Virtual enterprises in implementation projects of integrated machine-building CAD systems

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Abstract. The article discusses the problems of introducing CAD systems integrated into complex automated systems. One of the main reasons for failures and low efficiency of projects for implementation of automated systems are personnel problems. To accelerate implementation of the pilot project and adaptation of CAD systems’ users, it was proposed to create specialized educational project virtual enterprises (EP VE). EP VE is formed within the implementation project as a kind of digital twin of a real enterprise on basis of authorized training centers, including those created by companies developers in supporting universities.

1. Introduction
In a well-known study of implementation of automated systems [1] carried out by an analytical company Standish Group, on basis of representative statistics, it was shown that the share of undoubtedly successful projects for developing and implementing modern automated systems did not exceed 35% and had a downward trend. It was demonstrated that the subjective factors determined by the interest and qualifications of not only developers, but users of automated systems had a significant impact on the effectiveness of implementation projects.

By its definition, computer-assisted design is a complex information process of interaction between designers (CAD personnel) and a set of design automation tools [2]. The priority role of the “human factor” in creation and operation of automated (man-machine) systems and technologies is manifested in a significant increase in the volume and diversity of procedural guidelines (PG) supplied to the market by leading developers and integrators of computer systems. Training and retraining of personnel has become mandatory and one of the most critical in terms of duration and effectiveness stages in the implementation projects of PLM-solutions [1 - 6].

In order to accelerate adaptation of project personnel and development of CAD skills and know-hows among users of integrated automated systems, it was proposed to create specialized training and design enterprises at universities and training centers (EP VE). In addition, EP VE can be used as a particular layout (electronic twin) of PLM-solutions, designed to test new technologies, and anticipate implementation of a pilot project in implementation of integrated CAD projects [7].

2. Development and usage of educational virtual enterprise
Educational VE intended for mastering the complex automation technologies should not and cannot be an impression, a copy of the entire automated system of an enterprise. It is not only technically difficult to implement in the conditions of an educational institution, but also impractical for achieving
the learning objectives. At the same time, solving of specially selected educational design and engineering problems allows, within the framework of educational design, to fully and visually present the integration chains of information technologies, while the absence of material ones significantly minimizes all costs. However, when developing a methodological scheme of educational computer-assisted design in an educational VE environment, it is necessary to take as a basis a design model regulated by current standards and rules of a particular enterprise.

In an educational VE designed to train project personnel, an automated enterprise management system will operate in the simulator mode. Thus, the integration core of VE, as provided for in CALS/PLM methodology [2], should be the Product Data Management system (PDM).

As with implementation of industrial PLM-solutions, the bulk of work in the process of developing EP VE comes from creation of information (IG), organization (OG) and, of course, special procedural guidelines. It is the structure and substantive content of IG and OG that primarily reflect the IIS specifics of an industrial enterprise. And further capabilities of procedural guidelines allow the staff of EP VE to solve educational project problems effectively.

The structure of information models implemented in PDM databases is a conceptual framework for various processes that take place at the enterprise and are to be mastered by personnel. The following types of information models were identified in EP VE:

- project application environment model;
- project environment model;
- production environment model.

The information model of project environment can be implemented fully and realistically using the tools of corporate reference and information subsystem of the PDM/CAD industrial complex.

The information model of production environment of EP VE can be recreated in detail using a set of technological reference books.

The structure and composition of procedural guidelines of EP VE differ from industrial solutions by their significantly greater complexity. The databases were equipped with additional sections:

- collections of tasks and exercises for educational computer-assisted design;
- methodical recommendations for teachers on educational process implementation in the environment of EP VE;
- collections of demonstration projects and examples of engineering solutions.

Analysis of creation and usage of experimental EP VE allowed to formulate the main provisions and formalize the architecture of educational PLM solution in the form of a virtual enterprise. It was established that for formation of the informational and educational environment necessary for development of the competences of integrated CAD personnel, the standard corporate delivery of the program-methodical complex:

\[ S = \{ P_1, M_1 \} \],

including a lot of commercial software subsystems and modules \( P_1 \) and a fairly representative set of proprietary procedural guidelines \( M_1 \), must be supplemented by the following components:

- \( P_2 \) – additional software for educational purposes, including automated learning subsystems and knowledge control modules, as well as computer simulators to develop skills in the use of local computer-assisted design technologies.
- \( g \) – generalized version of the structure of electronic databases of PDM system.
- \( q \) – a specific set of organization guidelines, reflecting educational functions of VE.
- \( M_2 \) – methodological developments, teaching aids and recommendations for students on usage of PLM-technologies.
- \( M_3 \) – a basic set of special procedural guidelines necessary for the development of the author's version of the integrated educational computer-assisted design scenario.
- \( M_4 \) – guidelines on setting up and using an engineering data management system and Work-Flow for organizing the management of educational project activities, as well as an adapted installation method integrated with PDM by CAD system.
The author’s information $I_{uvp}$ and organization $Q_{uvp}$ guidelines of EP VE are formed as images of IG and OG of the industrial enterprise prototype $I_1$ and $Q_1$ respectively,

$$I_{uvp} = f ( I_1 ), \quad Q_{uvp} = g ( Q_1 ),$$
defined by functional relationships

$$g : I_1 \rightarrow I_{uvp}; \quad q : Q_1 \rightarrow Q_{uvp}.$$

As the experience of EP VE creation and operation showed, substantial additions to the supply are required in many sections of procedural guidelines:

$$M_{uvp} = M_2 \cup M_3 \cup M_4 \quad (2)$$

It should be noted that the PG of EP VE - $M_{uvp}$ under the terms of delivery should be formed at the base and using special elements $M_1$. However, the correspondence $M_1 \times M_{uvp}$ is not complete and not unambiguous. For example, in the conceptual plan the PG of EP VE is necessary to supplement with theoretical knowledge in the field of CAD, terms and definitions of current information and general technical standards, etc.

As a result, the deployment structure of EP VE on basis of university delivery takes the following form:

$$S_{uvp} = \{ P_1, M_1, P_2, Q_{uvp}, I_{uvp}, M_{uvp} \}. \quad (3)$$

3. Overall results and conclusions

The proposed methodology for implementation and usage of educational project VE is based on research and development [4 –8], and also takes into account the authors’ many years of personal experience in managing automated systems implementation projects, as well as training and retraining of CAD users at enterprises in the Volga region.

The experience of using experimental educational VE at an authorized ASCON training center at a flagship technical university of the Samara region showed a significant reduction in the time spent on user training. Compared with local methodologies, a positive effect is observed when working in an integrated information environment, which is manifested in the acceleration of learning (up to 30-50%). These results are easily explained, since the information technologies of VE provide for a multiple reduction in costs and temporary losses during the execution of such procedures, as searching, processing, exchanging and storing project data.

In addition, experiments show that the use of an information-filled and methodically well-functioning educational VE significantly reduces the unproductive expenditures of the tutor’s time and intellectual resources on face-to-face consultations and educational group management.

The use in the implementation projects of the methods and tools implemented in EO VE allows the user to form in advance a specific set of engineering competencies required by the specialists when working as part of modern automated industrial systems.

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