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TEACHING OF COMPUTER AIDED DESIGN SYSTEMS

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Abstract. *The objective of this paper is to analyze and describe computer-aided design training and its aspects. A traditional and technology-supported learning process is described with the purpose of analyzing computer-aided design training and provision of knowledge assessment, and identifying problems in the CAD system training. The article analyzes the learning process by defining its objectives, the necessity of student characterization, motivation analysis, the necessity of feedback and other basic components; it analyzes the training methods, provides insight into technology-supported learning process, identifies the provision and types of computer-aided design training and knowledge assessment as well as describes feedback and its role in the training process.*
Elaboration of an intellectual learning system would solve the problems associated with lack of feedback, lack of adaptivity and the emergence of plagiarism (since only the end result of the design is subjected to the test and not the whole process of creating it, it is easy to pass another's work for one's own). A solution to these problems would facilitate the work of the teacher and improve student learning outcomes.
Keywords: *CAD/CAM Systems, IT in Education, Knowledge Assessment, Learning Process.*

Introduction

Computer Aided Design, along with Computer Aided Manufacturing, emerged in the 1950s (Narayan, 2008). A well-known term for Computer Aided Design and Computer Aided Manufacturing Systems is CAD/CAM. Currently, CAD/CAM systems are used in a variety of fields, which include design and manufacturing management processes (Geometric modelling, Machine vision, Flexible manufacturing systems). Using specialized computer software, a created technical drawing, a specialized set of parameters (procedure description) describe the computer-aided designing. Design engineering, technical drawing and drafting combine extensive knowledge of theory and practice. Creation of a design is a very complicated process in itself (Madsen, 2012) (Asperl, 2005). Using computer-aided design makes contribution into designers' work productivity, humanization of working conditions, project quality improvement, communication speed, flexibility and the structuring and expansion of the production data repository. If the result of a computer-aided

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design (a project created in a CAD system) is immediately (without a design draft or printing) given for production (cutting, machining) of a product, it is called computer-aided manufacturing (CAM system software).

Due to the global economy development, CAD/CAM integration takes place in different fields of manufacture (construction, aviation, shipbuilding, computer manufacturing, clothing manufacturing, etc.), at different stages of production (design, product lifecycle management, manufacturing systems management, etc.). In order to meet the need for skilled workforce, CAD/CAM system training is included in the engineering discipline studies in various fields (along with this trend, the drawing skills are gradually reduced).

For acquiring computer-aided design both a teacher-led and independent learning activities are offered, a traditional teaching process is provided, and provision of technology-supported learning process is very limited. The teaching process involves five main tasks:

1. choosing objectives,
2. understanding student characteristics,
3. understanding and using ideas about the nature of learning and motivation,
4. selecting and using ways of teaching (methods, practices),
5. evaluating student achievement (learning) (Gage & Berliner, 1999) (Bloom, 1964).

The objective of the learning process is based on its organization – when a teacher prepares a lecture, he sets the goal of the lecture, also a student can set his/her personal learning goals (Phobun & Vicheanpanya, 2010) (Lai et al., 2016). In order to analyze instruction with the purpose to find out the specifics of the learning process, different learning processes should be considered: traditional and technology-supported.

Traditional learning process

The traditional learning process has three basic components: the teacher, the student and the content (Herbart’s Didactic Triangle (Hudson, 2000)). Interaction is occurring between all components; the processes are viewed from the perspective of both participants, that is, the teacher and the student, the interaction of the teacher with the instruction content and the interaction of the student with the learning content. Extending the description of all three components with their characterizing elements, several views on the learning process can be distinguished (Jank & Meyer, 2006):

- Pedagogy – paying particular attention to pedagogical practice, which usually emphasizes the teacher's responsibility/role.

- Instruction – paying particular attention to the development and implementation of tools and content (materials).
- Curriculum – with a particular focus on the content based on the curriculum as an organization's practice.
- Learning – with a particular focus on learning practice, which usually emphasizes the responsibility/role of the student.

Based on such views (understanding), the analysis of the traditional learning process allows us to conclude that the teacher and the student are the active participants of the process, while the content of teaching is the passive one, the role of which depends on the activities of the active participants. In the traditional learning process, the teaching content is usually reflected in the form of presentation material – books, lecture notes, handouts, practical work materials, experiments and experiment substances and auxiliary materials.

Interaction between the teacher and the student includes their reciprocal activities: teaching content presentation, questions and answers, preparation and execution of tasks, assessment of learning achievement and feedback. It is understood that such interaction is reactive – the activity of one participant calls for the activity of the other participant.

The role of the teaching content is characterized by the purpose for which it is prepared and used. The interaction of each active participant with the teaching and learning content can also take place independently of the other active participants involved. The teacher's preparation for the teaching process, improvement of the teaching content, analysis and preparation of tasks are considered to be interacting with the content of the teaching regardless of the student. Such a process can be initialized directly in respect of particular students (as a result of tests, the aspects of the curriculum that need to be emphasized more can be seen, questions asked during the lecture highlight a particular problem); initialisation can also take place under the influence of the external environment (improving the content of teaching through industry and scientific achievements). The interaction of the student’s activities with the content is characterized by independent learning: preparing for tests, doing homework, repeating lecture material, performing individual work. These or some of these activities may be optional.

In the traditional teaching process, the teacher's role is characterized by adaptation to the student. The activity of explaining the learning content is carried out by adapting to the situation when the teacher responds to the student's questions, the necessary knowledge structure, prior knowledge and personal interests (examples of study materials from the area of interest of the student).

Effective learning depends on learning objectives, learning environment, the student’s grounding, the student’s willingness to learn the specific content, the student’s abilities (wit), quality of teaching, and if all of these aspects are in balance, one can expect the learning objectives are achieved (Smith, 2012). If any of these aspects is insufficient, then the teacher must be able to adapt to the specific situation in the particular aspect to provide effective learning. Adaptation needs sufficient resources – the teacher’s contact/interaction with the student. Most often the traditional instruction is conducted to a large audience, where individual adaptation cannot take place due to lack of time and human resources.

Adaptation can be provided during tutorials and partly practical classes where the teacher examines the performance of each student individually, receiving an immediate feedback on the work done and the teacher adapting to the particular student's level of knowledge. Providing individual adaptation and feedback requires additional work time from the teacher, thereby increasing the workload. Integration of information and communication technologies into the learning process can solve its problematic aspects (adaptation of the study content, systematic assessment of knowledge and self-assessment, assessment of practical work and analysis of weaknesses).

Technology-supported learning process

Application of technology in the learning process is introduced to enhance the students’ learning experiences, expand opportunities and personalize the learning process (Walker et al., 2016). Expanding the learning process possibilities focuses on giving the students choice of pace, place and mode of their learning, and these three aspects can be supported by an appropriate pedagogical approach (practice) and this approach can be technology-supported (Gordon, 2014). Technology-supported learning is most often understood as e-learning that can be used no matter where the student is at home, on campus or at any other place where information technology is available, and there is a very large number of terms that refer to technology-supported learning as well as the technologies involved in supporting training (Yaghmaie & Bahreininejad, 2011).

By analyzing the range of technologies that can be used in learning, several groups of such technologies (subsets) can be distinguished. Computer-based training is where the computer is not connected to the web, the learning content is found in the computer memory, and it does not contain any links to materials outside the training course. Conversely, web-based learning, online learning and online instruction envisage network connection. Thus, two distinct categories can be distinguished: computer-based learning and web-based learning, which includes web-based learning, online-based learning and online learning

(Anohina, 2007). All these options are included in e-learning (also m-learning based on the use of mobile devices/smart-phones) that allows the learning process to be conducted using various e-resources, including e-mail and other forms of communication that enable training in the form of distance learning. As technologies used in the learning process can be varied, their use is part of resource-based training – interpreting resources as a broader concept (not only information technology, but also other training resources of practical and theoretical use).

Technology-based learning can be provided using various tools:

- Mobile (smart phone) applications (m-learning).
- Tablet applications.
- Various information technology-based devices providing augmented reality.
- Open online courses on various information technology devices;
- Webinars (online seminars).
- Special systems for specific learning content training, including intelligent tutoring systems.

Just a part of the learning process can also be technology-enhanced, such as demonstrations, tests, theoretical information. Regardless of how intensively (to what extent) information technologies are used in the instruction process, the process itself retains at least three basic components, yet unlike the traditional teaching process, in which the teacher, the student and the content are involved, these components can be supplemented with an additional component reflecting the learning content and the teacher may be partially or completely replaced by the technology used. The role of the teacher can be reduced depending on the degree of use of the technology, thus facilitating the work of the teacher and reducing the workload, as well as enhancing the adaptation of the learning process to individual needs by providing a technology-driven feedback.

Technology-supported learning process must be organized so that the technology-supported content performing the role of a teacher is at least of the same quality as the teacher in the traditional teaching and learning process. Adaptation and feedback should also be of at least the same quality as a teacher can provide in a traditional learning process. From the aspect of computer-aided design, the analysis of the work process plays a special role, which cannot be ensured by teacher's presence, but can be provided by technology-enhanced learning when analyzing each student's performance in the CAD/CAM system.

Providing computer-aided design training and knowledge assessment

Computer-aided design training is divided into two inseparable aspects: sector training and computer literacy (Lukač, 2011). The curriculum should ideally be developed in such a way that graduates' knowledge is in line with today's industry requirements, at the same time not losing universality – adaptability to different companies and their requirements for young professionals, and as well as maintaining the higher education approach – training at the highest level, thus promoting the development of the industry. However, the study content at the university regarding the requirements of the industry quite often is not sufficient. The main reason for this is the dynamic and ever-increasing development of industrial and technological support that cannot be achieved at university level due to limited resources and organization of training (Lukac, 2016).

When a student begins to acquire computer-aided design, it is believed that he already has prior knowledge in the sphere where CAD/CAM systems will be used. In reality, it often appears that knowledge of design and its processes is weak or even very superficial, therefore, the lecturer should devote additional time in classroom to explain the design aspects (Ye et al., 2004). Thus the learning process while mastering computerized design systems depends not only on the three basic components – the student, the teacher and the learning content, but also on the student's background knowledge. Most often, it is students' prior knowledge and ability to perceive the learning content, but sometimes also the teacher's prior knowledge particularly in the field of design may be too weak for successful teaching of computer-aided design system (the most striking example is specialized training executives of different CAD / CAM systems who have mastered the use of system functions, but their lack of knowledge in the field of design interferes with development of appropriate algorithms).

Currently available support for the learning process

The learning content and its representation follows directly from the learning objective – computer-aided design training, where for execution of practical tasks one of the CAD systems is involved (depending on the learning content area and curriculum that includes mastering of the given system). For such specialized training the traditional form of instruction is adapted using technology-based learning tools. Books and lecture notes publishing is limited due to continuous development of systems (CAD/CAM system developers develop and market new, improved versions of the system at least once a year to ensure its speed, ease of use and compliance with the industry). If books are published, most often they are books for training in the universal (less specialized) systems. For example, for learning AutoCAD systems books have been published in Latvian as well, but the most commonly used publications are in Russian or English – a wider audience understands both languages used.

Books with description of CAD systems used for specific industry designing needs are not published at all or it happens very rarely, as for learning of Lectra (application for clothing design, some modules for computer-aided furniture designing, in which 2D stages of the project are implemented: sketches, technical drawings, template drafting, their assembly, layouts, documentation, product lifecycle management, as well as 3D fitting of a completed design for its verification and making of corrections in templates. The system includes a series of interconnected or partially linked modules for automated computation in the particular sector, algorithms and procedures). Only a couple of books have been published for learning (Stott, 2016) (Stott, 2012), the author has no relation to Lectra's representation and only outlines the operating principles of a particular system module (even not the entire system). A very similar situation exists regarding the publication of other specialized system instruction materials such as Gerber Accumark (software similar to CAD/CAM Lectra) (Lininger, 2015). Unfortunately, such books remain up-to-date for a short period; they quickly lose their relevance to usage in the learning process due to the rapid development and changes of CAD/CAM systems (Asperl, 2005).

Content provision most often depends on the teacher - each year, according to changes in specialized CAD systems a teacher makes changes in presentations, lecture materials and notes.

Although computer-aided design system training is most often done in accordance with the traditional teaching process in which a teacher delivers knowledge in the form of lectures and demonstrations, a student perceives the new information, takes it into account and consolidates one's knowledge by carrying out practical tasks, however, given that CAD/CAM systems are taught, based on information technology, majority of them have integrated technology enhanced learning tools. Online help is part of the system that allows the student to get information about system performance in general or on use of a particular function or tool for designing (systems may have integrated both – *help* where the user searches for information and the help that is available upon request for a particular function/tool that is active at that moment). Such help, reasonably used, allows you to choose an appropriate action algorithm to solve your problem.

Currently available knowledge assessment provision

Working with computer-aided design systems, the assessment is the teacher's opinion about the conformity of the created design and/or drawing to the specified requirements, thus assessing the student's level of the acquired knowledge, skills and abilities. This aspect forms part of the student learning motivation, the other part is the motivation to develop their design and/or to create more sophisticated designs (Asperl, 2005). Since computer-aided design is related to creation of a practical design, students self-evaluate some projects automatically where they understand, if the project can be used at the next stage of the design. If the student fails to make the successive steps then it is clear that in the first stage there are errors that prevent further progress of the project.

The teacher prepares appropriate practical tasks and tests for the course examination. Already within the framework of the course, the basic skills can be evaluated using particular small examples and their completion is no longer evaluated in the exam (the result is taken into account in the overall assessment of the subject in the semester). The student must be able to finish each of these tasks within a very short time by using only a few operations and computer system tools. Thus, it is possible to test the abilities and skills that have been acquired at a given stage of learning. The rating of these examples is immediate – the teacher assigns a task, students finish it, the teacher evaluates the accomplishment.

In final examinations and/or course papers, skills and abilities to complete more complex tasks and make designs are tested by preparing a computer-aided design task that allows the student to demonstrate all one's abilities – not only to perform the learned design procedures but also to apply them creatively to other tasks. Such an assignment must have a variety of possible solutions, which can be used to assess the student's skills within the system and the ability to find the optimal solution. In addition, accuracy and compliance with technical requirements influence the final assessment.

Problems of study process and knowledge assessment

In a study on the preparation of students for the role of future engineers (Ye et al., 2004), a survey was conducted that found that only 8 % of the students (after starting their careers) expressed satisfaction with computer-aided design courses, 18 % felt that too much mathematics, computer science and mechanics were included in the training, while 74 % of the respondents acknowledged that all of these aspects, as well as the system practical application should be included in the curriculum to a greater extent. Also, the respondents acknowledged the need for individualization of the teaching content, especially in terms of complexity and speed of execution of computer-aided design work. The study on teaching CAD at various levels of education (Asperl, 2005) also emphasizes the diversification and adaptation of the content to the individual's desires (choice of task, choice of the degree of difficulty, possibility to return to a simpler project) as one of the main didactic principles to improve training.

Consequently, the adaptation of learning content is considered one of the main problems not only in the traditional learning process (Anohina, 2007) but also in the teaching of CAD/CAM systems. Adaptive tutoring can be defined as formation of a unique learning experience for each student based on the student's personality traits, interests and activities aimed at improving knowledge, the acquiring rate and quality and increasing the efficiency of the learning process (Limongelli et al., 2008) (Brusilovsky & Henze, 2007). The motivation improves letting students choose from different tasks (Asperl, 2005). This helps to avoid students who are over or under estimated. If the student is over estimated, expecting too high levels of skills, there is a growing threat that the student will quit one's studies without gaining the necessary skills. On the other hand, if the tasks are too simple, there is a growing threat that the students of a better level will be bored.

Teachers, through computer-aided design teaching, give insight into the design process, provide knowledge about the use of CAD system tools and demonstrate which algorithms of operations are to be performed for completion of computer-aided design tasks. Quite often such demonstrations are repeated: the student has completed his work, but this has happened repeating the teacher's presentation, thus the level of procedure mastering has been low. This problem highlights the need for short sample demonstrations – sequential task completion with instructions and screenshots, demonstrating the process of modelling and designing objects. In this way the students can control the rate of their learning progress, and the teacher can offer other similar exercises for execution, thus making sure that the specific task execution procedures and algorithms of operations are understood. Some CAD/CAM system companies offer reels to demonstrate the use of sophisticated software tools or designing of small projects.

If a teacher's knowledge is only theoretical, without real application, then students' interest may be low and there is no motivation to learn computer-based design. Providing realistic computer-aided design examples (besides, these sample models can be both real and virtual) that fit the student's age, level of education and future occupation, allows the student to master CAD/CAM systems. If students are convinced that they can use their CAD skills in working life, get a better paid work, their motivation for learning is growing.

When graphic files are created, the precision and speed of the graphic result is important. The graphical tasks in the CAD/CAM environment have their own specific sequence/order, but the quality of the tasks performed (accuracy, speed, etc.) is influenced directly by the drawer's knowledge and skills of using the system. Assessment of such designs includes evaluation of the final result and documentation, but there is no uniform approach to checking the knowledge working with CAD/CAM systems; it is not possible to check the work sequence, its progress, the procedures performed and the design development process.

Conclusions and discussion

Main conclusions:

- The components of learning process can be defined as: identification and understanding of learning objectives; learning student characteristics and personal objectives; the idea and motivation of learning that are relevant to the goals; teaching and learning methods, their effective application; feedback for motivating achievement of learning objectives and assessment of learning outcomes, as well as setting new learning objectives.
- In order to learn, students must understand the learning objectives, identify their current knowledge in relation to the learning objectives, and carry out learning activities to improve their knowledge. Therefore, feedback can be the basis for further cognition and student motivation to learn.
- Computerized design system training cannot exist without impact of manufacture – commercial CAD/CAM systems are designed to automate design and manufacturing processes. Industrial applications are the basis for the development of CAD technologies and CAD systems, with industry changing the computerized design systems are adapted and developed, thus the training process must be adapted to changes regularly.
- CAD/CAM learning is very complicated: the range of skills includes good knowledge of the production sphere, 2D and 3D design, mathematical and IT skills, object and product visualization, drawing skills and other complex knowledge. In the learning process there still is unknown interaction between the student and the content of learning. By studying how knowledge is acquired and what kind of learning support contributes to learner education and motivation, it is possible to improve computer-aided design training.
- The result of teaching is traditionally evaluated according to the change in students' behaviour/actions after the training process. Analyzing the methods of computer-aided design training process for assessment of the outcomes, it is concluded that there are no opportunities to assess the process / execution of tasks, but only the final result and the knowledge acquired by students. This highlights the need for a new approach.
- Introducing an intellectual/computerized system into the training process, it is possible to achieve greater training effectiveness, provide learning which is not influenced by time (students learn when they choose) and place (students learn where they choose), and provide

both feedback to students and information on students' activities and the time devoted to designing that would allow to make an appropriate assessment of the work performed.

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