Theoretical Foundations of Training Students in the Building Information Modeling in the Context of Sustainable Development of the Construction Industry

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Abstract: In connection with the implementation of the state program «Digital Economy of the Russian Federation», there is an increase in demand for engineers who have competence in the field of building information modeling (BIM). Only such professional staff will be able to ensure the sustainable development of the construction industry in the context of its digitalization. The article is devoted to the problem of insufficient teaching of bachelors and masters for BIM design. The purpose of the article is to develop a minor in the form of an online course «Building Information Modeling Technologies», designed for students studying bachelor's and master's programs at the Institute of Construction and Architecture. The method used is a general scientific method, namely, the analysis of scientific and methodological literature and normative documents on the topic of the study. The practical value of the work lies in the development of the structure of the minor academic plan and its content, which can later be used in universities to teach students for professional activities in the field of BIM design of construction objects.

1 INTRODUCTION

The state program «Digital Economy of the Russian Federation» is being implemented in the Russian Federation with the aim of creating a digital economy ecosystem in which digital data is a key factor of production in all spheres of socio-economic activity, including construction.

It is obvious that the sustainable development of the construction industry in the context of the digitalization of the economy involves the use of personnel employed in this field, developed platforms, technologies, institutional and infrastructure environment.

A number of researchers (Rothenbusch et al., 2021) call BIM (building information modeling) technology one of the trends in the construction industry digitalization.

It is obvious that specialists who are trained for professional activity in the construction objects design should be confident in the technology of information modeling.

The demand for specialists in this field is also determined by the trend towards the mass introduction of BIM technology in Russian enterprises according to the action plan for the implementation of the assessment of the economic efficiency of investment justification and information modeling technologies, approved by the Government of the Russian Federation on April 11, 2017, No. 2468p-P9.

However, an analysis of the academic plans of universities that train future builders has shown that the training of students in BIM technology is not intended. This circumstance determines the problem of the study.

The implementation of the state program «Digital Economy of the Russian Federation» requires close cooperation between the state, business, and science, which will inevitably entail the formation of state order for universities to train personnel who would

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have the necessary competencies to work with information modeling technology. This determines the relevance of the research topic.

The purpose of the article is to develop and offer a minor in the form of an online course «Building Information Modeling Technologies».

To achieve the goal of the research, it is necessary to solve the following tasks: to analyze scientific articles in this field; to determine the competencies that a specialist in information modeling in the field of construction should have; to develop a basic academic plan and content of the minor; to propose methods for monitoring and evaluating the results of the formation of competence in the field of BIM technology application, as well as recommendations for the formation of staff who teach students BIM technology.

2 LITERATURE REVIEW

The problem of training specialists in higher educational institutions with a certain level of competence to work with BIM technology is an urgent problem, which is confirmed by a number of studies.

Thus, over the past decade, the global construction industry has demonstrated an obvious and urgent need for professionals who know the technology of building information modeling (Chen et al., 2020).

The studies (Goldobina and Orlov, 2017; Yakshina et al., 2019) speak about the need to improve the system of training and implementation of BIM technology in the process of training civil engineers as part of the strategic development of the construction industry.

However, despite the increasingly widespread adoption of building information modeling technology, a steady stream of graduates ready to work with BIM, required to meet the demand in the industry, still cannot be identified (Casasayas et al., 2021).

The study (Maharika et al., 2020) notes that most of the current BIM implementation models are focused more on the construction industry (consulting firms and contractors) and less on higher education institutions. Responsibility for BIM education should be shared between industry and academia (Sampaio, 2021). Many researchers want cooperation between universities and industry (Chen, Lu, Wang, 2020).

The obstacles that make it difficult to prepare graduates of the appropriate level in the field of BIM technology proficiency were highlighted (Casasayas et al., 2021):

- The gap between the educational sphere and the construction industry;
- Problems of managing changes in the educational process;
- Limitations of educational and thematic plans and program content;
- Lack of teachers with the necessary qualifications.

It is quite obvious that these problems require finding solutions with the joint participation of representatives of higher educational institutions and the construction sector. However, some researchers associate a number of questions with these problems, to which there are no answers yet. For example, how both parties can contribute to the collaboration to achieve high-quality student learning (Chen et al., 2020).

The inclusion of BIM in university academic plans, along with core engineering disciplines, has been gaining momentum in recent years. BIM's models of integration into the learning process vary significantly from country to country in terms of the approaches, strategies, and methods applied to the professional and academic environment (Isanović and Colakoglu, 2020). According to the authors of this article, high-quality training of students to work with information modeling technology is a determining factor for the further sustainable development of construction, architecture, and other engineering areas within the framework of digitalization of the construction industry in Russia.

The implementation of the minor «Building Information Modeling Technologies» is one of the tools for the formation of a competitive construction industry that meets high standards of quality and efficiency, working on the basis of modern financial, economic, technical and managerial mechanisms.

3 METHOD

The interdisciplinary character of the article covers research at the intersection of pedagogical, economic and engineering sciences. In this connection, it was necessary to analyze a wide range of issues affecting the theoretical foundations of the digitalization of the construction sector and the training of BIM technology in the educational process of higher educational institutions.

To achieve the goal of the study, a general scientific method was used, namely, the analysis of

scientific and methodological literature and regulatory documents on the issues of digitalization of construction and the development of BIM technology.

Within the framework of the study, a target group of people was identified for whom the proposed minor «Building Information Modeling Technologies» is designed – it includes students studying bachelor's and master's educational programs in the field of construction.

The purpose of the minor program is to develop student's competence (relevant knowledge, skills, and experiences) to perform professional activities in the field of investment and construction project management using BIM technology.

4 RESULTS AND DISCUSSION

Minor «Building Information Modeling Technologies» is focused on professional standards for construction and design: Architect, Head of a construction organization, Specialist in the field of assessment and expertise for urban planning, Specialist in the field of engineering and technical design for urban planning, Organizer of design production in construction and professional standard for IT – Information Technology Manager.

The list of competencies that a specialist in information modeling in the field of construction should have:

- Availability of knowledge about the features of information modeling of construction objects with the use of special computer programs;
- Ability to develop project documentation based on the results of engineering and technical design;
- Ability to develop the architectural section of project documentation in investment and construction projects.

The minor developed in the framework of the research is focused on the formation of the basics of the listed competencies in students.

4.1 Minor Structure

To learning the minor «Building Information Modeling Technologies», 72 hours are required, including 18 hours – lectures, 36 hours – laboratory classes, 18 hours – independent work.

The form of implementation of the minor is full-time and part-time, with the use of distance educational technologies (e-learning), 4-6 hours a week.

The form of assimilation control of the minor is a test.

4.1.1 Content

The minor «Building Information Modeling Technologies» includes 6 topics.

Topic 1. Introduction to the Autodesk Revit software. Interface. Opportunities.

Topic Content 1: Software Interface. Basic principles of working in the Autodesk Revit environment. Developing of project and working documentation in Autodesk Revit.

Topic 2. Basic principles of working with families in the information model project.

Topic Content 2: Defining a family. Classification of families. Templates for creating families. Learning the interface of the family editor. The creation of a family, the download to the project, and location. The graphics of the family and creating specifications. Creating parameters.

Topic 3. Studying the features of data exchange between information modeling programs.

Topic Content 3: Import of drawings from CAD (computer-design automation systems). Export of project information to calculation complexes.

Topic 4. Visual programming: learning the basics.

Topic Content 4: Features of creating code for automating work on an investment and construction project. Interaction with project elements. Creating objects along a complex trajectory. Features of the placement of components. Finishing depending on the parameters of the projected object.

Topic 5. Working with projects: review, analysis, and verification.

Topic Content 5: Program formats. Performing a project build. Performing a check for intersections (collisions). Visualization in a software environment.

Topic 6. Working together on projects.

Topic Content 6. Basic principles of working together on a project. Storage of information in the cloud storage. Ways to link files for collaboration, a common coordinate system. Features of the distribution of functions between the specialists of the project department. Exploring of the «Collaboration panel».

4.1.2 Academic Plan

Table 1 shows the Academic plan of the minor «Building Information Modeling Technologies» developed by the authors of the article.

Table 1: Academic plan.

The number of topic	Hours	T.U.*	Including **		
			L.	L.C.	I.W.
1	12		3	6	3
2	12		3	6	3
3	10		3	4	3
4	12		3	6	3
5	12		3	6	3
6	12		3	6	3
Attestation	2	0	0	2	0
Total	72	1	18	36	18
List of abbreviations: * T.U. − test units; ** L. −lectures; L.C. −laboratory classes; I.W. − independent work.					

A feature of the learning process within the framework of the minor is its pronounced practice-oriented orientation. The increased volume of laboratory classes, the transfer of part of the educational process to independent work allows students to consistently master the basics of information modeling technology without interrupting the main educational process.

4.1.3 Monitoring and Evaluation of Results

The current control over the development of the minor is carried out by testing at different stages of training. The final control is carried out in the form of a test and a final laboratory work, for the performance of which the student receives a «pass test».

The development of test tasks is at the competence of the staff of the minor. Table 2 shows the criteria developed by the article authors for evaluating the results of students in the minor program development.

Table 2: Results and evaluation criteria.

Student results	Criteria for evaluation
1. Knows the methodology of information modeling of project elements.	Demonstrates management of the information modeling environment elements.
	There is a more complex element of the project.
2. Knows how to exchange data between programs that are used in the design and implementation of calculations.	The model created in Autodesk Revit was imported into another software package (anyone).
	Demonstrates management of the «Collaboration panel» functionality in Autodesk Revit.
3. Knows the methodology of working together on projects.	Answered correctly on at least 70% of the test tasks.

After passing the test and completing the final laboratory work, students sum up the results of training in the minor, taking into account the level approach in determining the level of competence formation (Paharenko and Zol'nikova, 2012):

- High level of BIM competence: the training material is fully mastered, the student fully understands the methodology of information modeling of project elements, methods of data exchange between programs, and methods of joint work on projects.
- Basic level of BIM competence: the training material of the minor is sufficiently mastered, the student is familiar with the methodology of information modeling of project elements, knows the ways of data exchange between programs and the methodology of joint work on projects, but makes minor mistakes. It is recommended to pay attention to independent work in programs for information modeling of construction objects.
- Average level of BIM competence: the training material of the minor is not sufficiently mastered, the student at the initial level knows the methodology of information modeling of project elements, methods of data exchange between programs, and methods of joint work on projects while making significant mistakes. It is recommended to pay attention to the repeated study of the theory, independent work in programs for information modeling of construction objects.
- Low level of BIM competence: the training material of the minor is poorly mastered by the student, the information modeling methodology is insufficiently studied, and allows a significant number of errors. It is recommended to pay attention to the repeated study of the theory and additional literature, as well as to independent work in programs for information modeling of construction objects.

4.2 Faculty Members

When implementing the minor, the combined teaching staff is recommended. It is advisable that lectures for students studying in the field of construction should be conducted by teachers of the main engineering disciplines. It is advisable to conduct laboratory classes for invited teachers-employees of construction organizations specializing in design using BIM technology.

This approach to the formation of teaching staff in the study of BIM technology has several advantages.

Firstly, the professional competencies of teachers of engineering disciplines allow students to easily present lecture materials in the field of building information modeling. Secondly, in the laboratory classes, students who master the minor have the opportunity to get answers to questions related to information modeling technology from practical teachers in this field.

Thus, the involvement of combined teaching staff in the implementation of the minor allows students to comprehensively master the advanced capabilities of digital technologies in the development of information models of buildings.

4.3 Requirements for the Results of Passing the Minor

The results of the development of the minor are:

- Knowledge of the methodology of modeling information model project elements using special computer programs;
- Ability to apply the basic principles of data exchange between computer programs for designing and performing calculations;
- Practical knowledge of the technology for performing joint work on an information model in an investment and construction project.

The totality of these results determines the competence that is necessary for a competitive specialist of building information modeling.

The following advantages are provided by students studying BIM technology at universities without interrupting the main educational process:

- Mastering the technology of information modeling even before the beginning of professional activity;
- Lectures, laboratory classes, and independent work in the complex allow students to master the theory and practice of using BIM;
- Interaction between students and teachers-employees of project organizations contributes to the establishment of new professional contacts in the future.

Thus, students who have been trained in the minor «Building Information Modeling Technologies» are prepared for professional activities in organizations focused on designing with the use of BIM technology.

5 CONCLUSIONS

The use of BIM technology in construction companies today is carried out on an initiative basis since in this area in the Russian Federation there is no state-mandated requirement for its mandatory implementation (Chikovskaya, 2013).

However, due to the trend towards the mass implementation of BIM technology in Russian enterprises, according to the action plan approved by the Government of the Russian Federation on April 11, 2017, No. 2468p-P9, the demand for specialists who own BIM is growing every year.

The article specifies the competencies that a specialist in information modeling in the construction field should have. On their basis, the academic plan and minor content were developed in the online course form «Building Information Modeling Technologies» for master's and bachelor's degree students studying in the construction field, which allows us to state that the goal of the study has been achieved.

The analysis of scientific articles in this field has shown that there are problems that make it difficult to teach information modeling technologies to students in higher educational institutions.

However, these problems can be solved by organizing the educational process through the joint efforts of the higher educational teachers and the construction sector specialists.

Methods of monitoring and evaluating the results of the minor study were developed. Recommendations on the teaching staff formation are given.

The study of the minor is aimed at forming the necessary professional competence of future developers of investment and construction projects based on information modeling technology. In the future, this will facilitate the selection of personnel for design organizations specializing in BIM technology, which will contribute to the sustainable development of the construction industry in the context of its digitalization in accordance with the state program «Digital Economy of the Russian Federation».

We hope for the introduction of this minor in Russian higher educational institutions for high-quality training of specialists in the field of information modeling of construction objects.

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