SOBRE A ADOÇÃO DA TECNOLOGIA BIM NO PROCESSO EDUCACIONAL DO ENSINO DA ENGENHARIA CIVIL

ON THE ADOPTION OF BIM-TECHNOLOGY IN THE EDUCATIONAL PROCESS OF TEACHING CIVIL ENGINEERS

О ПРИНЯТИИ ТИМ-ТЕХНОЛОГИИ В ОБРАЗОВАТЕЛЬНОМ ПРОЦЕССЕ ОБУЧЕНИЯ ИНЖЕНЕРОВ-СТРОИТЕЛЕЙ

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Received 12 November 2018; received in revised form 02 December 2018; accepted 28 December 2018

RESUMO

O artigo descreve o problema de melhorar o sistema de ensino de futuros engenheiros civis, em conexão com o desenvolvimento estratégico da indústria da construção. Formulários existentes, métodos de ensino de graduados de uma universidade de construção são estudados. A essência da modelagem de informações Tecnologias de Modelagem da Informação da Construção (BIM - *Building Information Model*) são analisadas. As correspondências entre os conhecimentos, competências e habilidades adquiridas pelos alunos no curso de estudo das disciplinas da área 08.03.01. Construção e funções dos especialistas que participam do projeto-BIM são revelados. O algoritmo de adoção de modelagem de informações de tecnologias BIM no processo educacional de futuros engenheiros civis é proposto com o objetivo de melhorar a qualificação de especialistas que são proficientes em tecnologias modernas do projeto de operações de construção.

Palavras-chave: *Tecnologias-BIM, produção de construção, processo educacional, formação de engenheiros civis, ciclo de vida de um projeto de construção.*

ABSTRACT

The article outlines the problem of improving the system of teaching future civil engineers, in connection with the strategic development of the construction industry. Existing forms, methods of teaching graduates of a construction university are studied. The essence of information modeling Buildings Information Modeling (BIM) technologies – is analyzed. The correspondences between the knowledge, skills, and abilities acquired by the students in the course of study of the disciplines of the area 08.03.01. Construction and roles of specialists participating in the BIM-projecting are revealed. The algorithm of adoption of information modeling of BIM-technologies into the educational process of future civil engineers is proposed with the purpose of improving the qualification of specialists who are proficient in modern technologies of the design of construction operations.

Keywords: *BIM-technologies, construction production, educational process, training of civil engineers, life cycle of a construction project.*

АННОТАЦИЯ

В статье излагается проблема совершенствования системы обучения будущих инженеров-строителей в связи со стратегическим развитием строительной отрасли. Изучаются существующие формы, методы обучения выпускников строительного вуза. Анализируется сущность информационного моделирования зданий и технологий информационного моделирования (ТИМ). Установлены

соответствия между знаниями, умениями и навыками, приобретенными студентами в ходе изучения дисциплин области 08.03.01 Строительство и роль специалистов, участвующих в ТИМ-проектировании. Предложен алгоритм внедрения информационного моделирования ТИМ-технологий в учебный процесс будущих инженеров-строителей с целью повышения квалификации специалистов, владеющих современными технологиями проектирования строительных работ.

Ключевые слова: *ТИМ-технология, строительное производство, учебный процесс, подготовка инженеров-строителей, жизненный цикл строительного проекта.*

INTRODUCTION

Building information modelling (BIM) has been changing the practice in the architecture, engineering and construction (AEC) industry. Uptake of BIM radically changes the workflow of a construction project, changes communication among different professions, and creates new job opportunities. Many Universities providing AEC courses are facing the challenge to incorporate BIM into the curricula so that their graduates are BIM-ready. It seems that there has not been any consensus on how BIM should be embraced into AEC education. Many universities are still experimenting and finding their way. Some have developed standalone BIM subjects whereas some have diffused BIM elements into the existing curricula. Some introduced BIM in the first year to lay the foundation whereas some put BIM as capstone subjects when student have acquired sufficient background knowledge.

BIM education has started early in the United States (US) and its development in the US is relatively more mature than that of Australia. However, according to Camarinha, BIM in the US generally has a rather narrow focus on visualization and clash detection and BIM education in the US implements a few of 40 functional areas of BIM identified by BuildingSmart International. Recently, the Academic Interoperability Coalition (AIC) called for a consensus about BIM education and aims to define a basis for curriculum development. This reflects that BIM education development still has a long way to go. Research on BIM education is somewhat limited. Many aspects of BIM education are still awaiting further investigation (Camarinha, 2016).

In 2015, the National Association of Surveyors and Designers (NOPRIZ) presents the strategy of innovative development of the construction industry until 2030. During the development of this document, attention is focused on the block devoted to innovative

methods of development, including information modeling – BIM-technologies (NOPRIZ...). In the same year, 2015, at the highest architectural and construction educational institutions of the Russian Federation, the first bachelors' students graduated who entered in 2011. At the same time, the system of sectoral education did not adequately provide the necessary level of unity of competence requirements (qualification) and the quality of graduate's training, and the construction industry was not ready for a mass adequate inclusion of graduates – bachelors in the production process (Project..., 2015).

The Ministry of Construction and Housing and Communal Services of the Russian Federation has embarked on a plan for the phased introduction of BIM-technologies in the field of industrial and civil construction (Ministry of Construction..., 2015). As a result, the demand for graduates of construction specialties, capable of using BIM-technologies in the field of construction, has increased. Professor V.V. Talapov notes: "with the training of information modeling in our universities almost nothing has changed, we simply do not prepare such specialists. Although some centers of BIM implementation in the masses still exist and even develop" (Talapov, 2014; Krivonogov *et al.*, 2018; Dainty *et al.*, 2015).

The problem is:

- On the one hand, the graduates turned out not to be adapted to the needs of the construction industry aimed at strategic development, their qualifications do not meet the requirements of employers;

- On the other hand, educational programs under the conditions of transition to the Bologna education system were often in the modernizing stage of compliance with modern technologies and lack of relevant knowledge among teachers in the field of new technologies.

In addition, V.V. Talapov notes: "The main problem of the construction universities of our

country is that the system of training specialists in them has developed in the 1930s and has not changed seriously since then. This system is based on the individual work of each student within his or her major. No collective work or joint work with adjacent sections is supposed at all, everyone gets used to working for himself and is not interested in what others are doing on the same project. Even when a complex thesis work is carried out, which has, for example, two authors, the rules require a clear boundary between what one of them did and what the other did.

At the same time, BIM is a collective technology, based on a single model and involving close interaction of specialists in all areas of design, construction, and operation of a building. So the existing university approach needs to be fundamentally changed, otherwise, we will continue to stumble on the issue of training personnel knowing BIM" (Talapov, 2014).

SUBJECTS AND METHODS

In this regard, the higher school faces the task of developing and introducing into the educational process the means, methods, and technologies aimed at the quality of training of the future civil engineer capable of carrying out the innovative development of the construction industry. The actual goal is the improvement of educational processes so that the graduate of a construction university professionally possessed not only the most modern tools but also design technologies (Kassem *et al.*, 2015; Pärn *et al.*, 2017; Scott, 2015).

Buildings information modeling (BIM) is the process of collective creation and use of information about a structure that forms the basis for all decisions during the life cycle of a construction project (from the planning stage to design, production documentation, design, construction, operation, and demolition). BIM is not a specific computer program. This is a new design technology. Hence, it is logical to understand BIM as a methodology. When teaching the BIM-methodology, it is necessary to clearly separate teaching to BIM tools and how to rebuild educational processes in connection with the implementation of the BIM-methodology of design. The majority of participants are engaged in teaching BIM-tools, and very few people are engaged in teaching BIM-methodology, changing design processes. Without this, it is impossible to

actually implement BIM (Reuter, 2016; Shelbourn *et al.*, 2016).

BIM is a defined principle of the work of specialized professionals at all stages of the life cycle of construction projects – adjacent designers: architects, constructors, specialists in engineering networks, specialists in working documentation (estimates, logisticians and others), etc. According to BIM, they all work in a single related model.

The analysis of working curriculums for the area 08.03.01 Construction, various majors, allows one to designate that in the process of studying various disciplines that are part of the educational program of civil engineers, students pass all roles of designers, at all stages of the life cycle of the building. Table 1 gives an analysis of the working curriculum of the area Construction, the major "Industrial and civil construction", which shows the development of the roles of designers of the life cycle of buildings, in the process of training future civil engineers in specific subjects of the educational program.

The analysis shows that the set of roles of the designers of the life cycle of buildings from subject to subject increases with the growth of the academic year. For the disciplines of senior students is characteristic that in one subject students can (should) be in the role of each of the designers of the life cycle of a construction object. Understanding the essence of BIM-modeling and its use in educational process, it is natural, from the first years, to offer students a project of building structures with a set of drawings, presentation videos and graphic materials, and to implement a complex design of the building with increasing complexity each term up to final qualifying work. This will allow a student to create and upgrade his project throughout the training period, to accumulate and expand it in the process of performing laboratory, computational, graphical, coursework, creative and other works with possible achieving of a new, better level of the thesis design. This approach allows not to perform chaotic, dot works, but to see its activity as an integrated, systemic, aimed at forming competencies for creating and working on global professionally oriented projects during the education process.

To successfully implement the described approach, fundamental changes in the educational process should take place, taking into account the essence of BIM technology. The difficulty here is that at the moment there are

recommendations on the introduction of BIM technologies in construction companies, production (Basic principles...; Talapov, 2016; Implementation of BIM...; Pismerov, 2012), but for the introduction of the designated design technology in the educational process of training future civil engineers, the material is not sufficient.

RESULTS:

The authors propose an algorithm for organizing the activity on the introduction of BIM technology into the educational process for teaching future civil engineers (Figure 1), which contains the following blocks.

Block 1 – Preparatory. or effective reorganization of education in an educational institution when BIM is implemented strategically, it is necessary to determine what changes the educational organization currently needs, at what organizational level of education the changes will be introduced, and what most important consequences are expected, and also to develop a further planned strategy.

The process of strategic planning of changes, first of all, should be aimed at identifying the critical needs of the educational institution and the designated goals. In addition to assessing the technical and financial aspects of the planned changes, it is necessary to assess the extent to which the teaching staff is ready to accept changes; whether the educational institution has the potential, for example, human resources (faculty, cooperation with construction companies, specialists in computer centers, etc.), who have the necessary qualifications to carry out projects on changes; and what technologies will be required for this. This block identifies the strategies and objectives, the development of a plan for their implementation; definition of the criteria for meeting the goals; evaluation according to the criteria for meeting the goals; development of corrective actions for improvement.

Block 2 – Formation of the pilot BIM group and its activities. A working group is being formed – a pilot BIM group that develops a program of management and correction of teaching in disciplines. In the process of BIM design, specialists/teachers of various specializations take part in the production/educational process, in accordance with all stages of the life cycle of buildings. The pilot BIM group should include

teachers of principal subjects, where knowledge, skills, and abilities are formed in each of the stages of the life cycle of buildings, as well as representatives of interested enterprises. This will allow establishing interdisciplinary communication, which is important for the BIM-design, where one has to think a few steps ahead. In particular, when working with parts of the model, we must clearly imagine how this will later be combined into a single whole.

Block 3 – Phased implementation of BIM. It provides three stages of implementing BIM-technology directly into the educational process:

The 1st stage is held within the framework of separate disciplines. The 2nd stage begins in the framework of interdisciplinary integration. The 3rd stage takes place within the whole educational process, in the conditions of well-developed implementation processes with clearly defined input data, procedures, roles of the people involved and the results of each step.

Thus, BIM technologies can be used in the educational process from the point (local) stage to the end-to-end (global) design throughout the entire educational process. All activities are regulated by regulatory documents, didactic and methodological materials.

The main difficulties in implementing a new technology arise in the first two stages (local and scalable implementation) since they are the most knowledge-intensive. It is at these stages that procedures are laid and developed that require unique knowledge and skills of developers (Grishina *et al.*; Anufriev *et al.*; Zakharova and Krivonogov, 2016a; Zakharova and Krivonogov, 2016b).

CONCLUSIONS:

Like the introduction of any complex information system, the introduction of BIM technology entails complexity, primarily because the unknown always seems more significant and complex. The unsuccessful implementation occurs, in particular, because some believe that learning software is enough to switch to new technology within the industry, in particular, in the training of civil engineers – skilled personnel for the construction industry, in which innovative development and the inevitable transition take place to a new design style. It turns out that they apply new tools to old methods, old processes and the previous structure of their organization,

but first it is necessary to correctly change the processes.

It is important to correctly identify goals and priorities and find ways of their implementation. The main thing is to remember that in itself, learning to individual software products will not help to implement BIM – this is a typical misconception.

Information modeling technologies – BIM design in the field of construction are moving from the category of innovation to the industry standard. Consequently, the task of training personnel with a new full-fledged BIM thinking in the design, construction, and operation of facilities is a priority and relevant for construction universities and construction industry. The strategic development of the construction industry with an orientation toward informational modeling of building objects is aimed at changing the methods and technologies of training future civil engineers ready for collective work, which BIM design cannot exist without. The entire educational process should be built on close cooperation between student teams and end-to-end system design throughout the entire course of studies at the university. The concept of innovative construction education should allow organizing the education of future civil engineers, consistently reflecting the entire lifecycle of construction projects ("Plan – Design – Implement – Manage").

For successful development and implementation of new educational programs and technologies for teaching innovative methods of modern information modeling, it is necessary to create a single team of an educational program, which includes methodologists of vocational education, teachers of principal subjects, and representatives of interested enterprises.

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Table 1. Mastering the roles of designers of the life cycle of a construction project in some disciplines in teaching students in the area 08.03.01 Construction, the major "Industrial and civil construction"

Year	Subject (discipline)	Form control	of	The roles of designers at the stages of the life cycle of BIM-design
I year	Engineering and computer graphics	credit		Architect, constructor
	Fundamentals of Architecture and Building Constructions	exam		Architect, constructor
	Electricity supply and the basics of electrical engineering	exam		Specialists in engineering networks
	Fundamentals of heat and gas supply and ventilation	credit, course project		Specialists in engineering networks
	Fundamentals of water supply and water disposal	credit, course project		Specialists in engineering networks
II year	Technological processes in construction	exam, course project		Technologist
	The architecture of buildings and structures	credit, course project		Architect, constructor
	Organization, planning, and management in construction	credit, exam		Specialists in working documentation
	Technology of building	exam, course project		Technologist
	Polymeric materials constructions	credit, exam, course project		constructor
III year	Metal structures, including welding	exam, course project		constructor
	Reinforced concrete and stone structures	exam, course project		constructor
	The architecture of buildings and structures	exam, course project		Architect, constructor
	Metal structures, including welding	exam, course project		constructor
	Reinforced concrete and stone structures	exam, course project		constructor
IV year	Foundations	credit,		constructor

	exam, course project	
Automated calculation of building structures	credit	constructor
The organization, planning, and management in construction	exam, course project	Specialists in working documentation
Pricing in construction and budgeting	exam, course project	Specialists of the estimates
<u>Elective courses:</u> ▪ Designing large-span and special buildings and structures ▪ Space-planning solutions in the reconstruction ▪ Designing buildings for areas with specific geophysical conditions	credit	Architect, constructor, Specialists in engineering networks, Specialists in working documentation, specialists in the operation of structures
<u>Elective courses:</u> ▪ Wear building structures and assessment of the technical condition of buildings ▪ The technology of repair and restoration works ▪ Building operation and control of their technical condition	credit	specialists in the operation of structures, Technologist
<u>Elective courses:</u> ▪ Engineering survey in construction ▪ Strengthening of building structures	credit	constructor, Specialists in engineering networks
▪ Technology and organization of construction ▪ Construction organization in the reconstruction of buildings and structures ▪ Construction of buildings in severe climate conditions	credit	Architect, constructor, Specialists in engineering networks, Specialists in working documentation, specialists in the operation of structures
▪ Automated design in construction ▪ CAD-based building design	credit, course project

Figure 1. The algorithm of the organization of activity on phased implementation of BIM technologies into the educational process