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Concurrent Engineering Approach to Teaching Fundamentals of Geometry and Graphics in Higher Engineering School

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The paper proves the efficiency of teaching fundamentals of geometry and graphics in the context of concurrent engineering and provides the results of problem- and project based team work performed by students within the scope of blended learning programme. Educational resources of the course comprise materials for declarative learning (educational tools based on GDP – PPT animation, logical schemes with frames, videos) and procedural learning (CAD-systems, graphic tests, different level tasks).

Key words: blended learning, learning fundamentals of geometry and graphics, graphic means of presenting information, problem-based modular learning, project-based method, team work.

1. Introduction

In the sphere of high-tech mechanical engineering, transition to concurrent engineering (CE) based on PLM software (Product Lifecycle Management) alters the nature of engineering activities, especially in terms of design and development. The foundation of CE rests on the principles of concurrent design, manufacturing, and PLM, which are implemented through integrated cooperation and simultaneous resolving of different tasks by the team of designers and experts. In CE/PLM, the integrated CAD/CAE/CAM-systems create particular design media, and the model designed in CAD-systems is an integrating digital product, which reflects interaction with all the elements and ensures graphic communications in enterprise digital media (EDM) over the product lifecycle. The activities of the design engineer in EDM are multifunctional and imply not only different types of activities, but also using principally different goal pursuits and strategies in resolving design tasks. Digital media used in CE/PLM for design engineering (DE) alters its approaches and techniques, which should be considered in engineer training. If for sequential flow of PLM-cycle (fig. 1, a) traditional discipline-based education was more or less acceptable, engineers working in CE/PLM should possess knowledge, skills, and abilities (KSA) essential for multi-aspect, and what is more important, integrated polytechnic thinking (fig. 1, b).

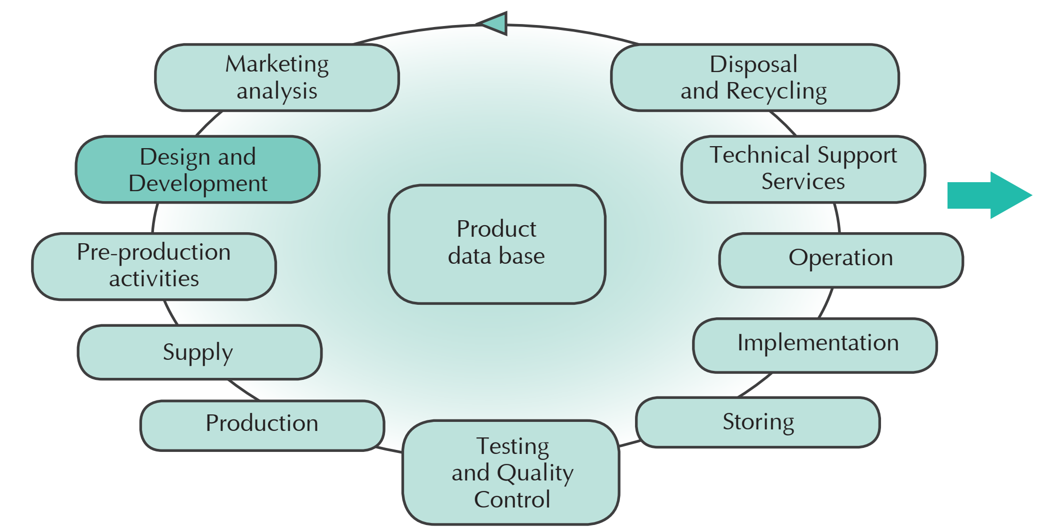
As a result, technical university graduates educated within the frame of discipline-based curriculum fail to be properly pre-pared for professional activities in CE/PLM. An urgent issue today is how to train new generation of design engineers able to create a competitive product in CAD-systems. To develop the required design engineering competencies, it is necessary to reform the system of teaching geometry and graphics (TGG), which are fundamentals of DE.

2. Systemic integration to ensure consistency in teaching geometry and graphics

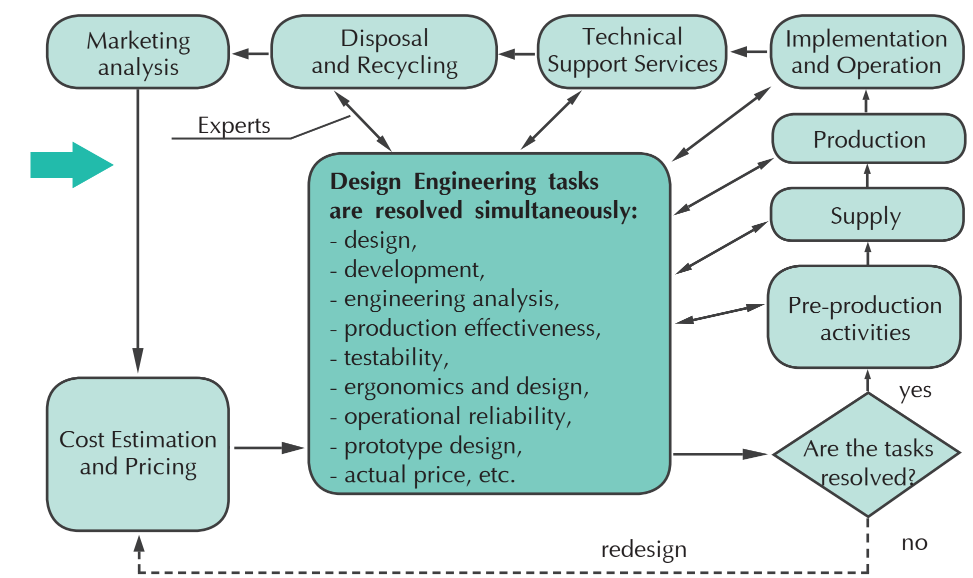
The geometry and graphics curriculum is to be integrated on the basis of graphic software, and this is an essential criterion to set the goals, select and structure the content of the curriculum in accordance with social and professional requirements to engineers within CE/PLM. The curriculum components aimed to improve cognitive and practical skills important in professional context should be integrated to increase students' intelligence and develop polytechnic mentality, so that they can be efficiently applied in DE and related fields.

TGG focused on CE/PLM can be split into two principle components – general professional and design ones, the former being basic for all programmes. The general professional component aims to develop geometry and graphics competencies essential for all engineers, while the goal of the design component is to improve the skills specific for a particular programme. Persistent IT development inevitably leads to alterations in TGG: content, forms, methods, techniques, means, and staff. Let us take a closer look

Fig. 1. Alteration of nature of engineering activities



a) PLM – sequential



b) CE/PLM – simultaneously

at discussing a case study of TGG general professional component.

2.1. Teaching techniques. When teaching fundamentals of geometry and graphics in the context of CE/PLM, IT implementation is far-reaching and implies graphical data presentation (GDP) and using CAD-systems in e-learning. Today, they are commonly used both in Russia [1, 2, 3, 4] and abroad [5]. TGG based on IT transforms the structure of traditional education, intensifies learning process and increases the level of knowledge acquisition. It is noteworthy that an increase in students' intelligence is not restricted to greater volume and better quality of the knowledge acquired. Compared to traditional education, students develop alternative cognitive skills, diverse the way of thinking, alter the system of logical operations and mental activities.

The basic competencies in geometry and graphics are developed through active forms of team and individual work based on problem-based modular learning (PBML) and using GDP and CAD-systems. The problems designed initiate cognitive educational activities and affect the students' intelligence. Moreover, PBML in education ensures intradisciplinary and cross-disciplinary connections.

The curriculum content structured in modules and concentrated in GDP forms, which are developed to reach the teaching goals, allows one to perform the activities as follows:

- to timely design multi-path education process integrating modules or diversifying the content;
- to give the educational material in modules with some didactic elements in GDP abridging the materials and reducing the number of class hours to approximately 33–14% in a way that does not have any impact on intensity of perception or quality of knowledge acquisition [6, p.81]. Within each module, this allows focusing on practical tasks during class hours and over the time given for individual work;
- to ensure monitoring within each module, which, in its turn, secures reaching the educational goals;
- to adjust education process to students' needs and abilities, which stipulates self-education at one's own pace;
- to focus on consulting and coordinating educational activities, with stimulating self-study in different forms of e-learning:
  - under the teacher's supervision (class hours);
  - completely individually (virtually);
  - individually but with a teacher consulting (blended learning: class work and virtual learning based on LMS).

According to the European University Association (EUA), in 2013 the most preferable form of e-learning (91%) was blended learning (46%) [7, p. 26].

2.2. Geometry and Graphics Fundamentals: Content. The priority in selecting and structuring materials for TGG is to develop basic level competencies essential to perform professional activities in CE/PLM and to continue education in DE using professional software. The goals of basic level training are as follows:

- to develop abilities for analysis and synthesis of geometrical shape;
- to prepare students for self-education and work with on-line self-study programmes to learn different ways of shape generating and annotating design documents using CAD-systems;
- to prepare students for team and individual work aimed to resolve DE tasks.

The educational course is regarded as a tool for self-development and the content is presented in modules based on:

- visual aids in representing educational materials;
- integrated educational process, sequential stages, and practice-oriented content;
- basic notions and methods being key components of the content structure;
- consistent and coherent materials;
- focus on self-study.

Modules are based on systemic analysis of conceptual framework of geometry and graphics, which allows one to identify key concepts, select the materials essential for the module, avoid repetitions within the course and in the related disciplines.

Fig. 2 shows the structure of the modular learning programme used for TGG.

The integrating goals of modules (fig. 2) contain particular goals, which can be reached using educational tools. The module content comprises basic (permanent) and optional parts, the latter being connected with updating information and programme profile. The module structure includes:

- programme of actions given as education goals;
- educational materials and support structured in the form of education components;
- assessment and self-assessment tools for each module.

2.3. TGG in E-Learning: Forms, Methods, Tools. Methodological approach, which the key principles of TGG depend on, is based on the system of approaches (activity-based, competency-based, systemic, etc.), concepts and didactic principles, with due regard to psychological mechanisms of KSA acquisition. In e-learning interaction between teachers, students, and online courses implies equal cooperation. Students are free in and responsible for the choice of learning path: if necessary, students can even design individual learning paths.

Fig. 3 shows experience of KNRTU-KAI in TGG fundamentals focused on blended learning, designed on Black board learning platform, and comprising integrated educational modules.

Educational resources of the course comprise materials for declarative learning (educational tools based on GDP – PPT animation, logical schemes with frames, videos) and procedural learning (CAD-systems, graphic tests, different level tasks). In terms of the content, the course includes such modules as "Technical drawing and GDP fundamentals", "Industrial Design: Fundamentals" (fig. 3). CAD-systems allow one to resolve the tasks of shape generating taking into account design principles.

The module "Assembly Unit Modeling and Part Design" implies problem- and project-based learning in teams [8]. The module is designed for the first year students (second semester), and since the students lack professional knowledge at the current education stage, education is provided in the form of the role-play. The range and distribution of roles depend on the problem set, which can be either analogue (in terms of unit type, shape complexity, assemblage methods, etc.) or heuristic (correcting the shape of the assembly unit part, new shape generating, etc.). The focus is on self-study in 3D solid modeling and team work, which allows using knowledge of different levels to develop the skills of assembly unit modeling. TGG based on blended learning is particularly efficient, which can be proved by the case-study of the Institute for Automation and Electronic Instrumentation (IAEI), KNRTU-KAI (fig. 4).

Team work broadens the scope of tasks increasing students' intelligence and

Fig. 2. Structure of modular learning programme used for TGG
MG – main goal, IG – integrating

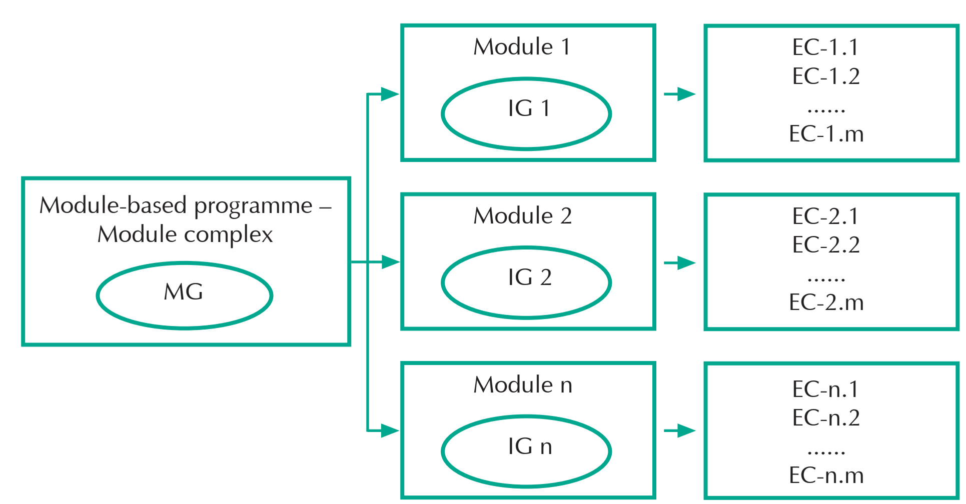
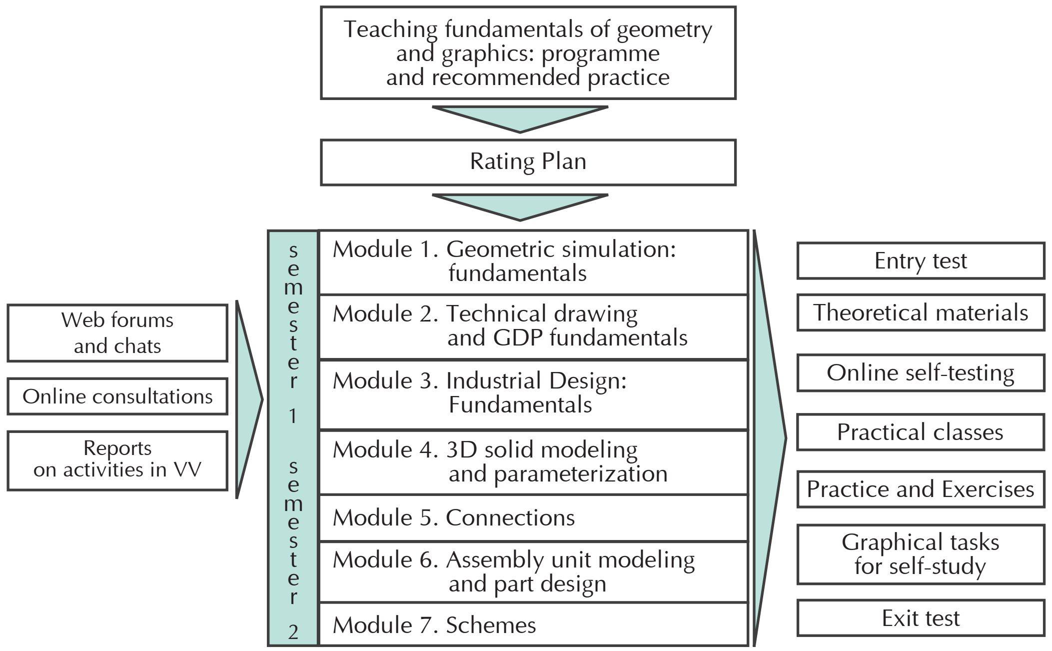


Fig. 3. TGG: education process



responsibility in taking decisions. Problem- and project-based learning makes it possible to train a team of design engineers and develop project mentality from the first stage of TGG. Since CAD-systems secures better quality in less time, their use for 3D-modeling and application of GDP in blended learning are indisputably beneficial.

2.4. Staff Assistance. Besides scientific and methodological rationale, implementation of graphic IT is inseparably connected with "staff training and retraining" [9, p. 50] in the spheres of didactics and IT development in education. IT penetration in TGG (the use of GDP and CAD-systems) is also associated with some psychological particularities, which can be efficiently used in educational process. The teachers should exploit the didactic potential of IT tools and develop students' intuitive reasoning, image thinking, and other rewarding professional qualities important for engineers working in CE/PLM.

Conclusion

The synergetic effect of using GDP and CAD-systems in problem- and project-based modular learning on the efficiency of TGG is caused by the factors as follows:

- high potential of cooperative creativity due to graphical techniques applied in information visualization and active learning: project-based learning, team work characterized by high level of individual responsibility, online and off-line communication between the teacher and the student within the scope of educational process;
- tight presentation of materials, tests, and quick assessment in each module. The students are engaged in cognitive activities, which are connected with reflection on and review of the studied information, as well as practical application of the acquired knowledge;
- educational process within each module can be controlled by the teacher and adapted to the individual needs of the student, who can design an individual learning path.

All together, these factors ensure high quality of TGG fundamentals.

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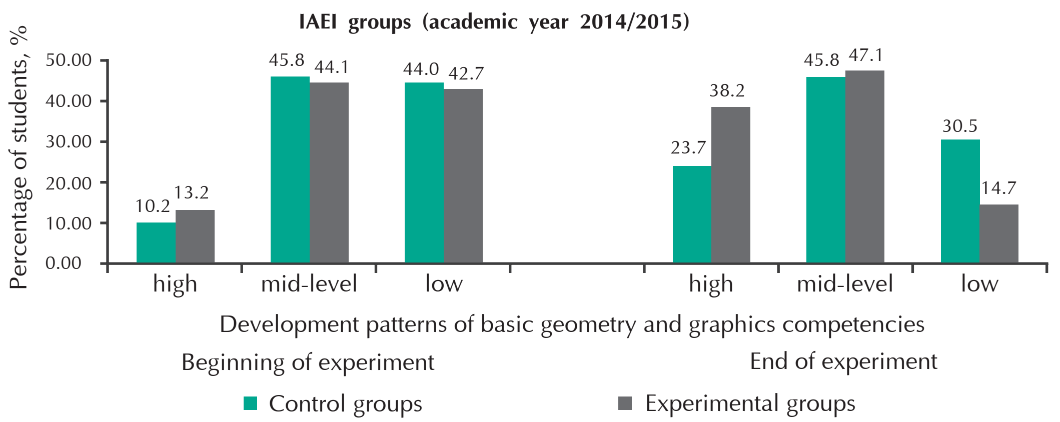
Fig. 4. Basic geometry and graphics competencies: development patterns



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