Review of BIM Implementation in Higher Education

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Building Information Modelling (BIM) creates integrated design process, where information flow from one computer application to another, throughout the project lifecycle, is possible, it relies on the development and use of common information throughout the disciplines of architecture, engineering, construction, and facilities management. For this reason, a lot of study programmes involved BIM methodology into their curriculum. However all of them have different attitude or way of BIM implementation. Therefore the aim of this research work is to analyse the curricula of Higher Education Institutions related with BIM in Lithuania, to identify and analyse disciplines related with BIM and their relations in Kaunas Technology University and to identify gained BIM competencies.

The analysis of the disciplines related with BIM shows that the strength of BIM development in Faculty of Civil Engineering and Architecture study programmes is the interdisciplinary joint semester project. Gained BIM competencies in study programmes merge the fundamental knowledge of study field and digital technology management. Those competencies are gained in undergraduate studies and it is a narrow volume of BIM process.

Keywords: building information modelling, BIM, education, Civil Engineering.

Introduction

"Digital Revolution" of construction field forces to change an attitude of activities in the Architecture, Engineering and Construction (AEC) industry. The digitalization in construction is established by using BIM methodology in the building lifecycle. That means investors, developers, architects, designers, contractors, engineers of different fields, construction site managers, teachers of Higher Education Institutions (HEIs) are involved into these activities. Smooth collaboration process of design team (lead designer, architect, structural engineer, mechanical, electrical, and plumbing (MEP) engineers etc.) is an important and actual issue of AEC industry. However BIM join not only stakeholders, but also create integrated design process (IDP), where information flow from one computer application to the next throughout the project lifecycle is possible, it relies on the development and use of common information throughout the disciplines of architecture, engineering, construction, and facilities management (AEC/FM) (Vidalis et al. 2013). That means BIM provides an opportunity to various users with different backgrounds to collaboratively work with a single BIM model of a building (Azhar et al. 2012, Migilinskas et al. 2013). Large AEC industry companies are adopting BIM as a tool in integrated project delivery (IPD) (Wong et al. 2011). However exchanging information (models and other data) between different software platforms remains one of the industry's biggest challenges on the way to fully integrate and make collaborations between project teams (Pezeshki and Ivari 2018). The biggest attention is on responsibility of the data and the information management. For this reason, the majority of study programmes in HEIs are fo-

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cused on preparation of BIM managers of the postgraduate level (Abbas et al. 2016). The students of the undergraduate level are mostly working with BIM technology especially with three-dimensional method in project design for the share information models (3D). However, they do not realize the connections through the whole BIM process (Fridrich and Kubečka. 2014). The students of the undergraduate level usually find their jobs in AEC industry just after finishing their studies due to the high demand of qualified engineers. They do not continue studies in postgraduate level and lose an opportunity to gain skills to manage information, apply and understand BIM appropriately. The implementation of BIM in the undergraduate level studies of higher education not only would influence the demand of BIM professionals, but also would give new opportunities for students in their professional careers in the form of their ability to deal with new occupational challenges with high efficiency achieved by applying BIM (Brokbals and Cadez 2017, Wong et al. 2011).

Therefore, understanding of BIM application opportunities and capabilities should be included into the curricula of the undergraduate level (Xiao 2018, Barison and Santos 2010). According to the review of the literature, where a lot of study programmes were investigated (Hietanen et al. 2008), BIM implementation into the curricula methods are as follows: 1) information modelling skills goes parallel with common professional disciplines; 2) at first BIM is introduced as a process, then BIM modelling skills goes parallel with professional disciplines; 3) BIM process is explained together with professional disciplines and BIM modeling. This is confirmed by the investigation of a current position and associated challenges of BIM education in the United Kingdom Higher Education (Underwood and Ayoade 2015). Overall findings here indicated that 24% of programmes are yet to incorporate BIM; of this 6.9% are not considering incorporating BIM. Notably, 57% have incorporated BIM into particular subjects. About 20% of programmes have developed standalone BIM subjects, however only 13% have partially embedded BIM, while only 7% have fully embedded BIM in majority of their programmes.

Denzer and Hedges (2008) state that before creating a comprehensive building design with BIM, students must understand Design Fundamentals (including orthographic drawing) and know subjects like Building Technology/Building Science and Professional Practice. In the first two years, the focus is on the individual skills of modeling and analysing the model, while in the following years, it is more on teamwork and dealing with complexity and integration through collaboration. In the final year, students are expected to work on actual construction projects in collaboration with companies, as suggested by Kymmell (2008). Pezeshki and Ivari (2018) outcome in his research that greater emphasis should be placed on supporting technical requirements to facilitate technology management and implementation across disciplines. The same author set that BIM implementation into the curricula must be founded on adaptations to national situation and constraints.

Therefore the aim of this research is to analyse the curricula of BIM education of different study programmes.

Review

BIM education in Lithuania

Lithuania, in comparison with other countries, has integrated BIM quite late. In 2015 Government of the Republic of Lithuania officially agreed to the initiative to digitalize Lithuanian AEC sector. At the same year, Minister of Environment approved Guidelines for developing Lithuanian AEC sector strategic aims until 2020. Particullar attention was focused on BIM education. The initiators of BIM promotion understand that a key success factor is – still missing – young professionals with adequate BIM knowledge.

Due to the fact that there is a lack of skilled workers and engineers in Lithuania, the initiative has joined with universities to sign an agreement to provide more education courses on digital construction. The biggest technological universities in Lithuania – Vilnius Gediminas Technical University (VGTU) and Kaunas Technology University (KTU) – adopted BIM education in several

study programs, which are related to AEC industry. VGTU is focused on the postgraduate level, where separate course of BIM management is delivered. The aim of this Masters programme is not only to train specialists and to enhance knowledge of BIM deployment and strategy but also to create and develop standards to guide and coordinate BIM drafting.

Meanwhile KTU is focused in undergraduate level, where BIM is involved in civil engineering disciplines. Since the implementation of Digital Construction, KTU organizes seminars on digital construction for their students. The presentations are given by participants from private and public sectors. The aim of the seminars is to show students the importance of digital construction and BIM in Lithuania.

Moreover, BIM is introduced and 3D design is delivered in a few colleges, for example, Kaunas Technical College. However, BIM education is mostly limited to software training in isolated courses.

According to statistical data, only 27 % of the stakeholder of AEC industry use a bit of BIM in Lithuania. That means the literacy of BIM use is very low. For this reason stakeholders of AEC industry are focused on training their employees, which usually organized by HEIs of Lithuania. This initiative will help specialists to enhance their competitiveness and their ability to participate in international construction projects. The main promoter of BIM development in Lithuania – public body "Digital construction" – delivers dissemination of BIM benefits, significance and stage of implementation. It organizes seminars and conferences every year. "Digital construction" established the best IPD (BIM project) awards for AEC industry (Digital construction 2014).

BIM adoption in curricula at KTU

BIM adoption in HEIs is a big challenge. There are a number of approaches due to adopting BIM in the curricula (McGough et al. 2013, Barison and Santos 2010, Sacks et al. 2010, Denzer and Hedges 2008). The HEIs generally have the options of adapting their existing curricula to include BIM for this purpose or teach BIM as a separate course, or both (Sacks et al., 2010). Some HEIs adopt integrated project approach - BIM is involved into different disciplines (architecture, structures, MEP systems etc.) to create communication based integrated project. This case usually is a task of undergraduate level. Meanwhile other HEIs adopt BIM project management approach, where BIM is a separate course and more focused to develop BIM management skills. This approach is usually delivered in postgraduate level.

The adopting of BIM as an integrated project approach and project management approach follows the requirements and demands of AEC industry. The industry seeks to recruit the professionals who can apply knowledge to practical situations and both types of skills, integrated BIM project and BIM management, are necessary. This is more likely through courses, which introduce new developments in technology or new methods of project delivery to students (Wong et al. 2011).

Faculty of Civil Engineering and Architecture (FCEA) at the KTU has chosen option of BIM adoption in the curricula, where BIM is a necessary part of civil engineering disciplines, which are delivered at the undergraduate level.

Since 2013 FCEA study programmes were adopted to BIM methodology and the main goals of the reform were:

- create a discipline of BIM fundamentals by explaining the whole process;
- strengthen 3D drawing and design skills;
- start of interdisciplinary semester projects by involving as much disciplines as possible;
- use more BIM software (modelling and simulation);
- strengthen a part of teamwork and communication;
- apply innovative study methods "PBL (problem based learning), design thinking etc.

Objectives and Methodology

This research presents the current situation of BIM education in Lithuania. By using the implementation of BIM courses in FCEA at the KTU as a case study for integration of BIM into Higher education. Package of Faculty's study programmes is presented in Table 1.

Level of degree	Title of the study programme	Specialization	Duration of the study programme, years
Undergraduate studies	Civil Engineering	_ Building Materials; _ Construction Technologies; _ Structures of Buildings	4
	Building Services Systems		4
Postgraduate studies	Structural and Building Products Engineering		1.5
	Construction Management		1.5
	Sustainable and Energy Efficient Buildings		1.5
Integrated studies	Architecture		5

Table 1
Study programmes of the FCEA

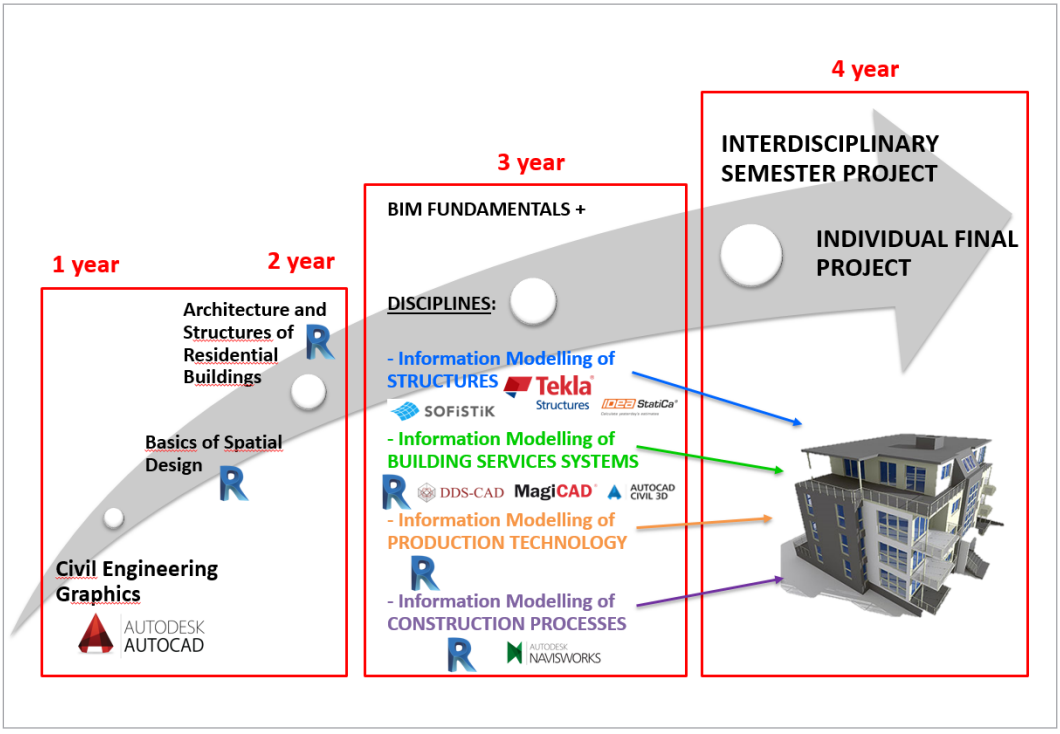

Fig. 1
Development of BIM integrated project approach into the study programmes Civil Engineering and Building Services Systems

Track of BIM development into the undergraduate study programmes of Civil Engineering and Building Services Systems is shown in Fig. 1. The used software in the mentioned study programmes is described in Table 2.

Table 2
The used software in the study programmes of FCEA

The software	Description
Revit	is one of the most popular, wide use BIM software package intended to develop (model) various disciplines as architecture, structures and building services systems (MEP). It allows users to design a building or structure in 3D, annotate and animate the model, collaborate between the disciplines by using cloud-based technologies, access information from the building model's database etc.
Tekla Structures	is very useful tool for detailing of steel, concrete, timber and even glass structures. It has good possibilities to prepare detailed drawings for production of structures and to draw detailed elements as welding's, reinforcement bars, bolts, screws, rivets etc.
AutoCAD	is a well-known, classical CAD (computer-aided design) software solution intended for drawing and drafting. AutoCAD is used across a wide range of industries, by architects, project managers, engineers, graphic designers, town planners and many other professionals.
DDS-CAD	software solution intended for modelling the building services systems (MEP systems) as heating, ventilation and air conditioning (HVAC), plumbing systems as water supply and sewerage systems either electrical installations.
Civil 3D	is a specified solution built on AutoCAD platform intended for design of roads and their infrastructure (drainage, storm sewer system, water supply, traffic management etc.).
MagiCAD	is a supplementary software package for Revit or AutoCAD platforms intended for Mechanical, Electrical and Plumbing design. It enables modelling and engineering calculations as well.
SOFiSTiK	software solution for structural calculations, analysis and optimization of building's structure based on finite elements method.
Navisworks	is a 3D design review package primarily used to combine models from different disciplines (architecture, structures, MEP models etc.). It allows users to navigate around them in real-time and review the model using a set of tools including comments, interference detection, measurements, 4D (time) simulation, photorealistic rendering etc.

First semester of the studies is intended for development fundamental skills of two-dimensional method in project design (2D) (including orthographic drawing) in AutoCAD environment by designing an architectural discipline of detached residential building. Second semester is intended to develop already started design in 3D with a Revit software in the study subject Basics of Spatial Design. Fourth semester is intended to design the industrial building and to develop not only 3D of architectural and structural disciplines, but also addition and use of attribute data (materials, properties, producer, class etc.). The essentials of the mentioned track is a continuation of the design, development from 2D to 3D and addition of more and more disciplines and attribute data.

The specialized and more detailed trainings of BIM software are included in the 3rd year curricula of Civil Engineering and Building Services Engineering study programmes. At that moment students already have main professional skills of structures, materials, construction technologies and building services systems (heating, ventilation, and air conditioning (HVAC), water supply etc.). Each discipline is covered by particular study subject of Information Modelling, which is intended to create specific BIM data and take advantage from that. Moreover, before the starting specialized training of BIM software, students are introduced with a BIM fundamentals. This cycle of the studies is involved into all specializations and are intended for understanding BIM as a process. Also such aspects as the main BIM standards (Employer's Information Requirement (EIR), BIM Execution Plan (BEP), BIM Protocol), importance of classification system, data exchange issues, cloud based collaboration and communication, level of development (BIM Level of Development (LOD)) are explained. Learning outcomes of mentioned study subjects are presented in Table 3. Particular attention is dedicated to development of teamwork, smooth collaboration and communication skills.

Table 3. Learning outcomes of specialized BIM disciplines

Spec.	Subject	Software	Description	Learning outcomes
Building Materials	Information Modelling of Manufacturing of Construction Products	Revit	The aim and the focus of the subject is on information modelling of construction products manufacturing technologies, parametrization and classification of construction products. Also it's coding systems, level of details importance, use of BIM data libraries and templates.	_ Ability to search, gather, and interpret individually various data of the information modelling of manufacturing of construction products, perform logically data analysis using different quantitative computer methods designed for the solution of engineering problems. _ Ability to apply the knowledge and understanding to identify, formulate, and solve the problems of BIM using existing methods of analysis and parametric modelling of construction products. _ Ability to apply appropriate parametric models in the field of manufacturing of construction products, based on logistic, safety, sustainable development, environmental and economic aspects.
Construction Technologies	Information Modelling of Construction Processes	Naviswork Revit	The aim is to clarify the objectives of the specific implementation construction technologies methods and processes, using necessary information tools. The knowledge about the organization of construction works needed to implement BIM is learned and needs of specialized jobs and how company staff perceives their responsibilities and roles. Also, this subject focuses on an evaluation of structural 3D buildings models and applying appropriate construction methods, a design of technology and organization, chain calculation of material and technical supply, planning of the measures for quality control and safety, creating of building site layout, scheduling and budgeting of building works (4D/5D) and assessment of status control within BIM.	_ Ability to search, gather, and interpret individually various data of the information modelling of construction technology, construction, project organization and quality assurance principles, perform logically data analysis using different quantitative computer methods designed for the solution of engineering problems. _ Ability to apply the knowledge and understanding to identify, formulate, and solve the problems of BIM using existing methods of analysis and parametric modelling of the technical facilities and their management techniques and construction methods. _ Ability to apply appropriate parametric models in the field of construction technology, based on design options, possible methods of construction, according to the construction environment, restrictive conditions, landscape, heritage, aesthetic, sustainable development and architectural issues, economic factors and expected operating conditions.
Buildng Structures	Information Modelling of Building Structures	Tekla	The aim is to analyse the loads and actions for object structures using necessary information tools, to perform the calculation of forces into the structural elements and joints of buildings and constructions, to perform the analysis of calculation results using the methods of computer design, to draw the object plan, sections and more complicated joints of connected structures, to prepare 3D model according to requirements of a technical project.	_ Ability to search, gather, and interpret individually various data of the information modelling of structural elements of buildings, perform logically data analysis using different quantitative computer methods designed for the solution of engineering problems. _ Ability to apply the knowledge and understanding to identify, formulate, and solve the problems of BIM using existing methods of analysis and parametric modelling of structural elements. _ Ability to apply appropriate parametric models in the field of structural engineering, based on logistic, safety, sustainable development, environmental and economic aspects.
Building Services Systems	Building Information Modelling of Services Systems	Revit DDS-CAD	The aim is to acquire theoretical and practical knowledge about building engineering systems information modeling through innovative software, to acquire knowledge about the work of the procedure, succession, responsibility and possible consequences, to gain skills to coordinate their actions and solve a common engineering problems, justify the chosen solution options and methods, able to prepare technical documentation and present prepared building information model with complex engineering systems.	_ Ability to generate and express ideas in a reasoned manner and accept constructive criticism regarding engineering systems. _ Ability to use information technology and advanced BIM software to solve engineering systems problems and produce a 3D model. _ Ability to process engineering systems information model, to carry out a systematic collision analysis, prepare a technical documentation of materials and equipment, to evaluate critically the application of technologies of the study area in legal, economic and functional terms and in respect of the impact on an individual and environment.

The paper examines the status of BIM in the two aspects:

- identify and analyse disciplines related with BIM and their relations in KTU;
- analyse managing aspects and challenges of an interdisciplinary joint semester project.

Results

Identify and analyse disciplines related with BIM

In order to determine the impact of BIM integration on the content of the study programmes, the discipline packages taught in the FCEA engineering profile (Table 1.) were analysed. The results of the study are presented in Fig. 2.

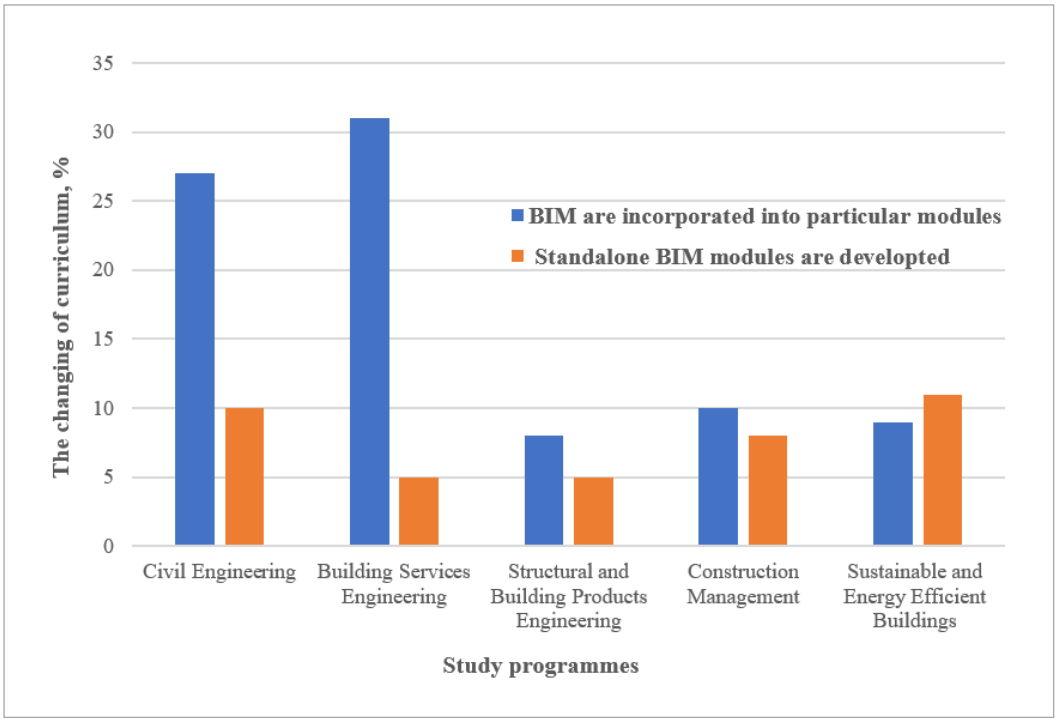

Fig. 2
The changes in curriculums of study programmes in FCEA

Analysis of the contents of the mentioned study programmes shows that BIM is incorporated in particular subjects of the Civil Engineering study programmes 27% of all disciplines package, in curricula of the Building Services Engineering study programmes - 31%, in the Structural and Building Products Engineering – 8 %, in the Construction Management – 10 %, in the Sustainable and Energy Efficient Buildings – 9 %. Analysing developed standalone BIM subjects: the Civil Engineering study programme has 10% and the Building Services Engineering – 5 %, the Structural and Building Products Engineering – 5 %, the Construction Management – 8 %, the Sustainable and Energy Efficient Buildings – 11 %.

Analyse an organization of interdisciplinary semester project

The interdisciplinary semester project starts in the 3rd year spring semester in the Architecture study programme to develop architectural and site plan disciplines. In the 4th year autumn semester in Civil Engineering and Building Services Engineering study programmes includes development of structural, fabrication technology, building services systems, construction planning and cost estimation disciplines. Several disciplines joins the project from Faculty of Electrical and Electronics Engineering, Electrical Power Engineering and Automation and Control study programmes (Fig. 3). In most cases projects tasks are linked with real situations and are offered by participants of AEC industry

(general contractors, fabricators, designers etc.). Participants usually are involved into the project and acts as a client or consultant. In some cases tasks of the projects are linked and relevant for the public sector (municipalities, governmental institutions, public bodies etc.).

Fig. 3
Schedule schema of interdisciplinary semester project disciplines

3rd course Spring semester (Architecture study programme)	4th course Autumn semester (Civil Engineering, Building Services Engineering, Electrical Power Engineering and Automation and Control study programmes)		Final
Architecture			
Site plan			
	Building Structures		
	Construction Technologies		
	Fabrication Technology of Building Materials		
	Building Services Systems (HVAC, Water supply and sewerage)		
	Electrical Power		
	Automation and Control		
Conceptual design	Design solution, Detailed design, Analysis Simulation	Quantity take-off, scheduling, cost estimation	Presentation of the interdisciplinary semester project

Concerns and challenges of the project are well known for teachers and professionals of stakeholders who apply BIM (Cinelis and Janilionis. 2013). The first challenge is the integration of different disciplines due to the use of different software. Usually we use Revit, Tekla Structures, IdeaStatica, Dlubal, DDS-CAD, Nawisworks. In this case, data exchange is possible only with a help of Industry Foundation Classes (IFC) standard, but the lack of data consistency is still a big issue nowadays. Actually, students are free to pick up the software type and vendor, but we prefer and encourage "openBIM" concept.

Second challenge is to ensure smooth collaboration, communication and teamwork. In this case, students are encouraged to use cloud based technologies, specific software for better communication collaboration and management (ProjectWise, BIM360 etc.).

Discussion

Introducing BIM virtual worlds into education stand out as a promising technological approach to constructive learning and productive teaching (Underwood and Ayoade 2015). But, how it was mentioned previously, the national market regulates the demand for skills and competences of ACE engineers. Lithuania took the decision due to BIM development and implementation too late compering with other EU countries. That is the reason in order that organizations in Civil Engineering field use 2D method in project design. According to statistical data, 73 % of Civil Engineering organizations use AutoCAD software and design on 2D environment. Therefore the students gain 2D skills in the first semester that need for small and medium organizations, which are not using BIM methodology in their projects. This method of project design is dying, therefore particular attention in curricula of KTU is focusing on BIM education. The created curriculum, where BIM track

is included, gives opportunity for students to not only get acquainted with BIM methodology but also gain the fundamental knowledge of building materials, structural and engineering systems design, construction technology, manufacturing of building products, management, economy and etc. This knowledge as specific information is included in the BIM project. But for this process students have to know the basics of IT and have to manage specifics software. That means the fundamental knowledge of civil engineering should go in parallel with IT. Students are trained to use the digital tools and to implement it in different kind of design processes. Also, the strength of BIM development in FCEA study programmes is the interdisciplinary joint semester project, where in the created model, there are inserted data from different disciplines of civil engineering, architecture, electrical, automation and control.

The weakness of presented BIM education at KTU is a narrow volume of BIM process. The simulation and analysis related only to fundamentals issues. The Stage of project design, where is done environmental performance analysis (6D) and stage of project design, where is information relating to the whole life cost, including operation and maintenance of the completed building (7D) should be included in postgraduate level. Faculty of Civil Engineering and Architecture at KTU has this possibility, because it has 3 study programmes (**Table 1**.). The deeper analysis should be made on structural and building manufacturing possibilities related a life cycle of the building by the students of Structural and Building Products Engineering study programme. The students of Construction Management study programme might develop issues related project management and integrate in semester project as a BIM coordinators. They also might provide requirements for operation of building (6D stage of BIM). The students of Building Engineering Systems study programme might do simulation related energy efficiency of a building that means they will develop the project in 7D stage.

The results of the investigation show, that FCEA is working on the issue of BIM adaptation and development in delivered study programmes (**Fig. 2**). However, the subjects, which are related to BIM, in the curricular of the FCEA study programmes are 2-3 times less comparing to a statistical data of HEIs the United Kingdom (**Fig. 4**), which are presented by Underwood and Ayoade (2015). That means, BIM education in KTU is not quite enough and should be developed and improved.

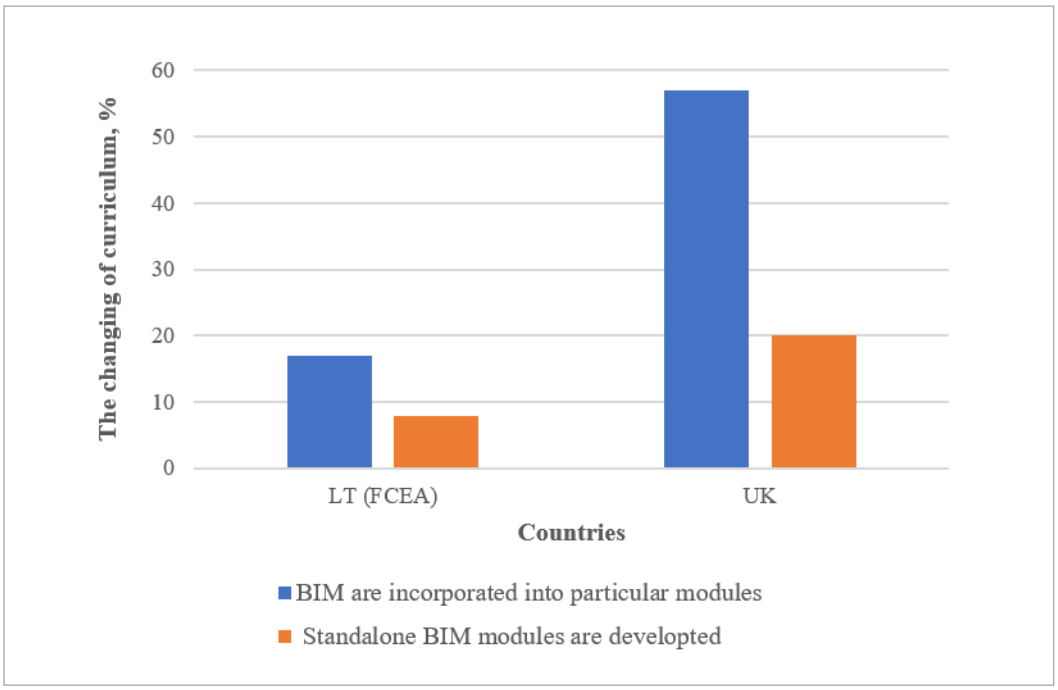

Fig. 4

Comparing the BIM adoption in curriculum between FCEA of Lithuania (LT) and United Kingdom

In Lithuania, BIM starts to enforce at the legislative level. From the 1st of July 2022 - will become compulsory to use BIM methods for the design and construction of all newly constructed complex and high-value public sector buildings, which undoubtedly will lead to greater transparency and it will encourage to search for civil engineers with the competences of digitalization. For this reason, BIM implementation and development in HEIs of Lithuania is an important thing.

The opportunities of BIM education leads to collaboration among the different public sectors, which relates Research and development (R&D) projects, BIM dissemination, the teaching of staff, the legalization of AEC and etc.

Conclusions

The analyses of disciplines related with BIM and their relations in KTU show that the strength of BIM development in FCEA study programmes is the interdisciplinary joint semester projects, where not only FCEA study programmes like Architecture, Civil Engineering, Building Services Systems are involved but also study programmes from Faculty of Electrical and Electronics like Automation and Control and Electrical Engineering.

The results of the investigation show, that BIM education in KTU is not quite enough and it should be developed and improved. Gained BIM competencies in FCEA study programmes marge the fundamental knowledge of study field and digital technology managed. Those competencies are gained in undergraduate studies and it is a narrow volume of BIM process. The 6D/7D stage of BIM as estimation, sustainability, facility management and operation should be included in post-graduate level.

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