Design, Simulations and Manufacturing Strategy in the Teaching of Engineering Subjects

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Abstract

Post introduces a potential for utilization of tools for design, simulation, design of production technology and data management in technical education. Tools are used in the context of the curriculum of engineering disciplines of secondary schools and colleges. Use of applications to support teaching of thematic units of basic subjects with a subsequent transition to a comprehensive use of the project education is expected. Target of the use of the listed application of these technologies according to the presented concept is to increase knowledge and skills of students of engineering disciplines for independent solutions of sophisticated design and technological tasks. The concept of teaching takes into account requirements of industrial experience on the professional competence of graduates. Optimization of the teaching methods is based on a research conducted at secondary schools and colleges of engineering and of information-engineering focus. In connection with the project teaching, supported by information technologies, growth of motivation of students to study engineering problems and their subsequent application in professional experience in the field of study is monitored. Experiences with computer-aided education and the possibility of advantageous use of potential of other, in engineering practice used, software tools are listed in the paper. In particular, the issues of application of tools for data management in the role of learning management system are presented, which is particularly beneficial in the final stage of preparation of technicians, where largely individual work and teamwork on complex projects of virtual prototypes is expected. The strategy of data management system enables checked work on educational projects also outside the school environment. Interim results of research are mentioned in the text with links to possible solutions and optimizing of the didactic system of teaching of engineering subjects is given.

Keywords


Introduction

Procedures applied in the current industrial engineering practice put new demands on knowledge and skills of graduates of technical schools, connected with a significant proportion of the use of tools for design, simulation, production technology and data management solutions for the design and technological tasks. Computer-aided engineering activities open up new approaches to creation and analysis of designs and also for creation of processes of manufacturing and assembly. A large number of data sets, the complexity of procedures and the need of sharing of information in various points on the planet with adequate check and security of shared information required the deployment of data management systems and processes. Features of tools deployed in industrial
practice and also in the school sector are known and have already been mentioned in many publications, intended for training of technical personnel in industry, but particularly in preparing of students at all levels of technical schools (Foť and Kletečka, 2007). Verification and optimization of teaching methods takes place within the long-term research conducted in the teaching of engineering-oriented subjects at the secondary school and college. Survey is focused on the increase of knowledge of students by teaching of basic academic subjects with the use of visualization and simulation possibilities of computer applications. Implementation of teaching procedures and results of undertaken experiments are presented in the text. The focus of research activities is the depth analysis of projects in progress and completed projects of students' virtual prototypes. The data sets represent an important carrier of information and, in addition to communication medium by the process of design and technical preparation of a specific products, it allows an insight into the thought processes of a student. By default knowledge and skills, their expansion and especially consolidation of cross-curricular links can be expected. Since it is a specific industrial sector and the priority is to prepare graduates for success in the field, the content and form of teaching must be based on the requirements of industrial practice. A part of a comprehensive research is based on this sector in addition to the analysis procedures carried out in sophisticated design and technological departments of industrial companies, the investigation is aimed at the adaptability of students and graduates in practice. The result of these activities should be an optimized didactic system of teaching of engineering subjects, supported by tools for design, simulation and data management. Educational procedures of relevant thematic areas of other subjects taught at all levels of schools can be derived of this concept.

**Tools for design, simulation and technologies in context of teaching of technical articles**

Applications of this category are commonly used in the school environment. A complete installation is very expensive, but a part of a business strategy of the majority of software vendors in this category of software is to ensure the accessibility of its use in the education sector with regard to the material possibilities of schools. There are academic licenses, fully functional and for a symbolic price. They can be often installed on home computers of students and educators (Kapusta and Munk and Turčáni, 2010) This important fact gives students space for individual development and learning outside the classroom. It allows to teachers continuous work on input, optimization and evaluation of pupils' work. Costs of academic licensing may be included in grant programs, or they may be involved in industrial enterprises for the region's schools. The financial aspect is not a barrier for the use of this category of software in teaching. Schematic representation of information flows among the main products of the described tools is in Figure 1.
Design

CAD - Computer Aided Design are tools for computer support of creating of 3D or 2D digital models and 2D drawings. Currently, the standard is production of volumetric or surfaced 3D model by parametric methods (Matějus and Šedivý, 2011). The parametric model has dimensions and relationships between related objects determined by values of parameters that can be constant or variable and whose value is the result of a defined formula. The starting point for creating of 3D solid body are usually 2D curves, which are extruded into space in a straight line, revolved around an axis, or drawn along a guide. In spite of the fact that the priority is the creation of a 3D volume model, we can still find examples of use of a 2D curve model. 2D curve model can be used for example to generate a NC code to control of a machine by the creation of the technology for machining of a simple body, or as a reference for the calculation and the finite element simulation. Besides creating a basis for further constructional activities based on calculations and simulations with 3D models and their set, it is used to create visualizations, the proposal in the context of the assembly and last but not least to perform basic measurements and physical analysis, directly in this module.

Knowledge and skills of work with 2D and then with 3D CAD applications are together with theoretical knowledge of basic and cross-sector engineering subjects basis for subsequent computer-aided design activities, and subsequent work on complex educational projects. Acquisition of basic skills is necessary already in the first years of the study, together with the knowledge and skills of using a computer, operating system and applications for creating text, spreadsheets and presentations (Dostál, 2009).

Simulation

CAE - Computer Aided Engineering are tools for implementing of simulations and engineering calculations on 3D digital models and assemblies created in the CAD module. Computational algorithm works based on Finite Element Method - FEM. In connection with the design of structural design strength calculations to determine the stress and strain in the loaded part of the structure is usually carried out. A network of elements is defined on a 3D digital model or assembly. Geometric and structural boundary conditions are specified according to functionality of construction. After completion of the calculation, the quantitative results for selected construction sites, or qualitative...
visualization of the monitored parameter on the surface and inside the volume element are to evaluate. Based on the obtained results the construction can be considered as properly designed, undersized or oversized, which is the basis for further editing and optimization of the model. Introduction to a CAE module in teaching is possible through case studies and examples of the topics taught in technical mechanics and physics, initially without further theoretical knowledge of finite element method. It enables a gradual transition from analytical solutions to computer-supported technical calculations. Gradually full use of the work on educational projects is expected.

Creation and verification of production technology

CAM - Computer Aided Manufacturing enables to create and verify machining technology for a numerically controlled machine. In addition to a tool-path that is determined by shape features of a design, the type and size of the used tool can be defined and cutting conditions can be determined. Production technology is optimized on 3D data of digital models.

Product Lifecycle Management

PLM - Product Lifecycle Management System is an application for data management, definition of information flows, including the management of processes associated with creating of the design and technical preparation of production. A specific example is the use of PLM tools in the role of the LMS - Learning Management System. PLM system can be used for organizing of all documentation competent to projects. They enable a quick access not only to CAD data, but also to text and other graphic files that are associated with the project solved. CAD data and documents can be viewed by designated users of PLM system however they have defined property rights, and editing rights.

The students can during work in teams work at different places, from the home. Information can be transmitted within the system and all activity can be monitored by a teacher - a project consultant. Instructions or intermediate and final evaluations can be added to the set of project data, which can be applied for the classification of individual students then. Another possibility of the system is the distribution of educational materials. The data may be available, for example in the form of a comprehensive training course, or in nonlinear form as sub-sample tasks. Interim results of research carried out in connection with the teaching of CAD technology show a lack of relevant learning materials and teaching supports. It is also confirmed by the survey among students in the course of teaching and project work. CAD model solution, text, or image presentations and movies with annotated methods can be distributed through a PLM tool. The advantage of deploying of a PLM tool in addition to standard LMS is to familiarize students with the application used in industrial practice and gaining of practical experience with the philosophy and procedures applied by work in the field after graduation.

Engineering and pedagogical teaching concept of engineering subjects

Creating and testing of new progressive ways of teaching of technical courses may be based on engineering and pedagogical approach to teaching, as detailed above all in (Melezinek, 1994).

„As engineering pedagogy are considered all activities aimed at improving of teaching of technical subjects regarding objectives, content and forms of teaching”.

Sources of engineering pedagogy and links between them are shown in Figure 2. Objectives in this area are predominantly determined by the demands of industrial practice. Content is given by yet acquired knowledge of field and should react on the on-going development and implementation
of new technologies. The development is evident also in the field of educational technology and teaching methods. Support for teaching of technical subjects through the instruments used in industrial practice and developing of new practices is an example of the close relationship of theory and practice in didactics of technical subjects. The paper presents one of methods of use of modern didactical technologies in practical teaching.

The deployment of information technologies in teaching of non-informatics subjects reflects the current trend of dispositions and interest of generation of potential engineers. This is connected with the achievement of learning objectives as listed in the taxonomy (Blom, 1956) and for teaching of engineering subjects closer specified by (Melezinek, 1994) not only in the cognitive area. Natural perception of computer applications environment leads to the gradual formation of the affective area and work with objects in a 3D virtual environment also to obtaining of skills in the psychomotor area. The structural design in a virtual environment, supported by performing simulation and design of technology solutions in the framework of educational project leads to the organization of knowledge structures and consolidation of curricular, and in some cases, interdisciplinary relations of a studied issue.

Figure 2: Sources of engineering pedagogy (Melezinek, 1994).

Concept of teaching supported by a computer

Teaching of sub-topics of basic subjects

Didactic potential of design and simulation tools can be applied already in the initial stages of studies to support the teaching of basic subjects. Engineering and technological subjects can be modeled in CAD applications and their subsequent performances can be carried out by a demonstration directly from the virtual environment. This method allows you to introduce for example geometry of cutting and forming tools, or molds for casting. Visualization of distribution in space, variability of a design, or a use of standardized parts can be done by engineering constructions. Samples of specific examples can be later used for complex performances of the broader issue for strengthening of relations between the sub-issues and within the subject also cross-curricular links (Balogh and Turčání and Burianová, 2010). Tools for design and simulation can
be also used with advantage in the education of theoretical subjects which knowledge is important for solving of complex problems for an example may be some parts of physics and technical mechanics.

**Project education, supported by tools of information technologies**

Efficient teaching methods with a goal to strengthen cross-curricular relations of specialist subjects are the teaching on complex projects. Knowledge of subjects such as technology of a field, engineering, engineering technology, technical mechanics, creation of technical documentation, information and communication technologies and other industry-oriented courses taught at lower secondary schools is used in the education. Transition to the teaching on project supported by CAx / PLM technologies is gradual and in the higher grades complex project work have predominantly role. In particular, teaching at college is since the beginning focused on project teaching to consolidate ties of gained knowledge and skills of the studied field.

The projects are solved in subjects of CAD, CAE and ICT in engineering. The number of lessons corresponds to one semester or term and the range is designed specifically for individuals or groups of two to three investigators. Some of the semester projects are developed to the level of successfully defended thesis. The recommended timetable for implementation of the educational project, indicating the most important activities, is shown in Figure 3.

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<th>Activity / Timing</th>
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<td>Creation of technical documentation</td>
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<td>Generation and verification of NC program</td>
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<td>Final presentation and data transfer</td>
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<td>Checking the status of the project</td>
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Figure 3: Timetable for ideal process of implementation of a pupils' project with key points.

Visualization of 3D data of the completed project of a virtual prototype of a model for pressure casting of aluminium alloy is shown in Figure No. 4. General principles of engineering design, rules for creation of tools and technology issues of inlet and solidification of the casting material in the actual process of casting were applied for the development of the project. A project of this type was processed by a student in a period of three months.
Progress of project work can be assessed both in the classroom observation, and by analysis of ongoing status of projects that listeners process outside school lessons. Final outcomes of completed projects can be also analyzed. The structure of CAx data enables to assess the level of technical thinking of a student, his spatial imagination and creativity. From this point of view, the most suitable are CAx applications that allow you to achieve the same result in different ways. Due to the material possibilities of schools and to different licensing strategies for different providers of these systems, this requirement is difficult to reach (Hubálovský and Jelínek and Šedivý, 2012).

Despite this fact CAx data created in any application are a carrier of sufficient amount of information to produce partial conclusions and for subsequent optimization of the concept of teaching, including teaching supports in the form of text and animated electronic materials. Animated materials are created directly through animation and visualisation tools of a used CAx application. They contain procedures of 2D and 3D design and setting up of corresponding simulations. Increase of knowledge and skills is verified by an experiment on two parallel groups in education. Sub-thematic unit is in the experimental group demonstrated with a use of a CAx tool. A classical method without the use of CAx applications is used in the check group. In both groups there are the same initial knowledge and skills, as measured by a pre-test. A post-test is entered and evaluated in both groups at the end of the learning process and this post-test is also repeated in a period of 1 month after completion of the interpretation of the topic. The results of the first post-tests of three final experiments are shown in Figure No. 5. In all cases it was a demonstration of the cutting tool geometry using a CAD model. Several so specified experiments were carried out throughout the research. Selection of pupils to groups was made according to organizational options and criteria, which do not affect the examined parameters. Independence of choice was assessed on the basis of pre-test results. Numbers of pupils in each group were 15 to 30. An experiment was performed repeatedly with an emphasis on ensuring of the same conditions, consisting of the initial knowledge of students, course work, testing and evaluation.
Figure 5: Verification of deployment of a CAD tool in education - students' success in posttest.

Research of attitudes of students and graduates to CAx technologies and to the teaching supported by these instruments is carried out using a questionnaire and an interview. A web questionnaire for obtaining the necessary number of respondents also from remote locations was created for this purpose (Chromý and Drtina, 2010). Selected results of positive responses, which have a significant influence on the creation and optimization of conception of computer-aided education is presented in the graph of Figure No. 6.

Figure 6: Results of the survey of attitudes of students and graduates of technical schools to CAx technologies.

**PLM application in the role of the educational LMS**

The following example demonstrates a configuration of a PLM system to meet the educational role of the LMS. The data structure and information flows are based on the experience and research investigations in education (Milková and Hubálovský, 2010). Use of a PLM system in comparison with
known universal LMS systems brings the opportunity to familiarize with the approach applied in industrial practice. Process Map of one possible solution is shown in Figure No. 7.

![Diagram of data structure of PLM system in the role of the LMS.](image)

**Conclusion**

Researches show the benefits of deploying of tools for design, simulation, technologies and data management in the teaching of technical, engineering-oriented subjects (Hubálovský, 2011). The concept of teaching, where the described applications are deployed with escalating intensity, is determined by the theoretical bases of education, experience, industrial requirements and by specific characteristics features of the used teaching tools. Research at this stage managed to show a significant influence on the growth of skills of students and graduates in technical fields and also their motivation to study technical issues and to professional orientation in the field. Increased knowledge can also be expected, however, the growth rate is not significant in comparison with the skills. Teaching can be realized through CAX applications, commonly available in industry and also in educational sector. Availability of academic licenses is not an obstacle for the deployment in teaching of not only engineering subjects. Deployment of CAX tools integrated with PLM application creates a comprehensive information system, allowing complete support for presence and distance learning.

This article was created under the project called Specific research in 2012 done at UHK Hradec Králové No. SV 2108.

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