Virtual Enterprise Approach for teaching students in electrical engineering

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Abstract. This article deals with the original approach which is proposed - a “virtual enterprise” that differs from the well-known by a more in-depth focus on the future specialist’s adaptation to the market economy. The methodology of a virtual enterprise is based on a project-oriented approach. The tools for the implementation of information exchange within the educational virtual enterprise, as well as for the implementation of the process of product design and testing has been proposed and considered. To implement the information exchange environment the usage of the training version of the SAP ERP application package has been proposed. To implement the environment for the development and implementation of technical solutions the usage of hardware and software of National Instruments has been proposed for realization of a concept.

1. Introduction
Modern society is characterized by an ever-increasing scientific and technological progress, the increasing complexity of the main types of engineering activities, the increasing dynamics of the accumulation of engineering knowledge. This causes, on the one hand, the emergence of new higher requirements to the quality of education, and on the other – stimulates the search and implementation of new forms and methods for educational services providing.

There is a need in acquiring a sufficiently large number of not only knowledge and skills, but also competencies in a short period of time by modern specialist. Forms and methods of the educational process realization should be continuously improved. One of the most difficult area of such activities is teaching in engineering specialties. In this paper organization of educational process for master program “Electrical and instrument engineering” is considered. Improvement of students' knowledge and skills is possible through the development of new approaches to the organization of the educational process.

One of the most effective and proven ways of endowing the student with the currently required competencies is the project-oriented approach. This approach is based on the preliminary collegial development of an integrated systemic model of actions to achieve the original goal with the subsequent implementation of such a model. The project-oriented approach allows to form the following competencies:
- team building and distribution of roles;
- establishing productive relationships;
- overall focus of the team on the result;
- resolution of possible conflicts;
- time planning;
- creative thinking;
- problems setting and solving;
- tracking schedules and overall coordination of actions.

The methodology of a virtual enterprise (VE) is the evolution of a project-oriented approach. At the same time, if in case of the project-oriented approach involves training in project management, then the VE methodology assumes the additional development of other currently relevant competences. These competencies are necessary to understand the basic business processes and effectively perform their functions in the course of subsequent work in enterprises:
- focus on customer needs;
- possession of the basic principles of business and economics, including: organizational aspect, market knowledge, business communication;
- basics of legislation in terms of regulating labor relations and interaction between enterprises.

Within the implementation of the project 573879-EPP-1-2016-1-FR-EPPKA2-CBHE-JP Internationalisation of master Programs In Russian and China in electrical engineering one of the main activities was focused on development of the virtual enterprise approach to teach students of engineering specialties. The results of the developed approach have been integrated in newly developed master program curriculum “Electrical and instrument engineering” in project partner universities as a core subject which is called “Virtual Enterprise”.

2. Methods
It is assumed that the real instrument enterprise operates as it is depicted on figure 1 and operates as follows:

The first step is to receive the order (the relationship between the "Customer" and "Customer Relationship Management" blocks). The complexity of this order, the availability of the necessary specialists, materials and technologies for development are assessed.

The second stage is the recruitment of additional staff. The internal HR management division of the enterprise, using the appropriate software for automating activities (“Human Resource Management” block), turns to an external recruitment agency (“Recruitment agency” block) to find employees, indicating the requirements for the level of a potential job seeker.

The third stage is the development of products according to the terms of reference for development, transferred from the department responsible for interaction with the customer ("Customer Relationship Management" block) to the appropriate department of the enterprise ("Automation Development" block). Based on the results of the development, the finished project, first of all, specifications for the necessary materials and components, is transferred to the department responsible for interaction with suppliers (block "Supplier Relationship Management").

The fourth stage is purchasing. It is presented in the form of interaction of the "Supplier Relationship Management" block with an external contractor enterprise "Supplier". A purchase order is transferred to the counterparty, and from the counterparty to the warehouse (block "Material Warehouse") the components are received, and to the "Supplier Relationship Management" department - the corresponding documents (invoices, invoices and others, if necessary).

The fifth stage is production (block "Production"). It is carried out in accordance with the updated data on components (transfer of information from the Supplier Relationship Management block to the Product Lifecycle Management block), using the material resources in the warehouse (Material
Warehouse block), under the control of the relevant department, using automated system ("Product Lifecycle Management" block).

The sixth stage is product testing (Testing block). Usually, it is performed under the control of the development department (the "Testing" and "Automation Development" blocks are highlighted in the same color).

The seventh stage is the transfer of finished products to the appropriate warehouse (Finished Goods Warehouse block).

The eighth stage is the shipment of finished products to the customer (connection between the Finished Goods Warehouse and Customer blocks) and the transfer of the corresponding acceptance documents to the department responsible for interaction with customers (the link between the Customer and Customer Relationship Management blocks).

![Diagram](image)

**Figure 1.** Real instrument enterprise.

To create learning conditions that are as close as possible to the real conditions of work at a modern instrument-making enterprise, a scheme for the operation of a virtual enterprise is proposed and depicted on figure 2. This scheme allows to provide:

1. Implementation of all the principles of an object-oriented approach to learning.
2. Creation of the enterprise structure - distribution of roles between students and the teacher, corresponding to various positions: 2.1. Teacher - director of the enterprise 2.2. Students: - customer service managers; - manager for work with contractors (suppliers); - project managers; - engineers; - programmers.
3. Creation of an environment for information exchange.
4. Creation of an environment for the development and implementation of technical solution

The implementation of virtual enterprise technology in the educational process has been carried out by using two software products. For the implementation of the information exchange environment has been used the educational version of the software package ERP SAP.
This software includes, among other things, the following modules:

1. Human Management Automation Module – SAP HR, providing a number of important from the point of view of training in a virtual enterprise functions: personnel administration, or personnel records; maintaining the organizational structure of the company; reporting in the form established by law; employee time management (actual accounting, analysis and data processing); development and talent management; management of employee motivation policy; formation and work with the personnel reserve; analysis of staff performance.

2. Customer Care Automation Module SAP CRM, which allows you to coordinate the actions of all departments and employees, whose job responsibilities include issues of interaction with customers and create in any company a single information space containing a complete, reliable and up-to-date database of each client.

3. Vendor automation module SAP SRM provides a number of functions that are important from the point of view of training in a virtual enterprise: identifying the needs of an enterprise, for example, by completing a complex purchase application from different departments of the company; selection of a supplier, including the possibility of implementing the most common procurement procedures at present, holding auctions and tenders; contract management, including electronic coordination within the enterprise and with suppliers, keeping a history of changes in contracts and monitoring their implementation; management of relationships with suppliers, for example, suppliers can independently register in the system and update their own profile; post-process analysis of the procurement process by collecting and analyzing data from various sources and further storage of analytics; work with reference books and catalogs, including your own.

4. Process control module SAP PLM, which allows to integrate various divisions into the overall process, including marketing, sales, planning, as well as manufacturing, material supply, maintenance and repair. This component is the most important and provides the following functions that are important from the point of view of training in a virtual enterprise:

   4.1. Management of data on fixed assets (document management; management of the structure of the object; integration with GIS, CAD, SCADA).

   4.2. Program and project management (planning and implementation).

   4.3. Management of the life cycle of fixed assets (management of technical objects, management of measures for maintenance and repair of equipment used in the main production).

   4.4. Analysis throughout the product life cycle (management of ideas and concept development; joint design with other enterprises; joint project management; joint quality control).

To implement the environment for the development and implementation of technical solutions has been used hardware and software of National Instruments company in the form of, respectively, CAD-subsystems based on three components.
1. LabVIEW software development environments. LabVIEW is a system design platform and development environment for a visual programming language from the company National Instruments. LabVIEW is the basis for building data collection and processing systems and includes various libraries:

- to connect external equipment using the most common interfaces and protocols;
- for remote control of the experiment;
- to generate and process digital signals;
- to implement a variety of mathematical data processing methods;
- for visualization of data and the results of their processing (including 3D models);
- for modeling complex systems;
- to store information in databases and generate reports.

2. Software for modeling electronic circuits Multisim. NI Multisim is an electronic graphic modeling program and includes microcontroller simulation, as well as integrated import and export functions in PCB design software. Multisim is tightly integrated with data collection systems created in LabVIEW.

3. Software for designing electronic printed circuit boards NI Ultiboard. So, the National Instruments software (LabVIEW, Multisim, Ultiboard) makes it possible to create a virtual devices and allows to maximize the effectiveness of training, without the need to invest significant financial resources in the material component of the educational process. To implement the testing of products can be used the same National Instruments software, and in the case of original solutions, made in the form of real devices – National Instruments hardware systems based on PXI and CompactRIO platforms.

3. Conclusion
The developed approach of virtual enterprise differs from the well-known in a more in-depth orientation towards the future adaptation of the future engineers to the market economy. The proposed scheme for the implementation of this approach has been integrated in the master program in electrical and instrument engineering. The implementation of virtual enterprise technology in the educational process has been carried out by using the educational version of the software package ERP SAP and hardware and software of National Instruments company.

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