

# Integration of content and technologies of teaching within framework of geometrical-graphic training of students

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**Abstract.** In this paper the problem of geometric-graphic preparation of civil engineering students is considered. The development of the integrative educational discipline "Descriptive geometry, engineering and computer graphics", implemented within the foundation part of the higher educational specialised program "Construction" is proposed. The prerequisites of the integrative approach in accordance with innovations in engineering design and modern requirements for the project culture of future graduates are discussed. Possible methods and pedagogical technologies for implementing the approach are considered. The manifestations of the integrative approach are shown at the innovative organization of the educational process, creating conditions for the functioning of the learning environment for the formation of professional competencies in students corresponding to the requirements of real design and engineering activities. An example of a complex task for the design of a building structure is given, the results of which allow one to assess the level of the students' competences, formed within the framework of graphic preparation.

## 1. Introduction

The main aim of modern higher technical education is the preparation of competitive specialists who are able to develop and master new high technology, participate in engineering and innovation activities [1]. The concept of engineering education of the "future" implies the development of system thinking of students and the formation of experience in solving professionally oriented problems on the basis of computer technologies used in practical life [2]. On the other hand, in order to create conditions for the transition of the Russian economy to a new technological level in professional educational programs, it is necessary to rely on the interdisciplinarity of education, i.e. on the integration of various components of the content, ensuring the formation of design and technological competencies in graduates [3].

In the process of competences' formation (the organization of the learning process), active and interactive forms of student education should be relied on. The presence of competence (evaluation of the learning success) is expressed in an integral style of thinking, in the ability to combine theory with practice, to integrate knowledge into practical activities [4]. It is thus, the implementation of a competence-oriented educational program involves the organization of integrative learning.

The rapid developments in modern manufacturing and automated digital technologies exacerbates the problem of training engineers with the ability to carry out their activities at the level of the latest



achievements in the field of science and technology. In this connection it is obvious that problem-oriented and project-organized training is one of the most effective innovative forms of enhancing the educational process [5].

An integrative approach is most effective methodology to form graduates' professional competences as integral neoplasms affecting the cognitive, activity and personal spheres. Professional problems are inherently integral, they require a system analysis and construction of an integrated models of their solutions. Complex actions, the actualization of a certain set of professional competencies and personal qualities are required from a specialist.

In connection with the above, the subject teaching of the general-technical and professional cycles should be carried out in the conditions closest to real professional activity, as a kind of immersion in the future industrial environment. This will contribute to the effective mastery of practical skills and related theoretical material. Building an educational process on an integrative basis contains many more technological opportunities, and it is the integrative approach, that should become decisive in the development of the content of educational programs and educational activities.

## **2. Innovations in engineering design**

Nowadays, digital technologies of 3d-printing, 3d-scanning, 3d-modeling and 3d-visualization are becoming the basis of high-tech production. They allow reduction of production costs and design time, bypassing technological limitations and improving the quality and competitiveness of the products. Information technologies fundamentally changed the design and engineering activities and made significant adjustments to the development and monitoring of design documentations.

The dynamic development of design as an engineering activity is influenced by improvements in capabilities of modern computer technologies and CAD, increase in the design engineer's functional, increased requirements for the project culture of the specialist, the system approach to the creation and engineering support of all stages of the life cycle of technical objects [6]. Informational models are present at all production life cycle stages, including 3D geometric electronic models, representing sets of data that uniquely determine shapes, structures and dimensions of products. The presence of 3D-model significantly increases the productivity and quality of the design process, its variability and visibility.

A big advantage of modern CADs is the ability to parameterize the objects created. Presence of conditions for creating a parametric model is inherent in the possibility of design systems, and a parametric description of an object becomes the ideological basis of modern design developments. This approach, in addition to streamlining the process of creating an object and using it in future as a prototype, allows the designer in a short time to produce a large amount of iterations while searching for the optimal shape of the model, and using the modern calculation modules to obtain optimal values for such physical (and not only) parameters like weight, strength, streamlining, flexibility, durability, environmental friendliness, ergonomics, etc. [7].

Considering the world trends in the field of design and following the above, it can be stated that offering today's engineering students modeling methodologies, based on parametrization, is a necessary step directed towards improvements in the competitiveness of future graduates.

All aforementioned points lead to the realization of the importance in developing novel teaching technologies that should be practice- and design-oriented, and organization of educational environment that is closely representing the reality of a designer, and the creation of the conditions for the demanded competencies formation in design and engineering activities for students [4].

## **3. Development of project culture in the course of graphic preparation**

The development of students' project culture should begin while studying the discipline "Descriptive geometry, engineering and computer graphics," which forms the part of the professional cycle, but is mastered by students already in the first or second year of university education. Therefore, the complexity in the organization of an applied design and design training in graphic

disciplines is obvious [8], and thus requires the use of adequate pedagogical technologies for the productivity of the learning process.

The effective technologies of productive learning for the disciplines of the professional cycle include the active learning technologies [9-13]:

- methods based on the modeling of professional activity in the learning process;
- developing, problematic forms and methods that intensify the learning process;
- technologies that ensure the individual's ability to self-development and self-improvement through conscious and independent actions.

For geometric-graphic training of students in the framework of foundation engineering education at earlier years of university, the issues of implementing the project method are especially relevant. It is thus necessary to develop project-oriented problematic assignments of professional orientation, as well as their effective and consistent implementation in the educational process [14].

Another difficulty in the organization of project training in the transition to bachelor's degree is the reduction of time, allocated to the curriculum for graphic training. Hence, there is an increased demand in integrative techniques and methods that intensify the process of teaching graphic disciplines [8,15].

A particularly significant effect in the intensification of teaching the discipline "Descriptive geometry, engineering and computer graphics" can be achieved by integrating its two basic sections - engineering and computer graphics, and combining them into a single course - geometric modeling [16]. This integration allows partially solve the problem of introducing elements of the "project method" at all stages of training, bringing the teaching technologies closer to professional conditions and help strengthen the practical orientation of the students' graphic preparation.

#### **4. Forms of integration in the framework of graphic training**

Traditionally, the higher educational foundational geometric-graphic training was presented in the curricula of technical specialties by disciplines "Descriptive Geometry" (the theory of the projection drawing), "Engineering Graphics" (the foundation for the development of design documentation) and "Computer Graphics" (instrumental preparation for the automation of output design documentation). They laid the foundations of the project culture of future graduates and studied consistently. With the development of computer technologies, in particular computer graphics, the integration processes of the interpenetration of graphic design sections were launched, which was especially accelerated with the spread of design technologies in 3d format [17]. The availability of 3d modeling multiplies the effectiveness of the educational process, allows creating new mechanisms for understanding the difficult to evaluate graphic information, develops spatial thinking in students and takes into account the individual characteristics of students.

Within the framework of the proposed integrative training course "Descriptive geometry, engineering and computer graphics", several applications of the integrative approach, confirming its effectiveness, can be singled out.

- Integration of requirements to the outcomes of geometric-graphic training in the unification of educational programs within the bachelor's degrees.

With the unification of competency-oriented education in graphic disciplines, there arises the need in level-based programs. Integrativity of this problem allows to optimize the process of required programs modernization of the subject education and at the same time ensures the formation of subject competencies at a level that would guarantee the achievement of a graduate's competence model for each of the educational programs in accordance with employers' requirements [18].

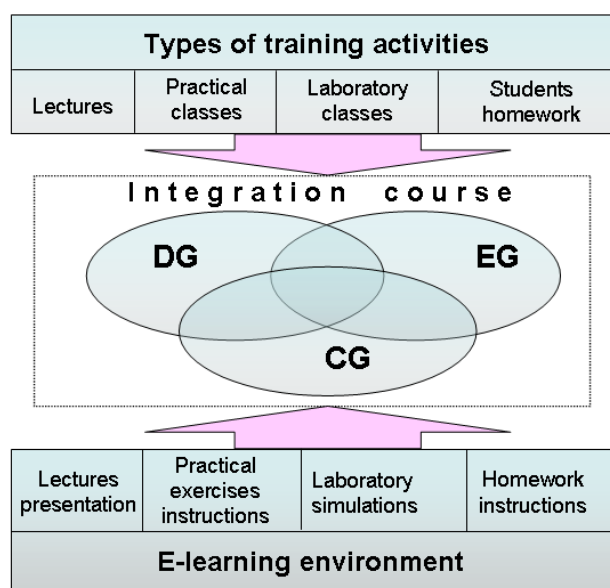
- Integration of separate sections of the discipline in the organization of various types of educational activities.

An integrated model of graphical preparation is shown in Fig. 1. During the development of an innovative course in graphic training, compensating a reduction in both the total number of hours of subject teaching and the hours allocated for theoretical training for the transition to a bachelor's degree, a special attention was given to the development of practical methods of using computer

graphics. A laboratory workshop, which addresses issues not only of automated release of design documentation (the synthesis of engineering and computer graphics), but also solved practical-oriented problems of geometric modeling, combining the theoretical foundations of descriptive geometry and modern CAD tools has been introduced. The workshop on geometric modeling contains tasks - modern analogues of metric and positional problems - of varying complexity levels, developing the spatial imagination of students, demonstrating the need to learn the foundations of descriptive geometry and at the same time allowing to improve the skills of using 3d modeling tools [16].

- Concentration of educational material based on the use of static and dynamic visualization of prepared 3d models.

Technical graphic information is linked with the representation of spatial objects data, its important characteristics are accuracy and visibility. On the other hand, one of the main and at the same time complex tasks of graphic education is the development of spatial thinking in students. The use digital 3D geometric modeling has qualitatively changed the level of the educational material presentation. Multimedia learning technology provides a unique opportunity to simulate images of real objects, phenomena and processes. This allows introduction of an abstract concepts, not only following the logic of the mind, but also through the feelings and sensations that arise when considering virtual models on a computer screen. This approach contributes to a holistic perception of the material, an increase in the speed and quality of its mastering [15].



**Figure 1.** Integration model of the course "Descriptive Geometry (DG), Engineering (EG) and Computer Graphics (CG)"

- Development of a comprehensive methodological support of the educational process, covering various types of educational activities.

An important factor in the success of the applied educational technologies is the methodologically well-developed support of the educational process, the adaptability and clarity of the reproduction of the planned assignments. The modern integrative educational and methodological complex of the discipline creates an effective learning environment, optimally organizes students' learning activities, sets the algorithm for independent design tasks, ensures the formation of the entire set of engineering and graphic competencies at the required level and taking into account the individual characteristics of students [15,19].

## 5. Example of an educational project assignment

Let us consider an example of a design object ("Spiral staircase") that is offered to students of specialization "Construction" closer to the final stage of basic graphic preparation.

The general algorithm of operation contains the following stages of work:

*The first stage* is the analysis of the initial data. Students are given individual versions of the initial information e.g. the height of the floor, the area of the staircase, the angle of rotation of the screw structure, the width of the step, the overhang of the stage, etc.

*The second stage* is 3d modeling of the construction in the following sequence:

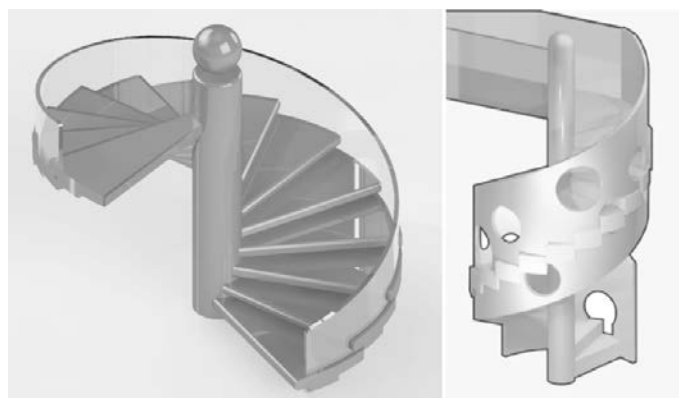
- Decision on the number of steps accounting for the building standards;
- Design of the step shape;
- Construction of a helical line at a given angle, dividing by the number of steps and array construction;
- Construction of a ladder enclosure;
- Assignment of materials.

*The next stage* is the formalization of the project documentation and preparation for the defense of the project:

- Visualization of the completed project;
- Construction of an associative drawing of a spiral staircase with structural elements;
- Manufacturing of a model of a spiral staircase on a 3d printer.

*The final stage* is the presentation of the design and the defense of the project (see Fig. 2 with examples of projects for modeling the spiral staircase, performed by students.)

Work on the project can be either individual or group [20], which to some extent becomes a factor in preparation to professional communication.



**Figure 2.** Examples of "Spiral Staircase" projects.

## 6. Conclusion

The authors proposed an innovative model of integrative basic graphic training for students of a technical university, laying the foundations of a modern project culture. Integrative processes allow the development of an educational environment that creates the conditions for the formation of trainees' professional competences as integral neoplasms affecting the cognitive, activity and personal spheres.

The integration of separate sections of graphic training - descriptive geometry and computer graphics, engineering and computer graphics - optimizes the educational process and gives a qualitative result. Complex tasks - educational projects create an imitation of real designs and design activities and stimulate students to master the technologies of modern geometric modeling.

It is shown that for the preparation of highly-in-demand and highly qualified technical personnel, it is necessary to create an educational environment that is as close as possible to production conditions, when the theoretical knowledge is superimposed with the future professional activity.

The testing of the presented methodology demonstrated that the improved technologies are perceived with interest by students and successfully contribute to the formation of professional competencies in accordance with the needs of the construction industry.

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