, he expects it to have a professional level of education, expand his existing knowledge, and enrich it with new experiences. Therefore, the education process must differ from the basic-general level, hence classical computer simulations take on a special meaning. They should provide answers not to how a given model works, but to show the details of its operation.

Thorough study will enable the student to develop and implement innovation in the model and use the acquired knowledge and skills in new problem situations. More importantly, the selection of the software should also depend, alternatively, on the control assessment of the abilities and knowledge of the participants. At this stage, we can mention the significant role of the teacher as the person organizing the classes, supervising their course and correcting the student's cognitive process. Preparation of classes based on the computer simulation method requires the teacher to make the student aware of the purpose of the classes, to present him with the expected results, work forms, methods and tools. Therefore, conducting the initial training in the field of software operation is absolutely justified and stimulates to further work. It should be mentioned that in vocational education there is a division of classes in a given subject into theoretical and laboratory classes. This division results from the specificity of classes and the expected effects of work (knowledge and skills). Theoretical classes are therefore a great moment to conduct such instruction and discuss the topics of the classes. The teacher can also prepare the materials in the online version, and thus introduce elements of asynchronous education. Preparation of documentation for exercises should also not be carried out in a strictly oriented (schematic) form, it may contain commands that give greater freedom and recommend selected literature.

Concluding remarks

The implementation of technical classes with the use of deterministic computer simulations is a didactic method that influences the increase in the didactic effectiveness of the education process. Information technology provides

new work tools, thanks to which the didactic process is perceived as an innovative model of education. The variety of computer software creates excellent conditions for the use of DSK in many classes, both at the level of high school and university with a technical profile.

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