The Use CAD/CAE Systems to Create E-Learning Courses on Technical Subjects at University

https://doi.org/10.3991/ijep.v8i2.8134

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Abstract—This article proposes an integrated approach regarding the use of different software for practice-oriented training in engineering disciplines. Emphasis is placed on the formation of a unified educational space for training in engineering disciplines. An approach to the integration of a large number of application software solutions based on the "Moodle" distance learning shell was developed. Examples of the developed training courses for the engineering disciplines are presented. Examples include the use of the proposed approach for "Machine Parts" and "Theory of Machines and Mechanisms" technical training courses in terms of practice-based learning.

Keywords—engineering education, e-Learning, 3D modeling, CAD, CAE

1 Introduction

Currently, the design and development of new aviation and space technologies performed by the world market leaders is done by means of multinational teams of developers. Designers and technicians may be located in different cities and countries. The team-work is performed in a single design environment based on a digital prototype of the product using specific development tools. A large number of computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM) systems are being used widely in the course of development. Almost all manufacturers of these systems are working on the improvement of these environments. One of the main problems is the tracking of the product design changes, since the rate of the design and technology changes is growing constantly. Therefore, one of the research university important tasks is to prepare professionals with practical skills to work with a large number of CAD/CAE/CAM systems. The development of the students' remote team work skills on practical tasks is important as well.

The educational process of the research universities should be based on scientific work. In fact, many scientific studies are carried out with the help of CAD/CAE systems. Enterprises of aviation and space industries, which are the training customers, are interested in further cooperation with the graduates, who have experience and skills in working with CAD/CAE systems. Moreover, training customers are interested not only in the students' ability to work with a particular system; they want to have professionals who have a certain set of skills to solve practical engineering problems.

Therefore, many universities make extensive use of practice-based training and case-based training (upon practical examples).

On the other hand, the educational market is being actively developed in the field of practice-based training and the use of modern communication technologies, including the new e-learning technologies. However, distance learning is mainly used to study the theoretical courses that do not have a practical orientation. Teaching practical courses in performed in small groups mainly and corresponds to a limited number of specific tasks. One of the main issues for a large university is to organize the wide-scale practice-based learning. To solve this problem, taking into account the current requirements for the knowledge of graduates, an integrated approach to the development of educational programs and the use of a wide range of software is needed for both the preparation of course materials, as well as for the organization of the practice-based training process.

Various CAD/CAE systems have their own characteristics that determine the processes of training courses development and their integration into a single educational space of the university. Therefore, the development of training courses for engineering disciplines, within which must deal with specific engineering problems, has a number of features and issues that need to be addressed. These problems include the formation of a unified educational space, application of the different systems integration, application of the development issues and the integration of existing content, taking into account the subsequent use in the practice-oriented training.

2 Software solution for the formation of a single training environment

One problem of major research university educational space organization is associated with the heterogeneity of the educational environment. As a rule, several learning management systems are used in major universities simultaneously. Each of these systems has its own characteristics. For example, there are two own e-learning systems in our university: Personalteacher2.0 [1] and training system for mathematical disciplines CLASS.NET [2]. The possibility of systems that have been developed by external suppliers and development communities are used widely as well: "Moodle" [3], eFront, REDCLASS, e-learning server 4G. These systems have a large amount of educational content to be used with minimal processing.

In addition to the possibilities of educational systems built-in editors, eAuthor and CourseLab tools for course development are used widely. A set of courses selected according to SCORM standard specifications is being formed. However, the practice of using different training systems showed that in spite of the support of the said standard, the courses containing unique multimedia objects (digital prototypes of products) do not always work correctly in a variety of distance training systems.

In accordance with the requirements of national legislation regarding personal information the information on students and teachers is stored in the university management system [4], which meets all security requirements. In addition, there are several electronic library systems. The thematic groups of the university on various

activities are organized via social networks. In such circumstances, consolidation of educational statistics and integrated management of educational content becomes quite a challenge.

On order to solve the above problem, the protocols for the exchange of information between the main learning management systems and library systems have been developed. Information about the users from the protected corporate systems is transferred to the main e-learning system in a partially impersonal form. "Moodle" program shell was chosen as the primary storage system of educational statistical data. Own authentication methods (authorization plugin), methods of enrollment into courses (enrollment plugin), blocks (blocks plugin) and modules (activity module) for the management of educational process have been developed for this system. Training systems provide the exchange of information with the "Moodle" software via modules which are integrated in appropriate courses. The module sends the information about the students into the connected educational system through a secure communication channel and then receives training statistics from the connected system in the form of a final rating. This approach enables the integration of different learning systems and external applications into a single learning environment. Electronic library systems are integrated through the blocks of training systems. A specific unit is designed for each library system that allows sending information about users to the system and receiving the necessary statistics from the library system.

The advantage of this approach is as follows: a smooth transition of students and teachers to the requested resources without the need for additional procedures for registration and authentication. The synergistic effect of the combined system has been achieved as a result of the work performed. The attendance of the thematic systems and library resources has increased. Optimization of the user registration process will allow to use the different training systems, depending on the specific application. In addition, the students have access to the transition to cloud services used for engineering computations and application servers in seamless mode due to the existing approach. In this situation, maintaining manageability of the education system is an important factor, since all statistics are stored in a single database, and is available for administrative staff.

By virtue of this approach it is possible to solve the problem of using multiple CAD/CAE systems based on multiple platforms in a training course. All resources are unified on the basis of "Moodle" software in a single training course. This course ensures that students do not just study the educational material; they also have practice-oriented training in the respective CAD/CAE systems based on the application server or a cloud service. All statistics are stored in a single system, and this fact provides a significant simplification of the activities of teachers and supervisors.

In addition, this approach solves the problem of personal data protection through well-defined standards of information exchange between the host training system and other related systems. The impersonal information relating to students is being transmitted to the connected system, which significantly increases the security of the information. The problems associated with the protection of information including commercial value have been solved also through a flexible system of differentiation of students' access rights to external information systems and knowledge databases.

The proposed approach has allowed to abandon the registration of users completely in a large number of related systems that required constant attention of the staff to the presence of errors in the personal data of students even with automation of the components. The effectiveness of the proposed solutions has been confirmed on the basis of two parameters - reducing of the maintenance costs and costs on audit of all electronic training complex databases and reducing of the access time to educational resources for students. In some cases, reduction of time was significant - from five days to a few seconds.

3 Examples of interactive content for practice-based learning

Our university uses a large number of CAD/CAE systems, but two of them - Solid Works [5] and Autodesk Inventor - are used widely for the development of materials for training courses and practice-based learning. One of the benefits of these environments is the ability to perform further analysis of the models developed in other CAE systems and the presence of own add-ins for engineering analysis. In addition, the data can be transferred to the CAM system for printing 3D models of various objects.

One of the solutions in the development of technical training was the use of the Autodesk Inventor 3D-modeling environment. On one hand, the actual models of technical objects enable the students to visualize their goals and functions. On the other hand, the model contains all the basic parameters of the original, so you can use it for the organization of independent practical work of students. In addition, the most successful solutions can be created on a 3D printer as a product demonstration.

"Machine parts" e-learning course may serve as an example. 3D-model showing different types of connections, gears, chain drives and other technical devices were developed for this course. These models are integrated into the material for lectures; their viewing is possible with the free Autodesk utility for viewing of 3D-models called Design Review. The theoretical course material is formed using "Moodle" standard development tools.

In addition to working with the theory, students can work with these models through the application server on the basis of product lifecycle management (PLM) of Geolus Search environment. This makes it possible to expand the possibilities of studying technical courses significantly and fill them with practical activities. According to the finished models (Fig. 1), students perform calculations for power and numerical experiments. This allows to develop the skills of practical and designing works.

Each task is a mini-project with a large number of possible solutions. In addition, the teacher introduces additional data that the project team should take into account in the subsequent work into the PLM system at certain stages of the mini-project implementation. Thus, it prepares the students for the real work with these systems and instills teamwork skills and agile approaches.

Due to the fact that the models are parameterized, each team of students (from three to five persons) receives a unique challenge with its own characteristics, imple-

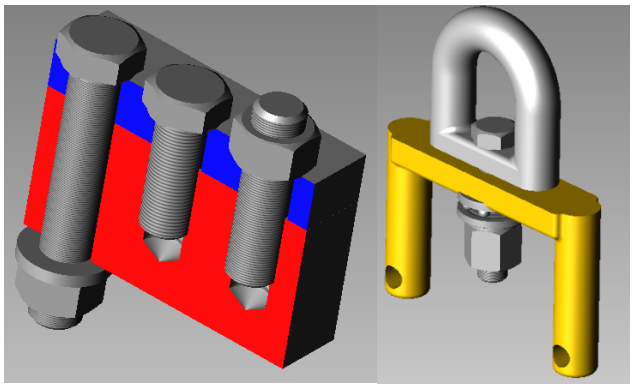

Fig. 1. Models of the compounds

mentation procedure (different input data for the product life cycle) and specific effects. Thus, the generation of large number of the unique tasks for project teams is being performed. In this case, due to the lack of possibility of making automatic changes in PLM system being used, the main focus of the teacher's work switches to this point.

The educational videos used to illustrate the operation of various technical objects, such as gears and transmissions, gearboxes, friction mechanisms and other technical devices were created using Autodesk Inventor software. While viewing the lecture material the students have the opportunity to "touch" the real technical objects, and this ability enhances the viewing experience greatly. Visual illustration of the lectures is not the only use of 3D-models in the theoretical course. The virtual laboratory work was developed on their basis: the gear assembly (Fig. 2.), the determination of gear parameters, the calculation of the friction coefficient on the end of the nut, etc. [6]. The guidelines regarding their implementation and the types of reporting were created for virtual laboratory works; this saves time for teacher during training in the laboratory and allows to work with each student individually. In some cases, it is possible to abandon the costly labs with accurate or expensive equipment without losing the quality of education.

One of the elements of practice-based learning is to develop the gear in the PLM environment in the process of studying the "Machine parts" course. Teamwork is carried out with a clear division of roles - the designers and technologists. Thanks to the PLM environment data, it is possible to assess the contribution of each participant to the overall project and the degree of elaboration of the product as a whole. The most successful projects are made by 3D printing.

The ability to perform measurements on the 3D-objects created expands the scope of the models application significantly. Autodesk Inventor software allows to create technical objects on the basis of earlier calculations, thus allowing to visualize the result. For example, this may be done to obtain a ready three-dimensional reducer from a source file in MS Excel format containing the calculations of the strength and defining all the parameters for the construction of the object including technological advices for the manufacturing of the parts.

An additional feature of Autodesk Inventor software is the ability to create animations from 3D-objects. This can improve the visualization of technical courses significantly. For example, a set of laboratory works used to study the structure, kinematics and dynamics of mechanisms has been developed for the "Theory of mechanisms and machines" course. This set allows the students to acquire the skills of working with the schemes of the mechanisms (Fig. 3), learn the basics of the mechanisms development, conduct dynamic analysis, etc.

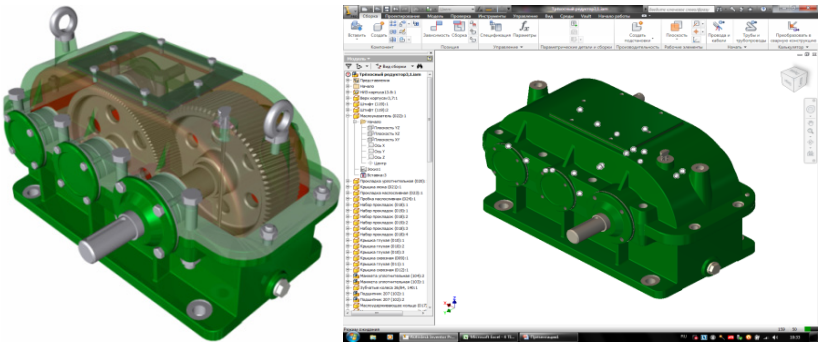

Fig. 2. Models for virtual laboratory works for the "Machine parts" course

Fig. 3. Models for the virtual laboratory works on the "Theory of mechanisms and machines" course

The possibilities of Autodesk Inventor software and other CAE systems allow the use the 3D-models for more complex calculations. At the same time, the use of PLM systems and a set of multiple CAD/CAE systems in one course makes it possible to operate in seamless mode. "Moodle" course workspace is organized for students, which is used to contain all the elements of practice, making the transition to a given system or application server.

4 Conclusions

The problem of the formation of the uniform educational environment for studying technical courses on the basis of "Moodle" is solved. The proposed model of the modules development for training courses capable of exchanging information using established protocols with CAE and PLM systems and application servers has proven to be effective. The reduction in the time for the registration of students in the various education systems, reduced maintenance costs, and cost of audit of the databases for complex e-learning systems has been achieved.

Using Autodesk Inventor software has increased the visibility of technical courses significantly. The tools for organizing teamwork of students in interactive mode and conditions close to real work were developed. Thanks to virtualization capabilities, students can work on the university servers, and teachers can monitor the results easily as well as improve the methodology for assessing the practice-oriented projects.

With the use of teaching tools provided, the process of studying the materials of engineering courses is becoming more accessible and convenient. Taking into account the opportunities of distance learning technologies and application servers, the learning process becomes convenient and affordable for students. Since all the materials are stored in electronic form, it can be reused in order to develop new practical problems.

Work with modern PLM systems develops practical skills of a student, such as teamwork, rapid response to changes and the ability to work remotely and keep track of large volumes of changes.

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Article submitted 19 December 2017. Resubmitted 10 January 2018. Final acceptance 05 April 2018. Final version published as submitted by the authors. This article is a revised version of a paper presented at the International Conference on Interactive Collaborative Learning (ICL2017), held September 2017, in Budapest, Hungary.