Assessing educational approaches to building information modelling (BIM) at construction management master studies in Croatia

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ASSESSING EDUCATIONAL APPROACHES TO BUILDING INFORMATION MODELLING (BIM) AT CONSTRUCTION MANAGEMENT MASTER STUDIES IN CROATIA

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Preliminary communication

Building Information Modelling (BIM) is the current trend of the Architectural, Engineering and Construction (AEC) industry today. For its successful adaptation, education and standardization are one of the key success factors. In education, BIM provides development of students' critical way of thinking and enables them to understand the complexity of the construction industry. As there is no accurate information about BIM education at Croatian universities, the aim of this paper was its implementation at the University J. J. Strossmayer of Osijek and the University of Zagreb. We have found that the current schemes enabled students to understand the BIM concept and how BIM changes and fosters the work processes in construction projects. However, we have also identified the deficient knowledge in coordination, interoperability and clash detection. Therefore, the future work involves extension on collaboration tools and covering the above mentioned, missing knowledge areas.

Keywords: Building Information Modelling; construction management; engineering education; 5D modelling; master level

Ocjena edukacijskih pristupa Building Information Modeling-a (BIM) na diplomskim studijima građevinskih fakulteta u RH

Prethodno priopćenje

Building InformationModeling (BIM) predstavlja trend u današnjoj arhitekturi, graditeljstvu i ostalim inženjerskim strukama. Pravilna edukacija i standardizacija predstavljaju ključne faktore prilagodbe na BIM. Primjenom BIM-a u edukaciji, studentima se omogućuje razvoj kritičkog načina razmišljanja i mogućnost zapažanja i razumijevanja kompleksnosti građevinske industrije. Kako ne postoje precizne informacije o BIM edukaciji na hrvatskim sveučilištima, cilj ovog rada je implementacija iste na Sveučilištu J. J. Strossmayer u Osijeku te Sveučilištu u Zagrebu. Zaključili smo da trenutna edukacija studentima omogućava razumijevanje BIM koncepta i načina na koji BIM mijenja proces rada u građevinskim projektima. Radom je također uočeno da u edukaciji nedostaju znanja o koordinaciji, interoperabilnosti i kontroli sudara. Stoga, budući rad uključuje širenje edukacije na ostale kolaborativne alate kako bi se obuhvatila spomenuta područja znanja koja trenutno nedostaju u edukaciji.

Ključneriječi: Building Information Modelling; diplomski studij; edukacija inženjera; organizacija građenja; 5D modeliranje

1   Introduction

Building Information Modelling (BIM) is one of the most advanced approaches of the Architectural, Engineering and Construction (AEC) industry today [1, 2]. Implementation of BIM is steadily gaining popularity in construction industry, which was confirmed by a great number of published studies [2, 3, 4, 5]. The benefits of BIM are twofold. On one hand, BIM reduces errors and omissions; improves collaboration within stakeholders during the design and construction phases; reduces rework, construction cost and the overall project duration; increases cost control, predictability and profit of the company; brings new business; improves safety; maintains repeat business and many other things [1, 6]. On the other hand, most common barriers to the introduction of BIM are: insufficient training, lack of expertise and technical support, high cost of introducing, opinion that CAD design is better, lack of interoperability and the fact that investors are not looking for the application of BIM [1, 5, 7].

In order to facilitate the application of BIM and achieve its benefits, many organizations put large effort to develop BIM standards. One of them is building SMART [8], which has been developed in partnership with International Organization for Standardization (ISO) and was the first to issue BIM standards. According to them, digital BIM model is built up from three separate standardized components: International Framework for Dictionaries Library (IFD Library, ISO 12006-3), Information Delivery Manual/Model View Definition (IDM/MVD, ISO TC59 SC13) and Industry Foundation Classes (IFC, ISO 16739)[9].

The IFD defines all building components (internationally standardized) and makes standardized terminology computable in order to assure quality and automate many manual processes in value chain [9]. IDM aims to provide the integrated reference for process and data required by BIM. IDM will provide the integrated comprehensive reference required by identifying the discrete processes undertaken within building construction together with the information that is required for and results from their execution [10]. IFC is a data model developed to facilitate interoperability in the building industry. IFC format exchanges geometry and object information, so all the information is shared by one open BIM format [10].

Second organization, which develops BIM standards, is British Standards Institution (BSI). BSI BIM standards are: BS 1192:2007 (Collaborative production of architectural, engineering and construction information – Code of practice); BS 8541 (Library Objects series); BS 7000-4:2013 (Design management systems: Guide to managing design in construction); PAS 1192-2:2013 (Specification for information management for the capital/delivery phase of construction projects using Building Information Modelling); PAS 1192-3:2014 (Specification for information management for the operational phase of assets using building information modelling) [11]; PAS 1192-4:2014 (Collaborative production of information (Fulfilling employer's information exchange requirements using COBie, Code of practice) [12]; PAS 1192-5:2015 (Specification for security-minded building information modelling, digital built environments and smart asset management) [13]. Although there is a vast spectrum of standards and

approaches developed, BIM and BIM software are still "market" products without a strict standard and interoperable files [14].

The governments of the most developed EU states have been trying to regulate implementation of BIM practices (e.g. BIM standard has been introduced in the UK, France, Denmark, Austria, Spain, Norway, Finland etc.). Furthermore, by the EU Directive 2014/24/EU, set forth by European parliament and Council, BIM was clearly indicated as the future of construction industry in EU. More specific, by 2016 in UK BIM Level 2 there is minimum target for all public-sector projects [15, 16]. BIM Level 2 means that all stakeholders are included in project working on their own 3D models (not necessarily one, shared model) where the information is shared through common standard, e.g. IFC [17] or COBie [18]. Information exchange within all stakeholders is the base for good collaboration, which is crucial characteristic for BIM Level 2 [15].

In Europe, the pioneers of applying and implementing BIM are considered to be: France, Germany and UK [19]. According to International BIM Report 2016, the usage of BIM is increasing and within five years it is expected that its usage in design professions in most world countries will be over 80 % [20]. Currently usage of BIM in UK is 50 %, in Canada is 71 %, in Denmark 81 %, Czech Republic only 30 % and in Japan is 49 %. By 2021 it is expected that the usage will be as follows: UK 95 %; Canada 71 %; Denmark 93 %; Czech Republic 90 % and Japan 88 % [20].

In Croatia, only 0÷25 % of construction companies use BIM in their businesses [21, 22]. Also, employees of the Croatian construction sector are familiar with the term BIM technology, but the majority of respondents are not aware of BIM tools which are offered on the marketplace. Further, the construction industry of Croatia is missing: integration of 3D drawings, cost, time and planning, and also communication and interoperability amongst participants of the design and execution stages. Such situation in Croatia is in some way a result of disengagement of Croatian state authorities in supporting BIM implementation [21, 22]. In many countries involvement of state authorities in BIM implementation and establishing rules, regulations, standards and code of practice had forced companies to implement BIM in business and resulted in a greater BIM awareness [7].

Even though BIM shows promising results and is the current trend of the construction industry, and many countries are obliged to use it, education of construction engineers (pedagogy, curricula etc.) still has not caught up with the trends [23]. As a result, the industry suffers from insufficient educated employees [14]. In order to increase the application of BIM, but also success of its implementation in higher education, Salleh and Fung (2014) suggested several strategies: provide training, government support, increase awareness and understanding of BIM, develop BIM guidelines, improve data exchange standards, provide education at university level, reduce cost and changes in procurement method factor [7].

Researches about education at Croatian Universities (in Osijek and Varaždin) and University of Maribor, Faculty of Mechanical Engineering were related to the implementation of ICT, online courses and e-teaching /learning in high education [24, 25, 26, 27]. Moreover, the introduction of BIM at the graduate university study programs is a result of development monitoring at the construction market and construction related disciplines [28]. From the above it is evident that specific data about quality and satisfaction of implemented BIM education currently does not exist. So, the aim of this paper was to compare and discuss educational approaches in education of civil engineers (specifically at the University of Osijek and Zagreb, Faculty of Civil Engineering) in order to fulfil the literature gap and adopt guidelines for further development of BIM and construction industry as well as increasing level of communication and integration within stakeholders who are involved in construction projects [21].

First, this paper presents literature review about BIM education. Then it gives the results of research conducted at two master study courses in Construction Management (University J. J. Strossmayer Osijek and University of Zagreb). The paper brings discussions by comparing the results with similar education studies. In the end, the paper proposes how to improve education practices of implementing BIM.

2 Literature review

BIM brings many advantages to the construction management (CM) field, both to performance of the construction companies and education. According to Becerik-Gerber et al. (2011) the most important knowledge areas which have to be reached in CM programs are constructability, 4D scheduling, model based estimating, followed by design, visualization and sustainability. Moreover, BIM (43 %) is put on the second place of top areas for PhD research conducted in CM programs, after sustainability (52 %) [29]. Reasons for absence of BIM in the curricula of Civil Engineering practices can be found in inadequate staff, inadequate resources to make the curriculum change and the fact there is no space left within curriculum [29].

According to Barison and Santos (2010), academic experience of BIM can be classified into three categories: single-course, when BIM is introduced only to one discipline; interdisciplinary collaboration, when students are learning BIM concepts through two or more disciplines within one university; distance collaboration, when students learn real BIM collaboration with students from two or more distance universities. Multinational academic experience remains unknown and unexplored [30].

In the higher education, BIM has to be represented like a collaborative process or process methodology rather than a content, technology or design tool and also implemented in education only through process and project-based learning. By practicing such pedagogy, students can learn theory through the dynamic classroom approach which enables to notice and understand the complexity of construction industry. Furthermore, the students would be able to solve the real problems in complex construction project in their future practice [2, 3, 23, 31, 32, 33]. Peterson et al. (2011) have shown that when students work with BIM-based project management

tools, they are exposed to a more realistic project situation. Furthermore, they operate in less predictable environment than one in the classroom, which then allows them to learn theoretically methods on real examples but also to understand complex relations, advantages and disadvantages of project management methods [4]. Moreover, in this way students understand roles and responsibilities of each stakeholder involved in project as well as the importance of collaboration, interoperable and integration processes in the construction delivery [34]. This education system comes with the information revolution and continuous development of information technology which makes comprehensive changes in education [14].

The initial part of the BIM education represents selection of software tools which will be used in education. The most used software in CM education are: Revit (material take off), Microsoft Project (time planning), Navisworks Manage (4D simulation, clash detection, MEP coordination) and Vico Office (cost analysis, 5D simulation) [3, 23, 33, 35, 36]. Furthermore, Taiebat and Ku (2010) have proven that in construction companies in US, knowledge about software tools Revit and Navisworks are the most demanding in construction curricula of graduate study [37]. Besides, research showed that in education is very important the usage of proven interoperable software combination [38] because the aim of education is not solving the problems of absence of propriety BIM standard but to learn basic knowledge about concept and tools. Unfortunately, the software industry currently still does not encourage entirely the compatibility of the software but only the marketing and sales [38].

Whilst construction projects are becoming more complex, spatial visualization tends to be very important to understand how processes of material procurement, cost estimation and scheduling work together, but also how to accomplish their integration. 3D visualization enhances the student's ability to conceptualize, understand and solve the CM problems in projects [32]. Tsai et al. (2010) measured time taken in different stages of transporting 2D drawings into 4D model. So, the students needed 54 hours for training, 156 hours for creating 3D model and 20 hours for establishing 4D simulation. They concluded that by converting 2D information into 3D models takes much more time than activities in time scheduling. In order to improve 4D modelling the following processes are needed: maintain a systematic drawing numbering system, develop a BIM element library and sharing information while establishing the 4D model [39].

Boon and Progg (2011) showed that CM education should start with the first phase of creating a new model or model from CAD drawings. If students did not complete 3D model, they would not develop needed skills of spatial visualization. Moreover, processes of comparing the architectural, structural and services models, for the purpose of coordination and clash detection, are proven to be a necessary step in understanding collaboration and interoperability [32, 40, 41]. Besides, if models were created in too much detail, students would get distracted to notice and understand information relevant for education [40].

Kim (2012) found the following objectives of CM education: evolve student's skills, ability and construction knowledge to develop appropriate levels of cost estimates; evolve communication skills and ability to function in multidisciplinary teams. Other researchers showed that 4D simulation and project planning represent the basic knowledge for CM education. Furthermore, Kim (2012) includes the step of developing 2D CAD drawings, before developing 3D model which other authors do not point out as a necessary step in CM education [35].

Larger companies with more employees find BIM in constructability and visualization to contribute the most to the success of their projects. Thus these companies need employees with two conceptual roles Design-Build and Construction Managers with BIM knowledge [37] in order to enable latest project delivery [42]. Moreover, profession roles, like project manager and BIM manager/engineer should have specified BIM knowledge. According to Wang and Leite (2014) BIM manager/engineer is required to understand what BIM is and how it changes the work process, have abilities to create BIM models, perform data analysis with existing BIM models, to use BIM visualization and communication tools but also have experience in working with specific BIM tools. In comparison with BIM manager, project manager may or may not directly use BIM, but has to understand what BIM is and how to changes the work processes, should have abilities to use BIM as a visualization and communication tools but also to perform data analysis with existing BIM models [23]. From the above it is obvious that, in the near future, project managers should have BIM knowledge and abilities to work with BIM models. By searching features on LinkedIn, Rahman et al. (2016) identify which BIM skills contribute to project manager success. Authors have considered 'BIM', 'Revit', 'CAD', '3D', 'steel detailing', 'Navisworks', 'submittals', 'modelling', 'construction drawings', 'AutoCAD', 'sustainable design', 'metal fabrication', 'renovation' and 'steel' as BIM skills. They conclude that there is no direct correlation between BIM skills and faster promotion to assistant project manager or project manager but there is correlation between BIM skills and other skills of project managers, so there is indirect correlation between BIM skills and project manager titles. Above indicated can help students to know which BIM skills they should learn, industry to find adequate candidates for BIM projects and universities to redesign their courses and implement BIM in education [43].

Sacks and Pikas (2013) identified specific BIM competency topics which are necessary to realize through the first or master degree level. LinkedIn, International workshop and job advertisements are methods for collecting the input information. They generate 39 topics classified in three categories: BIM-related general knowledge area and processes (12 topics), BIM technology (10 topics) and BIM applications/ functionalities (17 topics). Each of them is evaluated on the set scale, where grade represents level of knowledge about considering topic which students have to realize through education at the first or master degree level [3, 33].

Thus BIM knowledge represents important learning outcome in education of CM master degree students. In education BIM provides development of student's critical way of thinking and enables them to resonate and solve complex project problems in their future practice.

3 Methodology

There are more advantages of BIM application in later stages of project (construction, execution and facility management (FM)) than in preparation and designing phases [3, 14, 33, 37, 38]. So, it is expected that the roles like project managers and BIM managers own specific BIM skills [43]. In Croatia, there are currently only two universities (University J. J. Strossmayer in Osijek and University of Zagreb) that provide specific construction management courses at the master degree level ('Construction Management' course), encompassing BIM knowledge. However, there is still literature gap about the usage of BIM education at Croatian universities. To fill this knowledge gap we sought to examine students' perception about BIM themes, current satisfaction of BIM usage and the need of BIM usage in their further practice.

Thus during this study, we sought to taste and identify advantages and disadvantages of individual software. Furthermore, transmission of IFC forms within the software was examined as the combination of Revit, Gala and Navisworks in previous studies had proven to be the most appropriate for the BIM application in education [22, 44]. As discussed in the literature review, the students within their BIM education need to undergo the following steps: production bill of quantities using the software Autodesk Revit; cost analysis using software Gala; creation of schedule using software Gala; production of 4D and 5D simulation using software Navisworks Manage [44].

In this study we surveyed the students at the end of the semester, after they finished their studies in BIM by solving their own case studies and having created their own 5D BIM model (3D with schedule and cost). They were asked whether they have acquired the required skills in working with BIM tools but also the basic knowledge about the BIM concept. 30 students from the University of Zagreb, Faculty of Civil Engineering and 14 students from the University J. J. Strossmayer of Osijek, Faculty of Civil Engineering, participated in the survey. The Survey consisted of 3 types of questions. The first two types were closed type of questions (yes / no and closed select options). In the third type, the respondents had to rate answers using the Likert scale 1-4 (given scale; 1-minimum value of the offered answers; 4-highest value to an answer). The comparative analysis of the two university groups was based on the Relative Importance Index (RII), according to Eq. (1):

$$RII = \frac{\sum w}{A \times N},\qquad(1)$$

where w represents the assessment or response of the individual participant of the survey, A, the highest score given by the survey participants while N is the total number of respondents who participated in the study [45]. RII refers to a value in the range from 0 to 1. The higher value of the index RII means that element is more important or has better perception [22, 44].

4 Results and discussion

At both universities the students had never heard about BIM before entering the 'Construction Management' course which showed lack of BIM in undergraduate studies. At the University of Zagreb, Faculty of Civil Engineering, 100 % of students understood what BIM technology was, while at the University of Osijek, Faculty of Civil Engineering this percentage was slightly lower (92,31 %).

Table 1 Comparison of student's answers to specific questions

Question	Osijek		Zagreb	
	Yes (%)	No (%)	Yes (%)	No (%)
Do you know what the term Building Information Modelling (BIM) means?	92,31	7,69	100	0
Do you think that the application of BIM technology allows progress in education and understanding of the construction management?	100	0	100	0
Do you think that application of software tools that are currently available on the market can improve construction management?	92,86	7,14	100	0
Do you think that CAD and Microsoft tools (Word, Excel, Microsoft Project) are sufficient for proper and realistic planning?	35,71	64,29	6,67	93,33
Do you think that the construction industry requires the integration of drawings, costs and time plans?	100	0	100	0
In your opinion, is there any exigency for better communication of different professions during the design and construction using software tools?	100	0	100	0
Would you like to use BIM in your future practice?	100	0	100	0
Do you think that the BIM software tools are compatible with each other?	78,57	21,43	96,67	3,33

Tab. 1 shows how application of BIM brought progress in education and increased student's understanding of the construction management (100 % of respondents confirm the statement, Tab. 1), and consequently improved construction management practices (Osijek 92,86 %, Zagreb 100 %). Furthermore, the respondents thought that past CAD and Microsoft tools (CAD and Microsoft tools) are not sufficient for realistic planning and for complex projects which today's construction industry is exposed to (Osijek 64,29 %, Zagreb 93,33 %, Tab. 1). Moreover, 100 % of the respondents thought that integration of drawings, costs and time plans, as well as communication between stakeholders who are involved in construction projects,

are the areas completely missing. Further, 100 % of respondents wanted to use BIM in their future practice (Tab. 1). The results also showed that respondents saw construction companies in Croatia very inefficient with BIM use 0÷25 % (Zagreb 100 %, Osijek 93 %, Fig. 1).
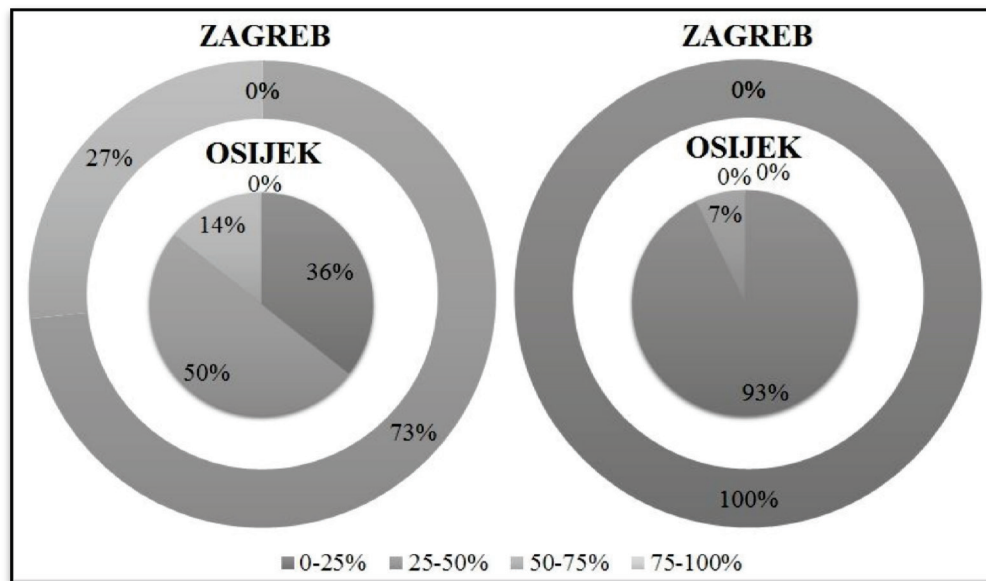

Figure 1 Comparison of students answers to question: 'In which percentage do you think that BIM technology is applied in the world (left figure) / in Croatia (right figure)?'

Besides, there was no experience found to evaluate wether BIM technology contributes to greater accuracy of CM projects or not (at University of Zagreb 47 % of students were not able to evaluate, at University of Osijek, Faculty of Civil Engineering 57 % of them, Fig. 2).
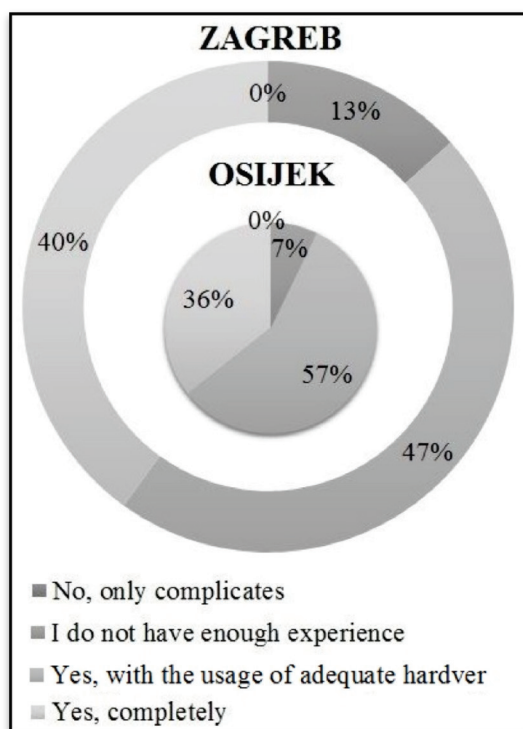

Figure 2 Comparison of students' answers to question: 'In your opinion, does BIM technology increase the accuracy of construction management?'

Furthermore, the BIM software which was used in education (Osijek 78,57 %, Zagreb 96,67 %, Tab. 1) was generally compatible with one to another. This confirmed that software combinations were tested before education started and were well prepared for this level of education. Software users were in general satisfied with the performance of used software (Revit, Gala, Navisworks). Even though in their BIM education the students had not used Microsoft Project for scheduling (they used a local application Gala) they thought of Microsoft Project as a natural BIM application. Revit (software for creation 3D models and bills of quantities) had very good performance as evidenced by high survey scores (Osijek 0,86, Zagreb 0,83 Fig. 3) while the Gala (Osijek 0,70, Zagreb 0,78, Fig. 3), Navisworks (Osijek 0,62, Zagreb 0,76, Fig. 3) and Microsoft Project (Osijek 0,68, Zagreb 0,72, Fig. 3) had slightly weaker performance. Students evaluated performance of Civil 3D (Osijek 0,83, Fig. 3) and ArchiCAD (Osijek 0,71, Zagreb 0,67, Fig. 3), and were generally satisfied with their performance. Vico and Bentley students found too complicated software to learn without prior basic education (Fig. 3).

The results show that, by the applied BIM education at the Universities of Osijek and Zagreb, Faculty of Civil Engineering, students gained basic BIM knowledge, even though some of important areas (Becerik-Gerber et al., 2011), in CM education (design and sustainability) were not represented [29]. According to Glick et al. (2010), Tsai eta al. (2010), Boon and Progg (2011) and Kim (2012) creating 3D model is a good start in BIM education in order to increase understanding of BIM concept [32, 35, 39, 40]. This step was missing in the education at the Croatian universities. However, the 3D models which were prepared for students were not too complicated and detailed and thus students understood the information relevant for their level of education [40].

The research also confirmed that 4D simulation, cost estimation and analysis are knowledge areas which are important in CM education of master degree students which was achieved through the implemented methodology at Croatian universities [29, 40]. Moreover, software Revit, Gala and Navisworks, represented quite compatible combination of software.

Furthermore, the skills in working within BIM environment, that students got out of the courses, were equal to project manager's BIM skills identified by Rahman et al. (2016) [43]. However, some of them ('steel detailing' 'sustainable design', 'metal fabrication', 'renovation' and 'steel') were not achieved through education at the Universities of Osijek and Zagreb, Faculty of Civil Engineering and need further development.
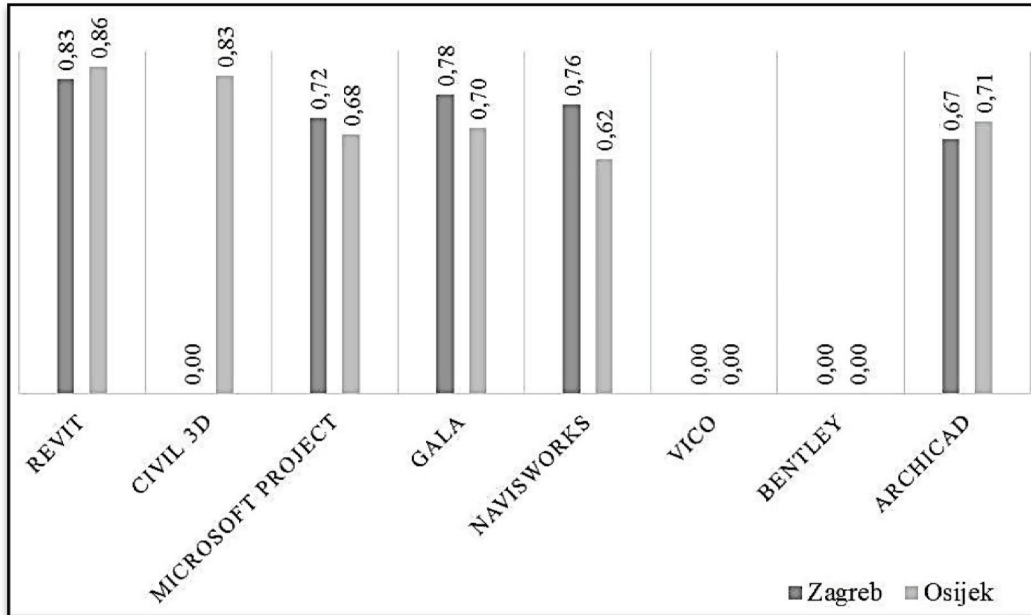

Figure 3 Comparison of software rating

Sacks and Pikas (2013) showed that it is necessary to realize 39 specific BIM competency topics through education of the first or master degree level. These competency topics (e.g. facility maintenance and management, design coordination, constructability review and analysis, modelling with standard catalogue elements, interoperability, communication tools, detect clashes, integration with project partner (supply chain) databases) were not included in learning outcomes of the course 'Construction Management'. Thus it was impossible to compare planned and achieved level of each knowledge area [3, 33]. Some of them (e.g. basic BIM operating skills, perform automated quantity take-off and cost estimation, perform 4D visualization of construction tasks) were achieved through the educational practices applied at the University J. J. Strossmayer of Osijek and the University of Zagreb. However, the survey did not examine the specific level of knowledge and skill. Thus it was impossible to assess the student's competency in BIM (e.g. by employing Bloom's taxonomy competency level scale: 1-Know, 2-Understand, 3-Apply, 4-Analyze, 5-Synthesize, 6-Evaluate [46]).

5 Conclusion and future work

This research has shown scarcity of knowledge regarding BIM education at the civil engineering faculties in Croatia, even though the students of the graduate courses understand the BIM concept and believe that these tools could aid them in their everyday work

practices. Further results show that by attending the 'Construction Management' course, the master graduate students at the University J. J. Strossmayer of Osijek and the University of Zagreb, Faculty of Civil Engineering, are able to understand the BIM concept and how BIM changes the work processes in construction projects. Furthermore, the current education practices give them skills to perform data analysis with existing BIM models, to use BIM visualization and communication tools but also have experience in working with specific BIM tools. According to Wang and Leite (2014) the mentioned abilities represent specific BIM knowledge of BIM managers /engineers but also of project managers [23].

Moreover, we identify that project-based learning and learning BIM as a process have good impacts on students CM education at master degree level. Further, in this study we have shown that by practicing mature BIM education methodologies, students gained satisfactory knowledge in BIM. Besides, we proved that combinations of software which were intended for usage in education on master degree level should be tested before the education process starts.

According to Barson's and Santos's (2010) classification, academic experience which was reached through the education at the Universities of Osijek and Zagreb, Faculty of Civil Engineering, was a single course collaboration because BIM was introduced only through one discipline within each of the universities separately. Even though the current education practice in BIM in CM courses is on a satisfactory level, further knowledge areas

are missing: coordination, interoperability and clash detection. In order to reach the mentioned learning outcomes, education has to be extended through two or more disciplines within the same university (interdisciplinary collaboration) or two or more distance universities (distance collaboration) [30].

Future work also involves analysing how creating a simple 3D model enhances student's spatial visualization of object and possible problems during all phases of the project. Furthermore, the education needs to be extended on the other software tools as well (e.g. Vico, ArchiCAD, Civil 3D and other). This extension will provide students with wider knowledge about 3D modelling, time planning (4D modelling) but also cost estimation and cost analysis (5D modelling). Finally, this study showed the importance of BIM in education and urged the universities to alter their curricula and their learning outcomes by involving the BIM knowledge areas defined by this and accordingly determining the recommended learning outcomes [3, 33].

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