Target training of technologists in a virtual enterprise environment

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Abstract. The article discusses the project personnel’s problems of CAD training integrated into complex automated systems. To accelerate adaptation and development of CAD skills among users of CAD systems in a digital design and production environment, specialized educational and research virtual enterprises (ERVEs) are created. The target training of engineering technologists is considered in detail. The structure and composition of means of informational and methodological support of ERVEs are substantiated. The use of ontological analysis for constructing optimum trajectories for training specialists in a virtual educational environment is proposed.

1. Introduction
The development and manufacturing processes of modern engineering products can no longer be imagined without the use of CAD (CAM/CAE/CA’x’ systems and technologies), which have become an integral part of integrated systems for information support of the product life cycle (Product Lifecycle Management - PLM systems) [1]. At the same time, the introduction and operation of human-machine systems without fail provides for the training of personnel, whose competencies directly determine effectiveness of a complex automated system as a whole [2].

Engineering by definition is a creative design activity, which requires, along with extensive knowledge and skills in the field of engineering and technology, development of specific competencies occurring exclusively in the process of a person’s practical activity [3]. And if at present, the methods of training engineers and technicians at the local stages of design work are sufficiently deeply and fully mastered, the training of specialists with necessary professional competencies for working in an integrated information environment (IIE) requires new ideas, practical developments and research.

2. Problems of CAD training
The importance of ‘human factor’ in the creation and operation of CAD (CA‘x’ systems) is clearly manifested in the fact that almost all the leading developers (vendor companies) are actively involved in the creation and promotion of numerous methodological support (MS), designed specifically for users [4]. In addition to the mandatory context-sensitive help information system (Help), this includes:

- Detailed descriptions of functionality of all components (Manuals);
- User Guides;
- Instructions (Readme) and recommendations (Tutorials);
- Specially selected examples of design solutions (Samples).
In addition, vendors who earn money by selling application software offer users tools that are purely for educational purposes:

- Textbooks presented both in classic paper and in modern electronic form;
- Manuals for self-training (CAST - Computer Aided Self Training);

Currently, when implementing MS CAD, almost the entire range of computer technologies is used, from universal e-learning tools (E-Learning) to subject-oriented knowledge bases [5]. However, they support the educational process well only in the field of knowledge formation.

For the formation of professional skills, practical work in the CAD environment is necessary. Unfortunately, the software for industrial purposes does not always meet the requirements of the educational process (cost of ownership, ease of development and operation, visual expression, etc.). For these purposes, it is necessary to develop special training programs and complexes (Training Tools). This category of CAD tools can include:

- Workshops and exercises (Exercises);
- Training (shortened and simplified) versions of industrial software (Light version);
- Computer simulators (Simulators) and training CAD (Student Edition version).

A special kind of methodological support for teaching practical skills of professional activity is represented by virtual environments:

- Virtual laboratories - VL;
- Virtual enterprises - VE.

3. A virtual enterprise as a means of training in the skills of design activities of machine-building technologists in a digital design and production environment

To accelerate the adaptation of project personnel and the development of practical skills among CAD users in the environment of complex automated systems, it is proposed to create specialized educational and research virtual enterprises (ERVEs) in universities and training centers. In addition, ERVPs can be used as a kind of model (electronic twin) of PLM solutions, designed to test new technologies, and to lead the pilot project in the implementation of integrated CAD systems [6].

The training functions of ERVE are manifested in the process of repeated, cyclical passage of certain stages and steps provided by the methodology of educational automated design, which allows developing the skills acquired by users, bringing them to a predetermined level.

At the Samara State Technical University (SamSTU), ERVE, covering, first of all, the processes of design preparation of production [7], has been developed and used for a number of years for training of engineering and technology masters.

The structure and content of the methodological support of ERVE differ from the used industrial solutions by significantly greater complexity. The databases have been equipped with additional sections, where the authors have placed the following:

- textbook and manuals on various sections of CAD;
- collections of tasks and exercises;
- methodological recommendations for teachers on the implementation of educational design;
- collections of demonstration projects and examples of engineering solutions.

This article discusses extension of comprehensive automation training to the stage of technological preparation of production, and in the future, the manufacture of product samples on digital equipment using additive technologies.

Analysis of the automated technological preparation of modern processes of machine-building production in IIE [6-8] showed that an IT technologist (a specialist with developed competencies in both the field of mechanical engineering technologies and the corresponding information preparation) has to have a significantly wider range of competencies compared to many other participants of the process:

\[
K_{ITT} = K_{CAD} \cup K_{CAPP} \cup K_{CAM} \cup K_{CAE} \cup K_{CAI} \cup K_{CAS} \cup K_{PLM}
\]
Each of the selected components of professional competencies, in turn, should be supported by some enlarged didactic units that make up the subject field of computer-aided design training.

1. The design professional competencies of $K_{CAD}$ and the corresponding skills of geometric modeling are necessary for an IT technologist to develop technological equipment and operating models of products:

$$K_{CAD} = \{d_{CAD_1}, d_{CAD_2}, \ldots, d_{CAD_i}, \ldots, d_{CAD_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘CAD technologies and systems’.

2. Technological professional competencies and intersecting skills in the field of 2D and 3D computer graphics enable to effectively automate the development and execution of technological documentation:

$$K_{CAPP} = \{d_{CAPP_1}, d_{CAPP_2}, \ldots, d_{CAPP_i}, \ldots, d_{CAPP_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘CAD TP – CAPP technologies and systems’.

3. Competencies in the field of programming are needed to develop control instructions for digital equipment, which in turn are based on the first two groups mentioned above:

$$K_{CAM} = \{d_{CAM_1}, d_{CAM_2}, \ldots, d_{CAM_i}, \ldots, d_{CAM_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘CAM technologies and systems’.

4. Competencies in the field of engineering analysis (CAE) are in demand in the modeling of technological processes, for example, casting or pressure processing:

$$K_{CAE} = \{d_{CAE_1}, d_{CAE_2}, \ldots, d_{CAE_i}, \ldots, d_{CAE_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘CAE technologies and systems’.

5. Digital measurements (CAI) are necessary for the control of manufactured products and the organization of adaptive processing on CNC machines and processing centers:

$$K_{CAI} = \{d_{CAI_1}, d_{CAI_2}, \ldots, d_{CAI_i}, \ldots, d_{CAI_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘CAI technologies and systems’. (Computer Aided Inspecting)

6. In addition, promising digital technologies (CA ‘x’) can be singled out as ‘Other’, which include additive (3D scanning and printing) or ‘Smart Production’ and ‘Internet of Things’.

$$K_{CAx} = \{d_{CAx_1}, d_{CAx_2}, \ldots, d_{CAx_i}, \ldots, d_{CAx_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘Innovative digital technologies in mechanical engineering’.

7. Specific competencies necessary for a modern engineer to work effectively in an integrated information environment (PDM/ PLM), including working with electronic technical archives, managing changes in design and technology documentation and organizing teamwork on large projects, should be highlighted.

$$K_{PLM} = \{d_{PLM_1}, d_{PLM_2}, \ldots, d_{PLM_i}, \ldots, d_{PLM_n}\},$$

where $n$ is the number of didactic units reflecting the essence of modular section ‘Continuous Acquisition and Life Cycle Support –CALS’.
Many of the didactic units in the groups of the given classification of IT technologist competencies are interdependent, and the competency groups themselves are organized in a certain hierarchy in the order of their presentation. In addition, it should be noted that the terms of rapidly developing information technologies often coincide, are repeated, and can at all have different conceptual content. For example, specialists in related fields of science and technology can decipher the abbreviation CAI, which is familiar to technologists, not as automated measurements, but as automated systems for supporting innovative processes in a company (computer aided innovation - CAI), which is also not alien to the methodology of ERVE.

It was proposed to use the ontological approach [9] for the formation of the subject field for the training of IT technologists in the environment of ERVE and the allocation of conceptual and terminological connections between many didactic units [9]. The construction of ontologies allows formation of subject-oriented knowledge bases that effectively support the design processes of technical objects in various subject areas [10].

In an experimental study conducted by the authors of this article [11], the continuous dynamic process of development of a CAD domain that is infinite in nature was represented by a discrete set of final states fixed by experts at a certain stage of ontology construction. In combination with ERVE methodology, the ontological analysis apparatus allows constructing optimum trajectories of individual or targeted training of specialists in a virtual educational environment.

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