

BOOK A

15TH INTERNATIONAL CONFERENCE ORGANIZATION, TECHNOLOGY AND MANAGEMENT IN CONSTRUCTION

Education Towards the Use of BIM on the Example of Polish Universities

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Abstract:

BIM (Building Information Modeling) has been one of the rapidly developing fields of digital techniques supporting the realization of construction projects in recent years. Further development, and especially the use of these techniques, depends to a large extent on the qualifications of young construction engineers who start their professional careers in this field. The article attempts to synthetically list and compare subjects, specializations or fields related to teaching about the BIM methodology in Polish universities curricula. The aim of the study is to present the key factors and differences in the approach to education in this field and on this basis an attempt to formulate conclusions regarding the optimal way of conducting the didactic process in the field of BIM education. The subject of the research were BIM education offers at Polish universities at various levels of education. The places where education occur at Polish universities were identified and the time of implementing BIM technology teaching was compared. The levels, paths, graduate profile, educational programs, the presence of practical elements, the achieved results as well as the types, forms and modes of conducting classes at individual universities were analyzed. The analysis was conducted on the basis of information available on the Internet about the faculties and programs of education of individual universities, supplemented with additional information obtained in e-mail correspondence and conducted by telephone interviews. As a result of the analyzes, the key guidelines for conducting education at the university level were proposed.

Keywords: *Building information modeling (BIM); engineers' education; construction project management*

1. Introduction

Launching training in the use of BIM methodology in the field of construction project management is necessary to meet the constantly growing requirements of competitiveness, sustainable development and progress of ICT technologies in every field of human activity, including construction. However, in the opinion of the authors, introducing even a few subjects concerning the use of BIM in construction in engineering education programs is not a sufficient measure. According to the research conducted among representatives of companies implementing construction projects (Kosiedowski and Wirkus, 2021), as well as comparing BIM curricula at Polish universities and analyzing the information obtained from teaching staff of these universities, there is a concordance of opinions postulating the extension of the educational offer with separate specializations and even courses of study dedicated to BIM teaching as one of the success factors in popularizing this methodology in the field of construction project management.

1.1 *What is said in the literature and business practice about BIM education?*

Among the researchers, there are opinions about the need to change the traditional way (regime) of education in the field of architecture, engineering and construction (AEC industry) to a new model using BIM (Witt and Kähkönen, 2019, p. 265). There are opinions that all forms of BIM education are important to meet industry needs and provide job prospects for graduates (Witt and Kähkönen, 2019, p. 265; Bozoglu, 2016, p. 161). The obstacles to the introduction of BIM to the curricula were presented in 2008 by Kymmel, distinguishing them into three groups: difficulties in learning and using BIM software, lack of understanding of the BIM process and concept, and issues related to the conditions of the academic environment (Barison and Santos, 2010, chapter 2). Other researchers indicate that one of the key factors of BIM education is the mutual cooperation of students, preparing them for such a practice that occurs later in the BIM modeling process during project work (Baradi et al., 2018, p. 224). BIM teaching methods, due to the type of cooperation between the participants of the didactic process, can be divided into single-faculty, implemented among students of one university faculty, inter-faculty, conducted among students of more than one university faculty, and online, carried out among students of different universities, which simulates the real cooperation of companies implementing projects construction (Barison and Santos, 2010, chapter 3). We can distinguish the existence of 'BIM-based education' where BIM facilitates the learning process and 'BIM-focused education' which aims to learn to use BIM (Witt and Kähkönen, 2019, p. 264). The growing popularity of BIM has resulted in the emergence of new specialized roles among its users, such as a technologist, specialist, leader, coordinator, manager, trainer, expert, etc. (Bozoglu, 2016, p. 155). In connection with the intensifying processes of innovation in construction and the increasingly faster implementation of new technologies, it has recently been possible to notice the development of teaching methodologies adapted to the training of professionals with many years of experience in construction-related professions (AEC) but at risk of exclusion from the labor market due to lack of qualifications in new technologies, including BIM and EPD (Environmental Product Declaration) (Nowak *et al.*, 2021, p. 40-41). In countries leading in terms of BIM implementation, such as the USA, teaching in this field was already in use in the first years of the 21st century (Barison and Santos, 2010, chapter 2), but according to some other researchers there are still no systematic efforts to integrate pedagogical considerations into the way BIM is learned and taught (Hosseini, *et al.*, 2021).

1.2 *BIM educational situation in Poland*

Against this background, the introduction of such teaching in Poland only in 2015, in the opinion of the authors, should be considered significantly delayed, which may also be one of the factors of lower popularity of BIM in Poland. In pilot practical studies carried out in Poland, representatives of companies implementing construction projects indicated the lack of sufficient availability of engineering staff prepared to work in the BIM environment (Kosiedowski and Wirkus, 2021, p. 31). In recent years BIM textbooks have appeared also on the Polish market, partially filling the educational gap in this field, such as Kasznia *et al.* (2020), Salamak (2020), Anger *et al.* (2021) or Nicał *et al.* (2021).

2. **Materials and Methods**

The analysis of the curricula of Polish universities in the field of BIM was carried out in January and was extended in May 2022. Information was obtained on the basis of a review of

curriculum lists and courses on BIM available on the university's websites. If there was a need to supplement the obtained data, it was supplemented with e-mail correspondence and telephone calls with employees performing didactic tasks.

2.1. Chronology of introduction of BIM education offer of Polish universities

2.1.1. 2015

- The Cracow University of Technology is starting postgraduate studies 'BIM – digital technologies in architecture and construction' [I, II].

2.1.2. 2016

- Poznań University of Technology at the Faculty of Civil Engineering introduces to the curriculum a subject 'Technologie BIM – BIM Technology' [III].
- AGH University of Science and Technology of the name Stanisław Staszic in Krakow is launching postgraduate studies 'BIM – modeling and management of information about facilities, infrastructure and construction processes', with the option of choosing one of two educational paths: engineering or management, students have the opportunity to participate in all lectures for both paths and in laboratories of the education path they choose [IV].

2.1.3. 2017

- The Częstochowa University of Technology at the Faculty of Civil Engineering is launching a study field '*Construction using BIM technology*' in intramural and extramural mode [V]. Education is conducted as part of first degree (engineering) and second degree (master's) studies, 7 and 3 semesters, respectively (intramural mode) or 8 and 4 semesters (extramural mode). It is the first university in Poland that has implemented education in BIM technology as part of higher education (not postgraduate) in a separate field of study [VI].
- The Łódź University of Technology is starting to implement postgraduate studies '*BIM - modern working methods in multi-sector project teams*' [VII].
- In the winter semester, the Warsaw University of Technology introduced the '*Inter-faculty Interdisciplinary BIM Project*', under which students from five university faculties prepared a multi-sector construction project using a digital BIM model [VIII, IX].

2.1.4. 2018

- The Lublin University of Technology at the Faculty of Civil Engineering and Architecture in the field of Construction in the curriculum of the second degree studies in the specialization Ecological Construction has the subjects 'Designing residential buildings in BIM technology' and 'Designing public buildings in BIM technology'; in the specialization Roads, Bridges and Ecoinfrastructure is taught subject 'BIM in communication construction' [X].
- Rzeszów University of Technology inaugurates postgraduate studies 'BIM technology in the design and implementation of construction investments' [XI].

- The Silesian University of Technology at the Faculty of Civil Engineering in the field of Construction at the second degree studies conducts a separate specialization 'Bridges with BIM technology' [XII].
- The Kielce University of Technology at the Faculty of Civil Engineering and Architecture, in the field of Construction, introduces a new specialty 'Building Information Modeling (BIM)' [XIII].
- Warsaw University of Technology launches two-semester postgraduate studies in the field of 'BIM Coordinator and Manager' [XIV]. The organizer is two faculties: Civil Engineering as the leading one and Architecture as the cooperating one [XV].

2.1.5. 2019

- Gdańsk University of Technology is starting to conduct postgraduate studies in 'Construction Project Management', which include the presentation of the construction project in terms of inter-sector coordination (sanitary, electrical, telecommunications engineering, thermal protection of the building) and BIM [XVI]. There are also lectures on BIM technology at the Faculty of Architecture at the 1st degree studies: 'Computer and Information Techniques', '3D Modeling' and at the 2nd degree studies: 'New technologies in construction' and 'Computing techniques - integration design processes', each of them lasting 30 hours and other classes at the university: 'Introduction to BIM technology', 'Contemporary architect's workshop BIM', 'BIM design support computer technologies' and 'BIM as a tool supporting risk management of an investment project' (Gęsiak, 2020, p. 15).
- The Cracow University of Technology at the Faculty of Architecture at the 1st degree studies conducts 'Computer techniques in design' in semester 1st (30 hours) and 'BIM techniques in design' in semesters 2nd (30 hours) and 3rd (30 hours) (Gęsiak, 2020, p. 14).
- The Łódź University of Technology at the Faculty of Architecture at first degree studies conducts the subjects of 'BIM Basics' (30 hours) and 'Basics of Parametric Architecture' (30 hours) and at the second degree studies 'BIM Architectural Design' (60 hours) and 'BIM – design process integration' (90 hours) (Gęsiak, 2020, p. 16).
- The Poznań University of Technology at the Faculty of Architecture teaches three subjects in the field of digital techniques for a total of 105 hours at the first degree studies, as well as 'Introduction to BIM technology' and 'Parametric design in architecture' classes. (Gęsiak, 2020, p. 16).
- The Warsaw University of Technology at the Faculty of Architecture conducts 'Computer Modeling' classes at the 1st degree studies, and at the 2nd degree studies 'Integration of design processes (BIM)', 45 hours each. (Gęsiak, 2020, p. 13).
- Wrocław University of Science and Technology implements education in the specialization of 'Building Engineering and BIM Modeling' at the 2nd degree studies at the Faculty of Civil Engineering [XVII]. At the Faculty of Architecture, 1st degree studies in the 4th semester are conducted classes in the subject 'BIM Introduction' in the amount of 30 hours (Gęsiak, 2020, p. 14).

- The University of Zielona Góra at the Faculty of Architecture at the 1st degree studies in the 7th semester teaches the subject 'Application of BIM in architecture' in the amount of 30 hours (Gęsiak, 2020, p. 18).
- The West Pomeranian University of Technology in Szczecin at the Faculty of Architecture at the 1st degree studies conducts 30 hours of classes in the subject of 'Introduction to BIM' in the 6th semester, and 'Parametric design' in the 7th semester (45 hours) (Gęsiak, 2020, p. 17).

2.1.6. 2020

- Bydgoszcz University of Technology (University of Technology and Life Sciences until August 2021) from the academic year 2020/2021 at the Faculty of Civil Engineering, Architecture and Environmental Engineering in the field of Civil Engineering, teaching subjects with BIM elements [XVIII].

2.1.7. 2021

- Białystok University of Technology is launching the 'BIM - Modeling and Building Information Management' study field at the Faculty of Civil Engineering and Environmental Sciences (information obtained by the author at the 52nd Scientific Conference Engineering of Building Projects in Białystok [XIX]). Second degree studies are carried out as part of the curriculum 1.5 years in the full-time (intramural) mode [XX]. The creation of this field of study is the university's response to the perceived needs of the market [XXI].

2.1.8. 2022

- Wrocław University of Science and Technology expanded its educational offer from 2019 by introducing the first edition of postgraduate studies 'Multimedia architecture. BIM + Visualization + Mobility' [XXII].

3. Results and Conclusions

Education in the field of BIM began in Poland in 2015 at the Cracow University of Technology, in the following years the educational offer in this field was successively supplemented by other universities, which are summarized in Table 1.

Table 1. Time of first implementation of BIM teaching at Polish universities (source: own work)

Year	University name in English	University name in Polish
2015	Cracow University of Technology	Politechnika Krakowska
2016	AGH University of Science and Technology (Cracow)	Akademia Górniczo-Hutnicza w Krakowie
2017	Poznań University of Technology	Politechnika Poznańska
	Częstochowa University of Technology	Politechnika Częstochowska
	Łódź University of Technology	Politechnika Łódzka
2018	Warsaw University of Technology	Politechnika Warszawska
	Lublin University of Technology	Politechnika Lubelska
	Rzeszów University of Technology	Politechnika Rzeszowska
	Silesian University of Technology	Politechnika Śląska
2019	Kielce University of Technology	Politechnika Świętokrzyska
	Gdańsk University of Technology	Politechnika Gdańska

	Wrocław University of Science and Technology	Politechnika Wrocławska
	University of Zielona Góra	Uniwersytet Zielonogórski
	West Pomeranian University of Technology in Szczecin	Zachodniopom. Uniw. Technolog. w Szczecinie
2020	Bydgoszcz University of Science and Technology	Politechnika Bydgoska
2021	Białystok University of Technology	Politechnika Białostocka

3.1. Juxtaposition and comparison of BIM curricula of Polish universities

There are currently significant differences occurring in Poland between the scope of education in the use of BIM (number of teaching hours, identification of only subjects, or specializations or entire fields of study) at different degrees, types (higher, post-graduate) and modes (intramural, extramural), which is indicated by for the lack of a uniform pattern considered optimal. Hence, it can be concluded that one of the key elements of the success of teaching in the field of BIM may be the development of a model of education in this field.

Table 2. Comparison of BIM curricula at Polish universities (source: own work)

University / Year	2015	2016	2017	2018	2019	2020	2021	2022
AGH Univ. of Science & Technol. in Cracow		G 192 (w:72 + x:120)						
Białystok Univ. of Technology							II F c.e.	
Bydgoszcz Univ. of Science & Technology						II B c.e.		
Częstochowa Univ. of Technology			I+II F					
Gdańsk University of Technology					I+II B 120 G 176			
Cracow University of Technology	G 158 (w:28 + y:130) arch.				I B 90 arch.			
Lublin University of Technology				II B 75 (w:15 + y:60)				
Łódź University of Technology			G 200 (w,m:68 + x,y,p:132)		I+II B 60+150 arch.			
Poznań University of Technology		II B 45 (w:30 + x:15) c.e.			I B 105 arch.			
Rzeszów University of Technology				G 186				
Silesian University of Technology				II S 210				
Kielce University of Technology				II S 450				

Warsaw University of Technology	(I) II B G 256	I+II B 45+45 arch.	
Wrocław University of Science & Technology		I B 30 arch. II S c.e.	G 286
University of Zielona Góra		I B 30 arch.	
West Pomeranian Univ. of Techn. in Szczecin		I B 30+45 arch.	

where: I – 1st degree studies, II – 2nd degree studies, G – postgraduate studies
 F / S – separate field/speciality of BIM, B – selected subjects of BIM
 x – exercises, y – laboratory, p – projects, m – seminars, w – lectures
 arch. / c.e. – architecture / civil engineering faculty the number = classes hours

Until now, separate entire fields of study covering BIM teaching in full-time (intramural) studies are offered by the following Universities of Technology: in Białystok and Częstochowa, while separate BIM specialties are offered by the Silesian, Kielce and Wrocław Universities of Technology. As an alternative, although only partially meeting the criterion of the availability of a separate field or specialization dedicated to BIM education, a supplementary offer of BIM postgraduate studies at a significant part of other Polish universities listed in Table 2 can be considered.

In some cases, there is a differentiation of curricula due to the role to be played by a graduate in the use of BIM after graduation, but it was observed only at some Polish universities, e.g. at AGH in the postgraduate studies program from 2016 possibility of choice the education path as an engineer or a manager, or at the Warsaw University of Technology from 2018 on postgraduate studies as a BIM engineer or BIM coordinator.

The postgraduate studies program of the AGH University of Science and Technology for both educational paths includes the following subjects:

- (1) Introduction to BIM,
 - (2) Technological and process standardization (ISO, OpenBIM),
 - (3) Coordination and data management in interdisciplinary projects,
 - (4) Costing in BIM,
 - (5) BIM and GIS integration,
 - (6) Information management in the cycle facility life,
 - (7) Implementation and advanced aspects of BIM.
- Additionally for the engineering path:
- (8) Acquisition and modeling of multidimensional data,
 - (9) Cubature design in BIM,
 - (10) Installations and construction networks in BIM,
 - (11) Infrastructural projects in BIM,
 - (12) Work automation and programming of BIM platforms.

On the other hand, for the managerial path, the following subjects are additionally provided:

- (8) BIM implementation strategy in the organization,
- (9) BIM project management with the use of cascading methods,
- (10) Lean management in BIM,
- (11) Legal aspects of BIM,
- (12) BIM in terms of agile project management methods [XXIII].

There is a lack of inter-faculty cooperation, e.g. education of managers in cooperation with management departments, trainers in cooperation with pedagogical departments, etc. Currently (2022) the presence of such a practice was found only in the case of studies at the Łódź University of Technology and the Warsaw University of Technology (at both universities from 2017).

The program of postgraduate interdisciplinary studies at the Warsaw University of Technology includes the following modules: BIM in theory and practice, Coordination - BIM standards, 3D modeling in Revit and Archicad programs - divided into beginner or advanced groups, Dynamo and Grasshopper visual programming, Information flows between BIM participants, Tools cross-industry analyzes, Practical implementation of investments in BIM, Project management and BIM processes, Cross-industry BIM project [XXIV].

3.2. Guidelines for conducting education at the university level

According to the authors, BIM should be seen as the process of designing and visualizing buildings supported by appropriate software, so BIM education is not only a programming science. Therefore, it should cover education from the stage of a detailed explanation of the design process, starting from the concept stage, and only in the next stages of education should it be discussed and practically shown how this process can be supported with specific computer software. The research also shows that it should strive to develop BIM education to the level of at least separate specializations, preferably full-time studies dedicated to the BIM methodology. Only individual BIM-related subjects as part of the courses and specializations held so far do not meet the expectations of the constantly growing requirements of the labor market in the professions of architects, engineers and constructors. Due to these growing requirements and increasing specialization in individual industries, it also seems advisable to consider the diversification of study programs at those universities that have not introduced it so far. This should facilitate the graduate's better mastering of specialization of a prospective engineer: designer, contractor, manager or trainer of BIM should perform. In order for engineers to be able to skillfully use BIM in their professional work and learn practical cooperation on a project implemented in a multidisciplinary environment, it is necessary to introduce to university practice, where this is not yet available, the standard of online cooperation of specialists from various industries cooperating in the implementation of the project. As part of supplementary (postgraduate) studies, it is advisable to propose training programs tailored to the needs of experienced specialists in the field of architecture, construction and engineering (AEC), at risk of exclusion from the labor market due to the lack of knowledge of modern ICT techniques, which have been dynamically developing, especially in recent years. According to the authors, solutions to this problem should be sought in the areas of additional educational programs related to the use of computer and ICT

techniques and their practical application in engineering practice, as well as in the wider context of everyday life. As Puolitaival and Kiroff note, the development of an optimal teaching method for such professional groups is not yet completed and requires further research (2021, p. 656).

3.3. Proposed paths of graduating in BIM education

According to the opinion of the authors among the potentially possible, the following BIM learning paths are proposed:

- Option 1: Basic engineering education in the field of construction, implemented in a dedicated BIM field of first degree studies in the profiles of: designer, manager, implementer or trainer. With the possibility of switching to supplementing the education in second degree or postgraduate studies according to option 2.
- Option 2: Basic engineering education in the field of construction with BIM subjects, supplemented with second degree studies with BIM specialization or postgraduate studies with BIM field in the profiles as above.
- Option 3: Basic engineering education in the field of construction or related, without BIM, supplemented with second degree or postgraduate studies in a dedicated BIM field with the division into profiles as above.
- Option 4: For graduates of construction or related studies without knowledge of BIM, postgraduate studies in the program as supplementary second degree studies in option 3.

Diagrams of proposed BIM education paths are shown on Figure 1.

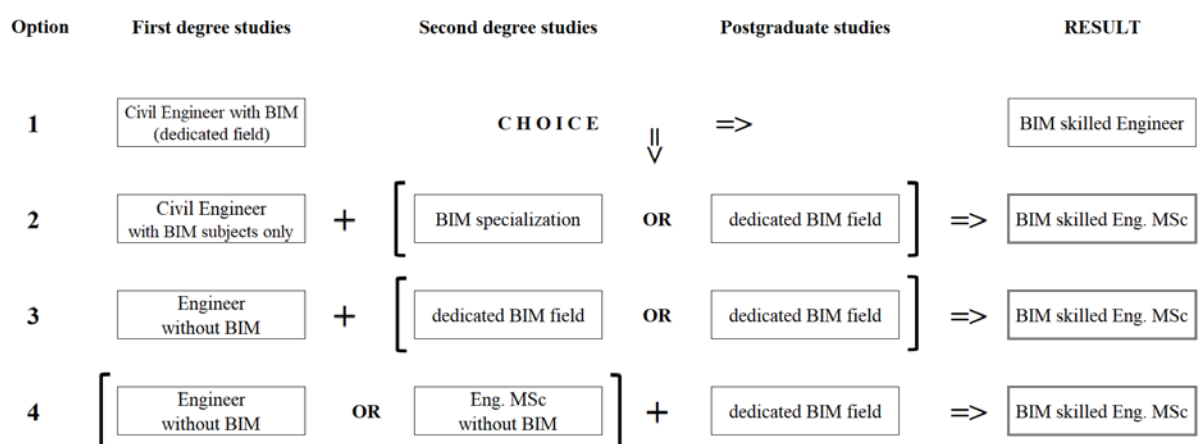


Figure 1. Proposed paths of BIM education (source: own work)

After completing the education program, graduates acquire the knowledge needed to work in the field of construction with the use of BIM in the field of design, construction management, construction supervision or technical and research activities, or practical and didactic as an implementer or trainer. The study program, including practical modeling of a building on a central model in a team together with other students, will enable the graduate to have the ability to prepare and modify projects using BIM along with the preparation of complete technical documentation of the designed objects. The acquired proficiency in using modern techniques of computer-aided design (CAD) in the course of studies will be

supplemented with the skills of modeling and building information management (BIM), and this knowledge will be thoroughly underpinned by theoretical and practical knowledge of computer calculation programs based on, for example, the *finite element method* (FEM). The graduate is to acquire knowledge that allows to obtain spatial data of objects using laser scanning or photogrammetry techniques in order to use them for three-dimensional representation in the mapped model. He should also be able to work individually or in a team and have the knowledge and skills to use appropriate techniques for solving tasks and problems related to working in BIM. The education process should also be supplemented with learning about the standards functioning in Poland and leading European and world countries (USA, UK, developed Asian countries) and understanding broader areas of work and engineering conditions, such as economic, social, and legal.

3.4. Proposed levels and profiles of a graduates in BIM education

In the opinion of the authors, the minimum amount of supplementary education in the BIM specialty or field should include the subjects indicated in Figure 2. The given subjects should be supplemented according to the education profile, taking into account the future role and so far obtained specific education of the graduate.

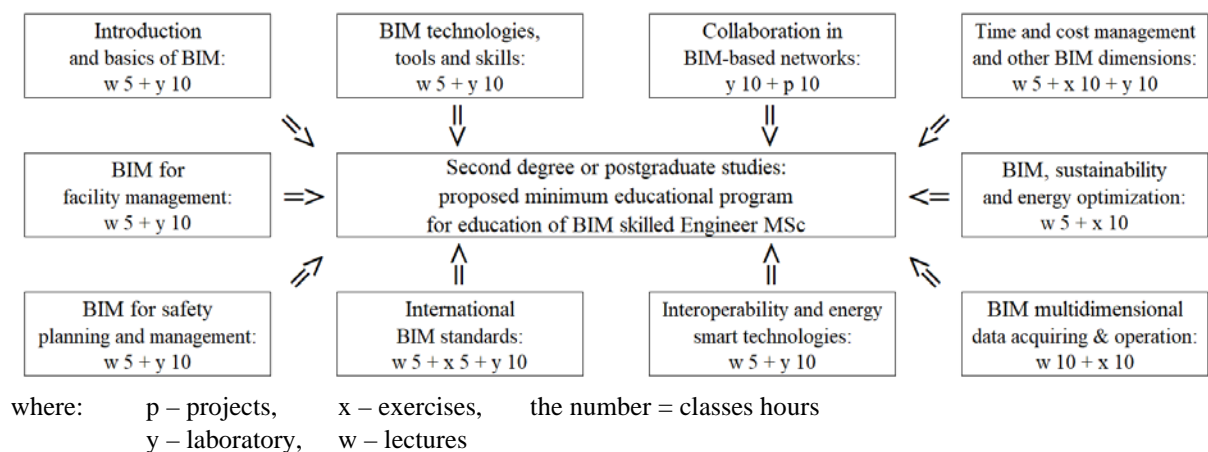


Figure 2. Proposed minimum educational program in BIM specialty or field.

4. Conclusion

In Poland, the introduction of BIM education took place in 2015 and significant increase in the number of universities educating in this field took place in 2018, and even more so in 2019. It can be expected that from 2021-23 there should be a noticeable increase in the number of staff available on the market engineering studies after 1st and 2nd degree studies, filling the gap in the needs of entrepreneurs in this area, which should contribute to reducing the distance in relation to leading countries in the field of BIM dissemination.

As a result of the analyzes, key guidelines for conducting education at the university level were proposed:

- Conducting education in the field of BIM in dedicated specialties or fields, individual subjects within the existing specialties and education fields will not meet the growing requirements and demand of the labor market.

- It is purposeful to introduce a division into education specializations, with the future leading role to be played by the graduate: specialist, leader, manager, trainer, etc.
- Multidisciplinary education is desirable, based on cooperation between faculties and universities, in areas such as engineering, construction, management, and teaching.
- Study programs supplementing education in new technologies, including BIM, should be provided for experienced specialists at risk of exclusion from the labor market due to the ignorance of new technologies.

As further research subject, according to the authors, it is worth considering a comparison with universities BIM educating in other countries. However, a limitation may be differences in the modes of education in those universities.

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