The efficiency of applying bim technologies in the educational process at professional schools

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Abstract. The article discusses the BIM competencies and their components in the preparation of highly qualified personnel in the construction field. It is imperative that educational institutions fully teach the students digital technologies and BIM competencies. The analysis carried out in this article shows that the students and graduates are poorly oriented in the rapid change of the construction industry. The developed course “Computer-Aided Design and Calculation of Building Structures” and methodological recommendations, with step-by-step instructions and the content of connected tools, show a positive trend. As a result, professional schools will be able to prepare the graduates with sufficient knowledge and skills to work with modern BIM tools.

1. Introduction
Digitalization has made a major breakthrough in recent years, without leaving the construction industry aside. The BIM technologies’ appearance on the market, clearly, had a positive effect for the architects and engineers in the projects’ implementation. “Building Information Modeling (BIM)” is a gain through the better specification and providing only the necessary amount of information regarding the design, construction, operation and maintenance of buildings and infrastructure, using the appropriate technologies [1].

This helps to ensure the efficiency and economy provided by the regulatory documents of various countries. International ISO standards are applied throughout the asset’s life cycle and can be applied to all the types of assets in a built-up environment - buildings, infrastructure, as well as to the systems and components within them.

Indeed, many countries of the world and mainly Russia have made BIM mandatory for their construction projects according to the government orders. However, professional education is not keeping pace with such a rapid pace. This is the main problem in the future employment of graduates who lack a complete understanding of the buildings’ design.

2. Application of BIM technologies in education
Large construction companies are in great need of qualified personnel who possess BIM competencies, becoming more important in comparison with other approaches that can improve the construction projects.

According to the well-known in training the professionals in the construction industry scientists Kassem, M. [2], O ’Neil, D. [3], Succar, B., Sher, W., & Williams, A. [4], an emphasis should be placed basically on building design skills. Zhang, J., Schmidt, K. and Li, H. [5] studied the issue of
industry-education collaboration to introduce the BIM technologies. Shelbourn, M. [6] considers the role of BIM technologies for a better understanding of structural elements in three-dimensional visualization. Quirk, V. and Bergin, M. [7] examined the professional competencies of BIM technologies from different perspectives.

From the stream of competencies, we single out the significant competencies for the students of professional schools:

CORE competency shows the personal qualities of individuals on the basis of which they can perform the evaluated activity or provide a measurable result.

DOMAIN competency refers to the professional abilities of a person that they use to solve the complex issues in multitasking and stress tolerance mode.

EXECUTION competency is characterized by a person’s ability to use certain tools and methods to achieve a high professional result, being able to use a software tool.

The author was integrated into the educational program of the professional module PM. 01 “Participation in the design of buildings and structures”, specialty 08.02.01 “Construction and operation of buildings and structures” [8]. The BIM technologies that we want to develop, allowed us to expand the professional qualities of graduates. Table 1 shows the components of the BIM competencies.

| BIM Technology Competencies      | Components                                                                 |
|----------------------------------|---------------------------------------------------------------------------|
| CORE Competency                  | planning and implementation of their own professional and personal qualities; work in a team and group, effective interaction with colleagues, management and clients; use of professional documentation. |
| DOMAIN Competency                | selection of building structures for the development of architectural and construction drawings; reading and execution of construction drawings; performance of static calculations; checking the structures’ bearing capacity. |
| EXECUTION Competency             | the use of information systems for the design of building structures.     |

In order to form the competencies, a round table was held in 2018 with employers of the large construction enterprises in the Togliatti city district, such as Capital Project LLC, StroyMontazhTolyatti LLC, etc. The questionnaire survey showed that when training the potentially highly qualified personnel in the secondary vocational education system, the three main indicators are poorly developed.

- an understanding of the construction industry’s development strategy - 53%;
- the ability to manage the changes in the construction field - 26%;
- orientation in the regulations and standards - 20%.

To achieve these goals, the authors developed and tested the training course “Computer Aided Design and Calculation of Building Structures”, which currently provides training for an enlarged group of specialties “Engineering and Construction Technologies”, includes the lectures, practical and interdisciplinary disciplines. This course includes the following topics:

1. Construction design in ArchiCAD [9] – makes possible to visualize the buildings with specified parameters, draw the working drawings up;

2. Computer-aided design in the PC Lira [10] - allows to make all types of calculations, get the ready-made technical documents;
3. Work in the electronic help system StroyConsultant - electronic database of regulatory documents of the construction industry.

The course aims to create an educational environment in which it is possible to develop the ability to initiate and lead a holistic and integrated process of design, construction and life cycle management through BIM, focused on a joint and interdisciplinary building design process. Studying the course, the students acquire the additional skills focused on information modeling and building management, which will allow them to work as BIM specialists in the practice of building design and in the construction industry. For the frequency of the experiment, the testing on the possession of professional skills at the initial and final stages of studying this course was conducted, in which 50 third-year students took part. The results showed a good rate of increase in the main indicators shown in Figure 1.

![Figure 1. The control tests results](image_url)

Students in the final qualification work were asked to design the building using CAD software, where they applied the knowledge gained from integrated BIM in theory and practice. According to the results of the work, one of the most important advantages noted by the students was how easy it is to get the building documentation from the BIM model, significantly expanding the design decision metrics. The process of facilitating the collaboration between different disciplines and identifying the conflicts at the design stages of the project was an important plus.

In our opinion, as a result of the BIM technologies’ successful implementation in the educational process, we will get the following results:

- An unambiguous understanding of the information necessary for a customer of any level, namely, the standards, methods, processes, deadlines and protocols that will govern the entire technological and production process.

- the quantitative and qualitative criteria for the information produced will be sufficient to meet certain customer information needs, while ensuring the functionality and safety of all processes

- the regulated exchange of information between the project participants will be effective, which will lead to absolute transparency of the development life cycle from design and implementation to operation

- a secondary, but no less important result of the implementation will be the reduction of waste during the design, construction, operation and maintenance, as well as the reduction of risk.

The introduction of BIM technologies in the educational process is not an easy task, requiring the training of teachers first. The difficulties faced by the authors when introducing the BIM technology into the educational process are [11]:

1. The complexity of integrating technology into the curriculum.
2. Lack of knowledge by the tutors teaching BIM disciplines and other modern technologies and work processes.

3. The reluctance of the teachers to change the established teaching methods in combination with the reluctance of some to learn new technologies.

4. Reluctance of existing the design organizations to cooperate with vocational schools.

At the moment, the graduates of vocational schools getting into construction companies can only read blueprints, perform geodetic work and use regulatory literature. But with the development of digitalization and building technologies, modern professionals will experience a growing lack of professional knowledge and skills. The introduction of BIM technologies into the educational process will allow using the 3D model for architectural solutions, monitoring the implementation of construction and installation works.

Vocational schools are aimed today at developing practical skills, the students have little opportunity to engage in research or design after training. In this regard, we must keep up to date, develop the students’ talents in building technologies, adjust the educational curriculum, teaching content, teaching methods and actively introduce BIM technologies, work closely with large construction corporations of the country for internships and further employment.

Today, students study mainly the software for designing or 3D modeling of buildings and structures, but the problem how to apply BIM technology in studying process remains acute. We have developed the guidelines where the steps and content of the tools’ connectivity are spelled out.

The graduates of a professional school should fully understand the role and potential of BIM for the construction industry, be able to plan the use of BIM in construction projects and ensure the right level of detail:
- to be able to comply with legal requirements and project cooperation;
- to identify, describe and apply the adequate modeling methods taking into account the customer’s requirements;
- to understand and implement BIM models for the specialties in the construction industry;
- to use parametric approaches to create complex objects;
- to be able to use the objects extensively in the BIM context through the interactive editors and object libraries;
- to apply the scripts to expand the capabilities of existing BIM platforms towards individual capabilities;
- to be able to evaluate the problems of interaction in BIM from a technical, semantic and organizational point of view;
- to apply methods for developing schemes and databases that are relevant to BIM, as well as the methods for exchanging specifications for building products;
- to be able to successfully solve the problems of interaction in BIM based on the exchange of design information in infrastructure and construction projects;
- to understand how a single BIM data environment can support other processes;
- to apply the possibility of BIM widespread use in professional activities.

The students and graduates will be able to apply the developed competencies in the training course, in the design, construction and operation of existing buildings. We can say that the BIM competencies do not contradict the Federal educational standard, but even complement and deepen. When developing the competency “Participation in the design of buildings and structures” FGES 3 in the training course:
1. Some BIM competencies will be applicable to several disciplines and roles, while other competencies will be specific to one discipline.
2. The same BIM competencies can be provided and measured in different ways.

Summary
Today there are many interested representatives of the BIM technologies’ introduction in education. Professional educational organizations introduce BIM technologies to the learning process whenever it
is possible. On the part of construction companies, investments in teaching BIM technologies with a clear focus on the development of the builders’ technical potential.

Thus, although the significant progress has been made over the past few years, the significant efforts are still required to expand education in the field of BIM technologies, overcoming the professional boundaries, and to encourage the stakeholders to establish a closer cooperation approach to training and project implementation in the field of BIM technology.

The result of the study is the effectiveness and practicality of introducing BIM technologies into the educational process. However, the following aspects must be fulfilled:

- to develop the theoretical and pedagogical tools that allow the implementation of BIM technologies;
- to develop the training programs that include BIM as an integral part of the modern building design process;
- practical use of the training process, according to the requirements of employers;
- obtaining a complete set of construction documents;
- the relationship of the studied professional disciplines with a future profession;
- create an educational information culture where BIM can provide an educational environment.

Verificaton models and BIM technologies used in construction can be used to evaluate the students’ performance:

- it can be viewed from any angle; it can be thoroughly studied to easily check for completeness and analyze how it works.
- the schedules to verify the completion of the assignment can be created: area schedules, room schedules, efficiency, etc.

Model validation can be used to evaluate the realistic spatial tolerances (e.g. staircase width, wall thickness, dimensions of structures and ducts), etc.

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