Implementing virtual enterprise methodology in masters program in electrical engineering

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Abstract. the paper considers applying virtual enterprise methodology to master's educational program “Radiophysics”. The paper presents the results of the development of a business process model of a virtual enterprise engaged in conducting research and development work. The options of platforms for the implementation of the models obtained and their use in the educational process for training masters in the direction of “Radiophysics” are considered.

1. Introduction

Modern enterprises are unthinkable without automated systems for managing resources and business processes. Such systems allow the manager to monitor the implementation of all production tasks, contacts with customers and suppliers, and work on personnel management in a single integrated system. For ordinary employees, this system makes it possible to quickly receive information on the resources required in the production and scientific activities, provides interaction with colleagues and external counterparties and allows more time to spend on performing their tasks instead of processing and coordinating paper documents. Therefore, for modern engineers and scientists, in addition to purely professional skills, such as the ability to design new devices and conduct research, the ability to interact with colleagues using enterprise automation systems is necessary.

The development of the competency model of the master's program in the field of Electrical Engineering and Quality Control during the implementation of the INSPIRE project as part of the program for the development of cooperation and cultural exchange in the field of higher education under the auspices of Erasmus + [1], [2] showed that it is necessary to include a course on working in a virtual enterprise [3] to get graduates the necessary competencies. The ability to organize their actions according to the business processes of the enterprise and the construction of a single information space based on a virtual enterprise complements the skills of using computer-aided design, computer graphics and modeling. As the exchange of experience between partner universities
has shown, some of them have already implemented similar programs for specialties aimed directly at design and production activities. However, Voronezh State University is more focused on the training of scientific personnel, which requires a serious reworking of the experience of partners to build a model of a virtual enterprise conducting research. Research has its own characteristics and business processes when they are organized differ from purely industrial, although they have many common features.

The purpose of this work is to select a platform for organizing a virtual enterprise, developing a diagram of the main business processes and modeling business processes of a virtual enterprise in which students will be involved in training. As a model enterprise we select a department of JSC “Concern “Sozvezdie”.

2. Enterprise resource planning systems
Enterprise Resource Planning (ERP) systems are specialized software products that provide integrated management of business processes, financial assets, human resources, and financial management. They appeared in the early 90s with the development of the MRP-II methodology. Now all the major global companies use ERP systems in their activities. In any ERP system, there are 4 main components:

- database with transaction support;
- web portal;
- users;
- software.

The database provides storage of data used in the system. These include financial information, lists of participants in specific business processes and their role, deadlines for completing tasks by employees, inventory, external counterparties, and other necessary for the company.

The web portal is used to customize the system and users work. It provides an interface for creating tasks and starting business processes, viewing analytics on the state of business processes and enterprise resources, and the interaction of employees in the performance of their duties.

Users are user accounts that uniquely identify employees working in the system. They allow you to distinguish between visible resources and tasks, as well as can be used as a simple electronic signature to certify decisions made in the system.

The software is the link between the portal and the database and provides the implementation of all the functionality embedded in the system.

Employees directly interact with only two components — the portal and users. The remaining parts are available only to developers and in a normal situation, their implementation should not be of interest to ordinary employees.

Currently, the most common ERP systems in Russia are SAP and 1C: ERP [4], of the rest, Microsoft Dynamics, Oracle E-Business Suite and ERP Galaxy should be noted. Each of these systems requires the optimization of business processes of the enterprise in the process of the implementation. However, the implementation process may require specialized skills and the involvement of third-party companies to perform work. Coupled with the high cost of licenses, this makes it difficult to use such systems in Russian universities, although there are examples of successful use of ERP SAP in curricula [3]. Alternatively, the French partners suggested using Bonita BPM [5]. This software allows us to create a business process management system in the form of an online portal. In addition to modeling processes, it is possible to create a data warehouse and obtain
analytics on processes and data using built-in tools. Bonita BPM is open source software that allows us to use it with almost no restrictions to build enterprise automation system. If required, paid support is available, including system implementation, customization on demand and system maintenance during operation. In addition to the lack of price for a license to install, a big plus of this solution is the creation of your own processes and data models using a graphical interface. Graphical user interface for creating processes is show in Figure 1.

For the description of the processes, the BPMN 2.0 representation [6] is used, which are the standard for the graphical representation of business processes during their modeling. In BPMN all processes can be constructed from basic elements. This elements includes flow objects (events, activities and gateways), connecting objects (sequence flow, message flow and association), swim lanes (pool and lane) and artifacts (data object, group and annotation). Flow objects represents different tasks that are connected using connecting objects. Artifacts annotate process by specifying input and output data.

3. Virtual enterprise in masters program in “Radiophysics”

Building a virtual enterprise will require the formalization of all processes specific to the development of instruments and scientific research. During the implementation of the INSPIRE project, standard schemes for organizing processes have already been described [3], work has been done on describing the classification of work processes, analyzing the organizational structure, documentation and electrical equipment [7]. But this work was carried out for instrument-making enterprises. In our case, it is necessary to create a virtual enterprise for scientific research and design work, which imposes its own requirements on the processes implemented. Unlike production tasks, when conducting research and development work, the purchase of materials has a much smaller impact, since the main goal is to obtain the necessary information, and not the finished device. For the same reason, the phase of product lifecycle management and the finished product warehouse disappear from the scheme. The
development department. The interaction of the customer with the customer relationship management system becomes two-way, as well as the interaction of this department with the development and research department. Taking into account the described changes, the scheme takes the form shown in Figure 2.

The part related to personnel management remains unchanged in the scheme. The processes of searching for the necessary employees for the project, planning their working time, training and tracking the quality of work are almost unchanged in all areas of activity.

As for instrument manufacturing, this scheme allows for the implementation of the principles of an object-oriented approach to training, the distribution of roles between students and teachers during classes, the creation of an information exchange and analytic system, and a management environment for conducting scientific research.

Since the size of the entire enterprise is large, and classroom hours are limited in teaching at the masters program, we will consider only two components of the scheme shown in the figure: the research and development department and pilot production, with an emphasis on the research department as the most likely place of work for our graduates.

Inside the department, the main functional roles are distinguished: head of department, researcher, designer, tester, technical writer. The number of roles in real conditions may be greater, but from the educational point of view, we consciously make some simplification. These 5 roles are sufficient for understanding the work of enterprise management systems and in the case of small study groups in graduate each student will have the opportunity to try himself in each of these roles. The number of employees for the roles in question may vary, with the exception of the department head, who will always be the only one. The role of department head will always be held by professor.

After consultation with our industrial partner we choose business process scheme as follows:

Technical task is formulated by the department head. Task consist of 3 steps.

First on is feasibility assessment. It requires publication review in the development field, creating mathematical models in computer algebra systems, making numerical experiments in CAD software or developing new software packages for necessary calculations. Result of this step should be either prototype’s project for producing and testing or abandoning this research direction due to poor gains or inability to produce prototype with current technology. Second result doesn't mean completely

Figure 2. Common business process flow for scientific research and development of new products testing phase is combined with production in pilot production, which has bilateral interaction with the development department. The interaction of the customer with the customer relationship management system becomes two-way, as well as the interaction of this department with the development and research department. Taking into account the described changes, the scheme takes the form shown in Figure 2.
failure to complete initial task. It's because of nature of research activity that not always lead to immediate results. The report on this investigation will be kept for future references in both cases and can lead to proposals of new research activities.

First step contains department head as initiator and inspector, several researches and developers as implementors. At this stage there is no production in any form, so no additional participants are needed. This step has two stages. One only checked to track progress, another serves as filter to pass development to next stage or abandon it.

Second step is constructing prototype. It begins if first step ended in certain technical task. This stage greatly resembles normal development of new models, but has less descriptive task definition, most of design can be altered on the fly and process is led by researchers instead of designers. Another point, that is important to know here, is possible long time for acquiring resources. It’s not possible to implement in our masters program, but in real work absolutely normal to wait several months until there will be access to production line or real products that need to be improved.

This stage require engaging of additional personnel – technical writers to document prototype production and prepare documentation for future repeating in mass series. Most of the work is done by designers, but researches have great control on production path. There is no steps on this stage. Since we already have prototype's project from previous stage, result is distinct – real hardware.

Third and the last stage is testing prototype. As with previous step it can require access to different facilities and can takes a lot of time in real life. But in education this step should verify obtained results and assumes all necessary resources are at hand.

At this stage we need additional personnel – testers, who are responsible for caring out all measurements and providing report with all product’s parameters. Based on this report researches should make proposal:

- for returning to first stage and correcting prototype’s project and repeat other stages;
- recommendation for applying new technologies for real products;
- abandon this direction.

In case of making final decision (either recommendation for production or abandoning) researchers together with technical writers produce report of overall research activity that contains:

- initial development field overview;
- all models and simulation data;
- prototype’s project;
- results of all test’s;
- conclusion of using or not using this prototype in mass production, or recommendation for future scientific research.

On all stages department's head serve as arbiter for approving of moving on to next stage or returning to previous. His task is also tracking progress and checking deadlines. There is no certain time for each stage or finite amount of repeats, but process can’t be infinite and personnel shouldn't drop this activities.

Overall this process is very similar to agile methodology [8] in developing software. Main points in research activity is collaboration between all participants, including interaction with external specialists on scientific conferences, regular meetings (as in SCRUM), possible changes in all stages of this process and no certain deadlines.
4. Conclusions

Based on the experience of domestic and foreign colleagues, a scheme for implementing the “virtual enterprise” approach is proposed for managing the process of scientific research and development work. The scheme takes into account the differences from the production process and will be tested in classes with masters studying in the direction of Radiophysics in the autumn of 2019. Bonita BPM software was chosen as the platform for creating a virtual enterprise. The choice is explained by the absence of payment for the installation and use of the system and the ability to independently create models of the necessary business processes without the involvement of programmers or integrator companies.

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