ITU A|Z • Vol 17 No 3 • November 2020 • 195-209

Students' perceptions of BIM learning scenario in architectural education

Hatidža ISANOVIĆ[1], Birgül ÇOLAKOĞLU[2]
[1] hatidzai@gmail.com • Architecture Department, Graduate School of Science, Engineering and Technology, Istanbul Technical University, Istanbul, Turkey
[2] bigi_c3@yahoo.com • Architecture Department, Faculty of Architecture, Istanbul Technical University, Istanbul, Turkey

Received: November 2019 • Final Acceptance: February 2020

Abstract

The inclusion of BIM in architecture curricula, in addition to those in engineering and construction, has gathered significant pace over recent years. The patterns of this inclusion vary significantly from country to country having different approaches, strategies, methods, and challenges associated with professional and academic environment. In countries like Turkey, many architecture educators still ask: 'What is BIM and why do we need it?". This paper presents one part of a larger research aiming to develop different 'BIM learning scenarios' for architecture schools which had not yet developed BIM tradition. The BIM learning scenario represents a flexible structure organized within the agenda of four basic questions: why (objectives), what (contents), how (methods), and who (management). The broader research proposes a strategy for introducing BIM in architectural education. The strategy is defined by the means of an exchange of experience between the academic world and practice. It also prioritizes self-learning and student-centered approach which are one of the key requirements of 21st century curricula. The current paper demonstrates students' perceptions of the proposed BIM learning scenario obtained through focus group study. We provide the framework used to plan the scenario, describe the scenario setting, present students' responses obtained through focus group, outline the lessons learned and discuss their implications for the future advancement of BIM in architectural education.

Keywords
Architectural education, Building information modeling (BIM), Focus group, Hybrid model, Learning scenario.

doi: 10.5505/itujfa.2020.87528

1. Introduction

Nowadays, architectural education is going through a transformation, tending towards the adoption of digital technologies and building information modeling (BIM). BIM is a digital model-based technology linked with a database of project information which is led by the idea to reintegrate design, construction, and project management, reducing project delivery time and overall costs (AIA, 2007). BIM represents a large innovation in architecture, engineering, construction and operation (AECO) industry with significant upside potential, but it also represents, as most innovations do, a disruption to entrenched culture and associated models of practice and education.

Teaching BIM is a complex issue which requires understanding and knowledge not only of the tool but also of materials and construction methods used in the aspired professional practice (Cheng, 2006). Students should not only learn the theory and functionality of BIM and understand its current implications, but also ‘learn to learn’ and continuously upgrade their practical skills and knowledge to be able to respond to the changing requirements of practice.

The inclusion of BIM in architecture, as well as engineering and construction academic curricula has gathered significant pace over recent years (Barison & Santos, 2018). While there is a visible increase of publications in this area and signs that it is becoming a growing field of research, there is a lack of agreement on how to include BIM in academic curricula. One of the major reasons for the still unresolved status of BIM in architectural education can be found in the presence of clearly opposite attitudes towards BIM in architectural education. While some educators (Clayton, M., Ozener, O., Haliburton, J., & Farias, F., 2010; Ambrose, M. A., & Fry, K. M., 2012; Ambrose, 2007; Aksamija, 2017; Cheng, 2006) regard BIM as an inevitable part of 21st century education and the opportunity to improve it, others consider it a threat to the creative development of students and the disruption of long-established models of educating architects (Denzer and Hedges, 2008). Moreover, architecture educators cannot agree on whether BIM should be approached as a tool/skill issue, as a new form of design practice, or as a new professional organizational model (Deamer, 2011). Each of these positions lead to different contents, pedagogical approaches and positioning in curricula (Becerik-Gerber et al., 2011). As a consequence, the question of how and when to introduce BIM into architectural education remains to be open and exploring innovative approaches is needed.

The literature review of articles on implementation of BIM in education shows lack of evidence-based interpretations of implementing BIM in architectural schools, especially in relation to the main actors of the teaching process – students and teachers. It is still not sufficiently illuminated what particular BIM learning scenario is the most effective one and which brings the best results. This prompted us to develop the longitudinal research study that lasted for three semesters and introduced different BIM learning scenario in each semester. Such research design enabled testing of implementation of a certain learning scenario, and at the same time improving it on the basis of previous evaluations. Before explaining our research approach, we shall first discuss different views on BIM in university curricula.

2. BIM in architectural education

Barison and Santos (2018) provided the extensive list of authors and universities who have integrated BIM into their curricula as well as a comprehensive overview of common trends in adoption across disciplines. According to their observations, architecture schools were among pioneers showing interest in BIM adoption when it first appeared. However, today, they are among the ones with the least agreement on how to do it.

One of the major reasons for this can be found in the presence of clearly opposite attitudes towards BIM in architectural education. On one side, BIM is seen as a threat to the explorative character of architectural education and the creative development of students. On the other side, BIM is seen as an opportunity to improve architectural education by helping to resolve some of its existing issues. BIM is also seen as a promoter of a more sophisticated 'design thinking' by allowing explorations of various dimensions of design solutions (Denzer & Hedges, 2008). According to this view, BIM is an inevitable part of 21st-century architectural curricula.

Another reason for the still unresolved status of BIM in architectural education comes from the fact that BIM means different things for different educators. While some see it as a tool/skill issue, others consider it as a new form of design practice, or a new professional organizational model (Deamer, 2011). Each of these positions leads to very different pedagogical approaches, teaching methods and contents. In addition, BIM is not just a new topic to be added to the existing educational models. Its adoption requires re-considering epistemological, cognitive and pedagogical aspects of education (Kiviniemi, 2013).

Along with potentials, there are also several obstacles and challenges associated with the introduction of BIM to architectural education. Education is built on a rigid and fragmented structure that often resists changes. Kymmell (2007) suggested that misunderstanding of the BIM process, difficulty in learning and using BIM software and issues pertaining to the environment in the academic institution are the main obstacles to its adoption in education (Kymmell, 2007). Furthermore, Deamer and Bernstein (2011) suggested that already overloaded curricula and design-studio centered structure of architectural curriculum are unsuitable for the adoption of BIM (Deamer & Bernstein, 2011).

The general resistance to BIM in architectural education originates from the belief that BIM is suppressing the creative development of the student by congesting his/her mind with a large amount of information and complex tools. Design activity and idea generation is a delicate process which does not always benefit from quantitative information early in the process (Poerschke, U., Holland, R. J., Messner, J. I., & Pihlak, M., 2010). Specifically, if students are not skillful with the tools, design exploration can be hindered by switching the focus from the task and content to learning the tools. Consequently, this can lead to reduced quality of design solution and loss of creativity until the new media becomes an integral part of the designer's mindset.

The development of successful education depends on more than just curricula development. Supporting curricula development there need to be knowledgeable tutors, a body of research and reference material and the appropriate environment in which to learn. BIM has put the learning challenge in front of educators and students equally. As BIM has recently gained popularity among architecture educators, many teachers do not have the required level of knowledge, expertise or design project experience to teach BIM. Most teachers are experts in 2D drafting, some in 3D modeling, but relatively few in BIM (Kiviniemi, 2013). Creating an information-rich virtual model of a building requires much more knowledge than architectural teachers teach. The lack of maturity and expertise of teachers can result in poor learning and teaching outcomes. Therefore, the issue of 'who' will deliver BIM-related knowledge represents an important challenge for its introduction in architectural curricula.

Additionally, developing appropriate educational material is another challenge. This is because, most of the sources of materials are either from research studies, which are only released via publication only, or vendor oriented material, which is biased towards proprietary BIM tools. In order to overcome this limitation, some universities create their own in-house resources that are used by the students and faculty involved in BIM education. however, this again is not shared among universities massively, and each university has to take a similar effort from scratch.

Furthermore, the interest and awareness of BIM, as well as the level of its implementation in practice and academia significantly vary from country to country (Rooney, 2017). Whilst BIM is being widely adopted, and even required by governments in some countries, in others, BIM is absent from academic curricula. In countries like Turkey, BIM utilization and recognition of its importance has recently started in professional practice under the pressure of international projects and their requirements to use BIM. Educators cognizant of these changes and their significance for education, are searching for the best ways to reflect them in academia. Some of the leading universities in Turkey have already started the introduction of BIM into undergraduate and graduate courses. However, lack of research literature and practical examples of BIM adoption in academic curricula indicates that this issue has not been studied with a significant level of depth locally. Still, the general question among many educators is: 'What is BIM and why do we need it?'. This points to the necessity to raise the local BIM awareness and knowledge which will open the way to its wider adoption among the architectural education community in Turkey.

3. The present study

To address this need and to build on the current scholarly discussion about BIM adoption in architectural education, this study explores ways of introducing BIM in architecture schools without developed BIM tradition. It is difficult (and probably unnecessary) to recommend any single model or curricular change that could be applied to all schools similarly. This paper presents one part of a larger longitudinal exploratory multi-level case study aiming to develop different 'BIM learning scenarios' for architectural education. In the context of this study, the BIM learning scenario represents a flexible structure organized using a framework proposed by Teymur (2007) and UIA (2011), which suggests organization of new inclusions in architectural curricula within the agenda of four basic questions: why (objectives), what (contents), how (methods), and who (management). To avoid congesting students' minds with the complexity of BIM software and concept, the learning scenario consists of the introduction of the main framework that enables one to understand the essential principles of BIM and the logic of its tools in general. The BIM learning scenario made the basis for creating a new culture in education by proposing a strategy for introducing BIM in architectural education. This strategy is defined by the means of an exchange of experience between the academic world and practice to simulate professional practice in the university. In addition, they promote self-learning and student-centered approach which are one of the key requirements of 21st century curricula.

The study was conducted in the period of three academic semesters from Spring 2017– Spring 2019 including intensive research activity aiming at investigating ways of BIM integration into architectural curricula in schools without developed BIM tradition. One segment that this study addressed were students' perceptions of the proposed BIM scenarios. Given the longitudinal character of the study, it was possible to implement BIM learning scenario continuously over the time and to compare different students' perceptions. At the end of the semester, a focus group was organized in order to collect students' perceptions about the BIM learning scenario. In total, 3 focus groups were organized with 17 participants, on average, 5 participants per a group. Students invited for the focus groups were those who had attended the course on BIM learning scenario, for they had relevant experience to draw from.

This paper presents students' perceptions of the proposed BIM learning scenario. For this purpose, the study used focus group, a qualitative research method typically used for obtaining information about participants' feelings, attitudes and perceptions about a particular topic through conversations (Puchta & Potter 2004). As argued by Flick (2009: 204), focus groups have the potential to reveal meanings people have about a certain problem. On the other hand, its limitation originates from relatively small number of participants compared to the overall population, and pragmatic nature of data analysis instead of providing extensive and general interpretations (ibid: 205). As it is the case with qualitative research as such, conclusions made on the basis of focus group data should be taken more as illustration of how certain patterns work in the given contexts not as the general rule. In order to increase explanatory value of focus group data, we conducted multiple focus groups with different participants enabling thus comparison of students' perceptions.

In the remainder of the text, we will present the framework used to plan the scenario, describe the scenario setting, present students' responses obtained through focus group, outline the lessons learned and discuss their implications for the future advancement of BIM in architectural education. Although the primary focus of this study is on educational practices in Turkey, the issue in this area is present in countries with a similar level of social and technological development.

The study was based on a single institution, imposing obvious limits on the generalizability of our findings. We acknowledge that the findings are suggestive and are in need of replication in multiple institution studies. Nevertheless, in discussing the results, we will speak of universities, rather than just the one studied.

4. Framework

Technological developments in 21st century created new learning opportunities and brought new profiles of students. By casually using technology to acquire, communicate and process information, the new profile of students seeks flexible learning structures and create their own self-learning packages according to their own interests and needs (Foqué, 2010). In such a context, the role of university education increasingly becomes to provide the guidelines on an approach of 'learning how to learn' and the classical role of teacher transforms into a moderator in the learning process, like 'scaffolding for a new building' (Niemi, 2009).

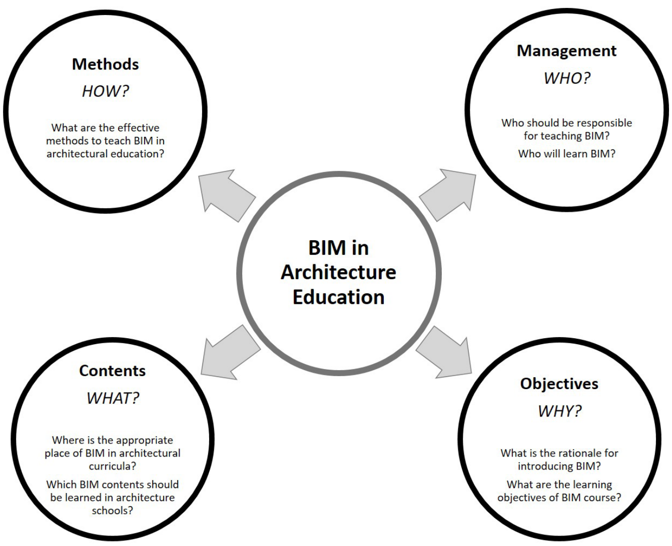

Figure 1. *Framework for BIM in architectural education.*

In line with this context, this study proposes 'BIM learning scenario', a student-centered flexible framework for organizing the learning activities with the aim to provide guidelines for learning to learn. As a basis for organizing the BIM learning scenario, we used a framework for planning and proposing new contents in architectural education proposed by Teymur (2007), adopted and further elaborated by the International Union of Architects (UIA, 2011). According to this framework, new inclusions in architectural curricula should be organized within the agenda of four basic questions:

a) Contexts and objectives (i.e. why) - the rationale for introducing new content which is defined by considering various contexts of architectural education and specific objectives pertaining to them. The objectives of specific courses are defined within this rationale.

b) Content and curricular structure (i.e. what) - the contents that should be taught and where should they be placed in the curricula.

c) Methods and media (i.e. how) - the modes, means, techniques, and vehicles by which the contents and objectives of courses are achieved.

d) Management and structure (i.e. who) - the management of knowledge, people, time, space and financial resources in educational contexts; who delivers the knowledge, who are the students and who evaluates and validates courses.

All these components are linked, determining and influencing each other in a variety of ways. Although based on a simple set of questions and concerns that already exist in educational studies separately or comprehensively (Pektaş, 2007; Salama & Wilkinson, 2007), this framework represents a unique and legitimized approach. Using this framework can contribute to better communication among those interested in BIM in architectural education which is one of the key reasons for its utilization in this study.

5.BIM learning scenario

For the purpose of this study, BIM was introduced in Special Topics in Architecture (MTZ508E), a 3-credit course which is a part of the non-thesis graduate program at Istanbul Technical University (ITU) Faculty of Architecture. The course was developed and taught under the supervision of the Authors. Considering the non-existence of BIM-related courses in the curricula, the selected architecture school does not have developed BIM tradition. The limited course time of 3 hours per week required careful planning of contents that would be introduced to students new to BIM. A homogenous group of 17 architecture students attended the course and agreed to participate in the research. The course required a flexible structure to allow development and the necessary revisions as we gained more understanding of how students responded to BIM.

Following the aforementioned questions, BIM learning scenario was arranged in the following way:

Objectives. The central learning objectives were to: understand the role of BIM in achieving better, more efficient, sustainable, socially and environmentally conscious design solutions; recognize the changing role of architect and the importance of BIM knowledge and skills in contemporary practice; learn the main principles and methods of BIM approach; and learn how to develop BIM knowledge and skills in the future.

Management. The scenario was organized around hybrid model which combined three complementary components (Figure 2):

(I) university class providing the supporting structure and guidelines;

(II) professional practice contributing with expertize and real-life BIM projects;

(III) online learning repository to supplement the in-class learning.

The course was prepared and taught

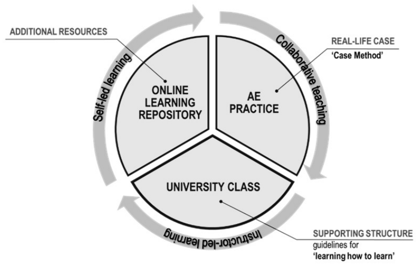

Figure 2. *Hybrid model components.*

in collaboration with BOLD Architecture, an architecture-engineering firm from Istanbul. The reasons for selecting the firm were their interdisciplinary approach and collaborative working methods; experience in BIM utilization and development of effective methods for its implementation; and their readiness to collaborate and openness to share experiences, knowledge with teachers and students. In this setting, the three roles and interactions emerged: learner (student) - moderator (teacher) - practice mentor (architect/engineer). Although practice mentors have valuable project experience and practical skills, they lack theoretical knowledge about specific concepts. They are usually able to do rather than theoretically elaborate on how they did something. To make their contribution effective and to extract the valuable knowledge and adjust it to the level of beginner learner, the teacher's task was to guide them by providing the framework defining the focus and direction of the course.

To meet the course time frame, only the basics and fundamental principles were provided in the class, while students were encouraged to expand their knowledge using course-specific online learning repository. Serving as a supplement to the contents presented in the class, the learning repository contained a variety of texts, websites, and visual materials from BIM-related literature, as well as high-quality tutorials and videos about BIM tools. The content of the repository was continuously updated.

As we agreed with practice mentors that they would not be teaching BIM software skills, nor the time of the class allowed it, the flipped classroom instructional strategy was adopted (Bishop & Verleger, 2013). Students were

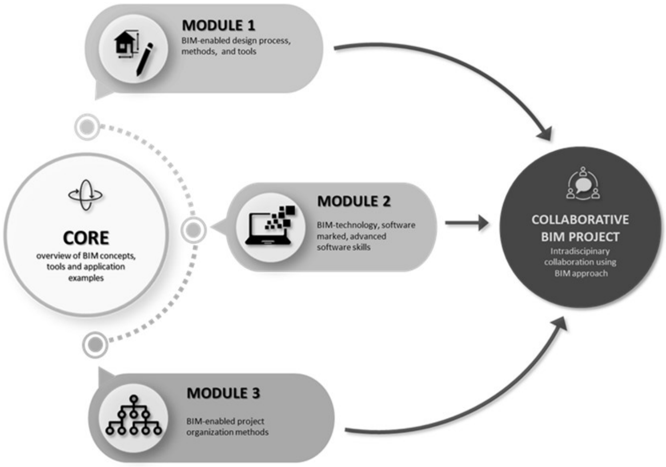

Figure 3. *The three level oganization of scenario contents.*

required to learn the basic technical skills on their own using carefully prepared video tutorials form learning repository. This allowed the in-class time to be use efficiently for the questions about the aspects students could not resolve on their own. Although it was a self-learning process, students were given the framework to follow, such as the required tasks and time to complete them.

Contents. In order to support the gradual development of student's knowledge and skills, and to avoid to avoid congestion in learning with too much content and complexity, BIM content was presented in three levels: (I) Core; (II) Modules; (III) Collaborative project (Figure 3).

The core provided an overview of BIM theory, technology and examples of application in professional practice. This also provided the background for selecting the BIM area students wanted to study in one of the modules they select. The organization into modules was based on the proposition that some students are good in design, some in tool/technology area, while others can be good in organization and leadership. By selecting a module, students could select a BIM area according to their preferences. The main themes from the core were further extended into modules, each focusing on a specific area in more depth. Module 1 focused on design in BIM environment and introduced the concepts and tools for performance-based design. Students explored how building form, its location and orientation, materials and architectural elements influence building performance, its cost, energy consumption and daylighting. Module 2 primarily focused on BIM technology and the proper application of the tools in correct visualization of different types of BIM objects. Module 3 introduced BIM methods for effective organization and communication between project participants, the main principles of the BIM execution plan, BIM process and BIM standards.

Finally, in intradisciplinary collaborative project, students were expected to compile the knowledge and skills learned in individual modules into a common project. Students were divided into teams in which they took the role according to the module they selected previously. The collaborative project aimed to help students in developing communication and teamwork skills and the ability to work efficiently within intradisciplinary teams using BIM technology. The key to this process was for each team member to build awareness, appreciation, and understanding of other members within the team. The projects were not focusing on proposing new designs, rather their purpose was to demonstrate students' understanding of presented contents and their ability to apply them on the given task.

Methods. Pedagogically, the course was designed as a series of lectures and demonstrations followed up by hands-on exercises. In addition, the involvement of practice enabled us to use the case method in delivering BIM knowledge. Although relatively new in architectural education, this method has been used for decades in a wide range of professional schools, such as law, business, and medical schools, to teach the skills required for real-world activities (Garvin, 2003). The top-down process of the case method involves disassembling, analyzing the structure, function, and operation, taking it apart and examining its workings in detail to try to recapture the underlying principles of its creation. The main purpose of using this method was to enable students the exploration of real-life BIM projects and processes that integrate design, construction, mechanics and other sub-disciplines. In this way, the technological and non-technological principles of a model as an integrated system could be analyzed and examined.

For this purpose, the AE practice provided the 'BIM case', a fully realized BIM model of already designed and completed building and its documentation (Figure 4a, 4b, 4c). Practitioners from each discipline involved in the development of the model, such as architects, structural and MEP engineers presented their components within the model and processes that led to their creation. The role of different disciplines in the overall process and the importance of collaboration between architects and engineers in the development of design solutions were strongly emphasized.

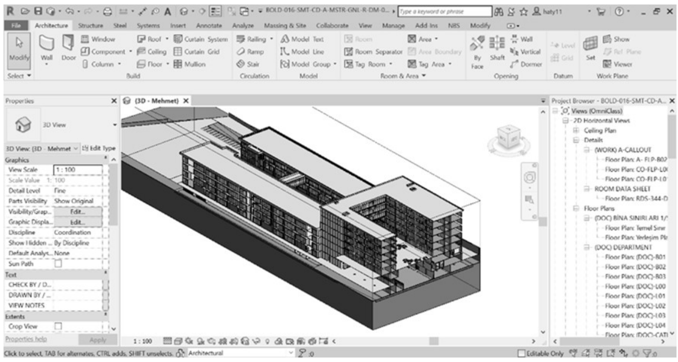

Figure 4a. *The 'print screen' of BIM model provided by BOLD Mimarlik.*

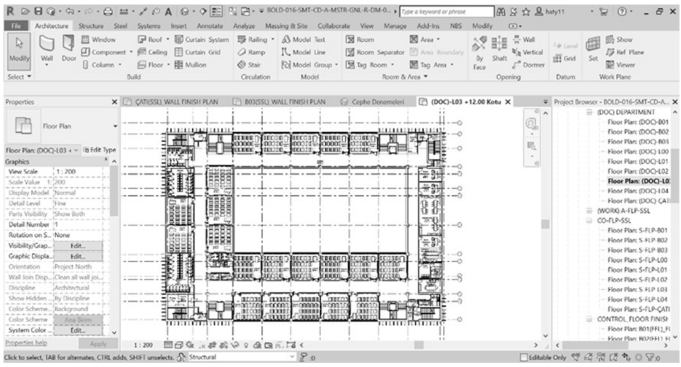

Figure 4b. *The 'print screen' of BIM model provided by BOLD Mimarlik.*

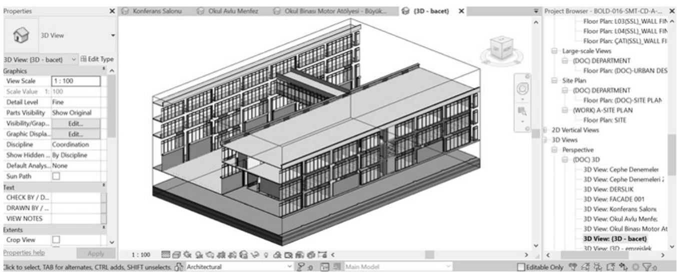

Figure 4c. *The 'print screen' of BIM model provided by BOLD Mimarlik.*

6. Research methodology

This paper describes and discusses one part of a larger exploratory multi-level case study aiming to explore different BIM learning scenarios for architectural education. This paper presents students' perceptions of the proposed BIM learning scenario. For this purpose, together with our observations during the course, using focus group method was considered appropriate and convenient. Focus group is a qualitative research method for obtaining information about participants' feelings, attitudes and perceptions about a particular topic through conversations (Puchta & Potter 2004). In focus group, the researcher can collect in-depth answers to the questions posed and ask supplementary ones if necessary.

In the context of this study, focus groups were used to obtain information about students' attitudes, experiences, and evaluation of several aspects of BIM learning scenario. The focus group was conducted upon completion of the course with 17 architecture students who took the course. The researcher prepared a script for capturing the data which was then circulated to course instructor and practice mentors for comments. An external focus group moderator was engaged to get realistic answers from students. We used Krueger's guidelines for preparation of different categories of questions and their utilization throughout the focus group (Krueger & Casey, 2014).

The focus groups were recorded and transcribed into texts. Together with the notes taken during the focus groups, transcribed texts were coded by highlighting the statements of interest. The texts were analyzed using content analysis as defined by Krippendorff (2018). To ensure that the approach remains unbiased and the findings valid, the course instructor and practice mentors were asked to collaboratively analyze and discuss the focus group findings.

7. Students' perceptions of BIM learning scenario

Analysis of focus group discussions and conversations identified the key themes that were critical in students' experiences and perceptions of BIM learning scenario in every single focus group. Those findings were further compared between the focus groups in order to develop more profound understanding of the commonalities between different students' perceptions in relation to BIM learning scenario. These themes, together with noteworthy quotes, are presented and discussed below.

Firstly, students were asked to rate as 'successful', 'partly successful' or 'not successful' the effectiveness of BIM learning scenario in improving their understanding of BIM. From 17 participants, 11 said that the program had been successful, 4 students said it had been partly successful, and 2 said it was unsuccessful.

7.1. Involvement of practice

All students expressed positive opinions about the involvement of people from practice and their continuous presence in the class. They also appreciated the opportunity to directly communicate with architects and engineers and their openness to share their experiences. Some of the selected responses support this:

'I think practice mentors have much more knowledge about BIM than teachers generally'.

'Honestly, I took the course only because it was mandatory, thinking it will be boring. But at the end, I had the most interesting course so far. Having direct connection with real-life and ability to choose what I am interested in was the exciting part'.

'This is what matters when you graduate, to know how real-life works'.

'I liked that engineers also came to the class, not only architects. The real building is not just architect's work'.

'When I listened to instructor and architect explaining the same thing, no offense, but architect sounds more convincing because they use the example to support what they say and are full of real-life stories'.

Moreover, the presence of practice gave students the confidence that BIM is locally accepted and used, although previously much importance had not been given to it in their education. As one of the students noticed 'BIM seems to make our lives a lot easier. Practice mentor told us they use it more than ten years. I am wondering why nobody taught us BIM before'. Many students believed that practice-mentors should teach BIM because 'BIM is all about making real-life buildings', as one of the students observed. Students also clearly expressed their wish for having people from practice involved in teaching BIM in the future.

7.2. Real-life BIM case

When it comes to using the BIM model from real-life practice, students thought it was useful but still too complex for them as beginners. Furthermore, using real-life example allowed exposure to different tasks and roles in a project which helped students reveal their different interests in different BIM areas. Students also considered it very useful to see '…how it all works in real projects with real parameters'. Similarly, another student considered it useful to see all the elements together: 'I saw these elements for the first time, thanks to the virtual BIM model. I could never guess that there are so many pipes and elements…after all architecture is only one small part'. However, some students thought it is irrelevant for them to know about non-architectural elements: 'I liked to see the MEP elements in the model, but I will never create them. So maybe we could use more time in the class to learn how to create more architectural elements?'

Although students generally thought it is important to have a real-life example, they expressed disappointment about not being able to produce similar models. They felt that they lack knowledge to build the 'complex information-rich BIM models' as they did not think they have enough knowledge about construction, materials, and many other building elements' properties. As one of the students observed: '…the real-life model is completely different from the sample project shown in the tutorial.' They were aware that it is different from the one they produced and 'far from reality' as one student said.

7.3. Self-learning

Students generally thought they can learn the technical skills more efficiently in the self-learning approach rather than in the classical instructor-led approach. According to their responses, using the learning repositories allowed them the self-defined dynamics and flexibility to choose '…what to learn and when to learn'. For many students, learning the basic commands was not the problem. However, what it all means in the project and how to put the properties correctly represented an issue for many. Students also thought that they needed more time to learn the tool to be able to follow up and understand what was demonstrated in the class. As they were new in BIM tools, it took time to get comfortable with using it. Many of them would return to the 'safer option' of using the tools they are more proficient in. As one of the students commented: 'Revit looks good, but if I need to submit something really important, I would use AutoCAD and Max rather than Revit because I use them for five years and I can do it faster.'

7.4. Modules

Students generally considered the division into modules more dynamic than the classic course setting. They also thought that focusing on a single BIM area is a good way to understand more clearly the specific topic 'without having too many concepts from different BIM areas to learn'. In addition, they also liked the opportunity to choose what they wanted to study, as one of the students commented: 'I liked the idea of modules because BIM looks very complex having too many fields and subfields. It is impossible to learn it all. Everyone should choose something they can be good at.'

One of the main issues that students highlighted was the need for more time for learning BIM. They complained about not having enough time to learn the tool and to follow up with the content of the course. Their suggestion was to have more courses instead of one, so they can 'have more time to organize it all in their minds'. However, some students thought that they would need more knowledge about specific areas to be able to select a specific module. One of the students from module 1 said: 'I selected the design module because I think the design is the most important for architects. But later, I think maybe it was better if I took the module 2 because I would learn the tool better.'

Furthermore, they had difficulty in understanding the meaning of most performance parameters, numeric values produced in the software (daylight factors, energy usage, and carbon footprint). Module 1 students, who focused on design in the BIM environment, were unsatisfied with the lack of knowledge and lectures about building performance. A student from module 1 said: 'I could understand that changing some parameters about building can change the overall energy consumption, for example. But I didn't understand which parameters and how to change them. They seem too complex and I think we should have separate courses for this.'

7.5. Collaboration and teamwork

Although they showed relatively good results in individual module assignments, students could not demonstrate them in collaborative project. They generally lacked collaborative experience. One of the students said: 'I liked the idea that we can create a project together as a team. But most of the time we worked separately, and later we would put it all together in the class.' Although students theoretically understood the concept of collaboration, they lacked skills to apply it. As one of the students observed: 'Collaboration is not only about creating a project and saying that we worked together, it is a process and a way of thinking.'

Another student described negative collaboration experience: 'My role was to organize the team and to follow their progress. I created the BIM execution plan, but it seems that nobody really took it seriously. Everybody did what they wanted and how they wanted.' Another student also commented: 'This was 'individual collaboration', I did my part for myself, the other for himself and then we put it altogether for submission.'

Another student from module 3 expressed disappointment about the collaborative experience: 'BIM has very good structure and description for everything in the project. What I saw in the class, the documents and technology are well organized. But this is not helping if people are not using it. In our team, nobody followed the plan. So why to make it if nobody will follow it?' Another student also observed that: '…collaboration is all about trust. You can do the job with someone you trust and who will stick to the schedule. No technology can give you trust. You have to build it.'

One student observed that 'For a collaborative project, I think we need more software skills and more collaboration skills. Many of us don't know how to use Revit very well, and at the same time we are not very familiar with how to work with others in the BIM project.'

Table 1. *Comments from students on the course main aspects.*

Course Aspect	Student's comment
Practice involvement	'I think practice mentors have much more knowledge about BIM than teachers generally'. 'When I listened to instructor and architect explaining the same thing, nc offense, but architect sounds more convincing because they use the example to support what they say and are full of real-life stories'. 'I liked that engineers also came to the class, not only architects. The real building is not just architect's work'.
Real-life BIM case	'I liked to see the MEP elements in the model, but I will never create them. So maybe we could use more time in the class to learn how to create more architectural elements?' '…the real-life model is completely different from the sample project shown in the tutorial.' 'I saw these elements for the first time, thanks to the virtual BIM model. could never guess that there are so many pipes and elements…after all architecture is only one small part'.
Self-learning	'Revit looks good, but if I need to submit something really important, I would use AutoCAD and Max rather than Revit because I use them for five years and I can do it faster.' 'I could decide what to learn and when to learn.'
Modules	'I selected the design module because I think the design is the most important for architects. But later, I think maybe it was better if I took the module 2 because I would learn the tool better.' 'I could understand that changing some parameters about building can change the overall energy consumption, for example. But I didn't understand which parameters and how to change them. They seem too complex and I think we should have separate courses for this.'
Collaboration and teamwork	'This was 'individual collaboration', I did my part for myself, the other for himself and then we put it altogether for submission.' 'My role was to organize the team and to follow their progress. I created the BIM execution plan, but it seems that nobody really took it seriously. Everybody did what they wanted and how they wanted.' 'For a collaborative project, I think we need more software skills and more collaboration skills. Many of us don't know how to use Revit very well, and at the same time we are not very familiar with how to work witl others in the BIM project.'

These answers demonstrate the general lack of teamwork experience and poor collaboration skills. This points to the need for more collaborative projects and exercises in BIM learning and in education in general. This also points to many aspects of intradisciplinary collaboration that should be learned before moving to interdisciplinary collaboration. For the future, one of the main suggestions that students highlighted is learning to work in a team, designing with BIM tools, and learning about building performance. Some of the students, who used the skills and knowledge for projects in other courses, also suggested that: 'It would be useful to learn more how to use the tools so I can apply them for assignments in other courses.' Another student also suggested making a connection with the design studio, so they can use what they learn in BIM course for the design project.

A summary of representative students' comments on the main themes is presented in Table 1.

8. What have we learned?

The BIM learning scenario proposed and tested in this study represents an approach to introducing BIM to architecture students who are new to BIM concepts and tools. The goal was to introduce students with the main principles and demonstrate its importance in practice and contemporary design project. It also aimed to provide the foundation for learning and development of self-learning skills in the future education and practice. Although every student is individual and different, having his/her own learning patterns, whose exploration is beyond the scope of this study, there are common patterns and conclusions that could be drawn from this study.

The hybrid model proposed in this study is a step towards creating a new culture that merged professional expertise and experience with pedagogical methods and technology based learning environments. This proposition emphasizes the role of university education to provide guidelines on 'learning to learn'. It also well accommodates the real-life dimension of BIM extracted from professional practice. Students become responsible for determining the dynamics of their self-learning process which extends beyond the boundaries of classroom unit. Seeing architectural practice and education as partners in teaching BIM is beneficial in multiple ways. Involvement of practice not only influenced positively on student learning processes during the course and increased their interest and motivation to learn BIM, but also motivated them to explore BIM further.

Having practice mentors involved in introducing BIM concepts and explaining their application in real-life BIM case improves students' understanding of BIM and gives them confidence that they are learning skills required in today's practice. In addition, the use of real projects makes educational exercises much more meaningful. Students understand and adopt new BIM concepts more easily when their meaning and application in real-life examples are demonstrated to them. They also gained more knowledge about what happens after the design stage and improved understanding of the development of building projects as an interdisciplinary activity. Using real-life examples also allowed exposure to different tasks and roles in a project which helped students reveal their different interests in various BIM areas. BIM concepts and tools should be explained in parallel, having one part of the course explaining a theoretical concept and the other part its application on a specific task. Since all BIM concepts are essentially practical, for students to understand them, each learning unit should involve combination of theory and hands-on application, mind and hand. To make BIM learning more meaningful for architectural student, the clear relationships with architectural knowledge should continuously be made. Theory is important but should not dominate and give space to practical examples.

The complexity of BIM concepts and tools makes it difficult for students to grasp, particularly for beginner learners. Too much content leads to congestion and inability to understand and apply the knowledge on required task. While some architecture students have more interest in design, others have interest in technology or in organization of design projects. New content should be carefully introduced to avoid congestions with too much new information and complex tools. The division of BIM content into learner-defined modules, smaller chunks and more focused topics, which a student can grasp are more effective way of learning then having all students learn everything together. However, the relationship with the overall BIM concept has to be continuously emphasized. Although the areas were divided, there is still a substantial amount of overlap and interaction, among all three of these areas.

This example also emphasized collaboration and teamwork in which student-to-student relationship was specifically important. One of the main goals of the collaborative project was to experience different aspects of collaboration such as trust, team building, role, and responsibilities distribution. However, the negative experiences of students in teamwork showed that none of these aspects is sufficiently developed in architectural education. This indicates the necessity for more collaborative projects and exercises in BIM learning and in architectural education in general. This also points to many aspects of intradisciplinary collaboration that should be learned before moving to interdisciplinary collaboration. Using the top-down approach of the case method, in which the whole finished building is presented first, also demonstrated the need for interdisciplinary approach as well as building as a system of related parts that are created through the efforts of different professionals and disciplines. Teaching the skills and knowledge required for developing such models points to the need for interdisciplinary approach in architecture, engineering and construction education. However, this study showed that before interacting with others, students should be aware of their own disciplinary roles and responsibilities (intradisciplinary). The condicio sine qua non for collaboration with others disciplines is learning to collaborate within one discipline.

Using clear, understandable, high quality and up to date resources and software tutorials are invaluable supplements to in-class learning and represent complementary component of BIM-related classes. Apart from using external resources such as global websites and links of certified institutes, companies, organizations related to BIM research and application, it is also necessary to produce in-house resources, such as special purpose video tutorials. Using these resources, students learned where to find specific information according to their interests, how to properly use them and how to develop their learning based on self-defined dynamics. This provided the foundation for student's development of BIM knowledge and skills in the future which is important for following up the continuous technological developments. Moreover, the use of video tutorials has, in particular, helped students to acquire the practical BIM skills by self-learning. The in-class time could be used for discussing the advanced issues and real-life aspects that students cannot learn on their own. The impact of self-learning was significant, both in terms of the quality of the results and the level of student engagement and commitment to their own self-selected definitions of success.

9. Future development

The learning scenario proposed in this study concentrated on the introduction of BIM in architectural curricula. This is an open-ended proposition, leaving space for further development. The question for future research is: 'How to advance BIM in architectural curricula'? One of the opportunities for advancement is through the establishment of relationship with other courses in architectural as well as in curricula of related disciplines. To support the curricula development there need to be knowledgeable teachers, a body of research and reference material and the appropriate environment in which to learn. As BIM has recently gained popularity among architecture educators, many teachers do not have the required level of theoretical knowledge or practical design project experience to teach BIM. Creating an information-rich virtual model of a building requires much more knowledge than architecture teachers currently teach. Therefore, along with planning education for students, educating faculty is essential for development of BIM in architectural curricula. Another way for advancement is through development of models for collaboration between practice and education. Architectural education is practice-oriented and needs to look to the advancements from practice as a source for teaching. Future research efforts should develop the ways to make practice and collaborative teaching integral part of university education in BIM adoption process. Finally, BIM is complex and evolving concept. Trends in human-computer interaction (HCI), augmented reality (AR), cloud computing and generative design, continually and rapidly influence the evolution of BIM. The new opportunities they create for architectural design practice and education should be investigated in future research.

No single approach to BIM inclusion in architectural education will suffice. Each academic program is different. The important task still remains for the future: educators and practitioners from architecture and related fields, researchers, institutes and governmental bodies should collaboratively approach to the development of a new educational paradigm in which BIM will have the central role.

References

Abdirad, H., & Dossick, C. S. (2016). BIM curriculum design in architecture, engineering, and construction education: a systematic review. *Journal of Information Technology in Construction* (ITcon), 21(17), 250-271.

AIA (2007). *Integrated project delivery: A Guide*. American Institute of Architects, AIA California Council.

Aksamija, A. (2017). BIM in Architectural Education: Teaching Advanced Digital Technologies to Beginner Designers. *The International Journal of Architectonic, Spatial, and Environmental Design*, 11(2), 13-25.

Ambrose, M. A. (2007). *BIM and integrated practice as provocateurs of design education.* Paper presented at the Digitization and Globalization: Proceedings of the 12th International Conference on Computer-Aided Architectural Design Research in Asia. , Nanjing, China: Southeast University and Nanjing University.

Ambrose, M. A., & Fry, K. M. (2012). *Re: Thinking BIM in the Design Studio-Beyond Tools… Approaching Ways of Thinking.* Paper presented at the CAAD, INNOVATION, PRACTICE: 6th International Conference Proceedings of the Arab Society for Computer Aided Architectural Design, Manama, Kingdom of Bahrain: The Kingdom University.

Barison, M., & Santos, E. (2018). Advances in BIM Education. In R. F. Ivan Mutis, and Carol C. Menassa (Ed.), *Transforming Engineering Education: Innovative Computer-Mediated Learning Technologies* (pp. 45-122). Reston ASCE American Society of Civil Engineers.

Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. *Journal of Information Technology in Construction* (ITcon), 16(24), 411-432.

Bishop, J. L., & Verleger, M. A. (2013). The flipped classroom: A survey of the research. In *ASEE national conference proceedings*, Atlanta, GA (Vol. 30, No. 9, pp.1-18). Retreived on: November, 3, 2020, from: https://peer.asee.org/the-flipped-classroom-a-survey-of-the-research

Cheng, R. (2006). Questioning the role of BIM in architectural education. *AECbytes Viewpoint, 26.*

Clayton, M., Ozener, O., Haliburton, J., & Farias, F. (2010). *Towards Studio 21: Experiments in Design Education Using BIM*. Paper presented at the Disruption, modeling and construction: changing dialogues: Proceedings of the XIV Congress of the Iberoamerican Society of Digital Graphics, Bogotá, Colombia: Universidad de los Andes.

Deamer, P. (2011). BIM in Academia. In P. Deamer & P. G. Bernstein (Eds.), *BIM in Academia* (pp. 9-12). US Yale School of Architecture.

Denzer, A., & Hedges, K. (2008). *From CAD to BIM: Educational strategies for the coming paradigm shift.* Paper presented at the AEI 2008: Building Integration Solutions.

Flick, U. (2009). *An Introduction to Qualitative Research (4th edition).* Sage: London.

Foqué, R. (2010). *Building knowledge in architecture*. Antwerp ASP/VUBPRESS/UPA.

Garvin, D. A. (2003). *Making the case: Professional education for the world of practice*. Harvard Magazine, 107, 56–65. Retreived on: November, 3, 2019, from: https://harvardmagazine.com/2003/09/making-the-case-html

Holland, R., Messner, J., Parfitt, K., Poerschke, U., Pihlak, M., & Solnosky, R. (2010). *Integrated Design Courses Using BIM as the Technology Platform, Academic Best Practices. Implementing BIM into Higher Education Curriculum.* Paper presented at the Annual Meeting: EcoBuild America Conference.

Ibrahim, M. M. (2014). *Early integration of Building Information Modelling in education.* Paper presented at the Fusion, Proceedings of the 32nd International Conference on Education and research in Computer Aided Architectural Design in Europe, Newcastlem UK: Northumbria University.

Kiviniemi, A. (2013). Challenges and opportunities in the BIM education–how to include BIM in the future curricula of AEC professionals. In: BIM Academic Workshop.

Kocaturk, T., & Kiviniemi, A. (2013). *Challenges of integrating BIM in architectural education.* Paper presented at the Computation and Performance–Proceedings of the 31st International Conference on Education and research in Computer Aided Architectural Design in Europe, Delft, The Netherlands: Delft University of Technology.

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology* (4 ed.). Thousand Oaks, CA: Sage publications.

Krueger, R. A., & Casey, M. A. (2014). *Focus groups: A practical guide for applied research* (5 ed.). Thousand Oaks, CA: Sage publications.

Kymmell, W. (2007). *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations*. McGraw Hill Professional.

Nakapan, W. (2015). *Challenge of teaching BIM in the first year of University: Problems encountered and typical misconceptions to avoid when integrating*

BIM into an Architectural design curriculum. Paper presented at the The 20th International Conference of the Association for Computer-Aided

Niemi, H. (2009). Why from teaching to learning? *European educational research journal*, 8(1), 1-17.

Pektaş, Ş. (2007). A structured analysis of CAAD education. *Open House International*, 32(2), 46-54.

Poerschke, U., Holland, R. J., Messner, J. I., & Pihlak, M. (2010). *BIM collaboration across six disciplines.* Paper presented at the Proceedings of the International Conference on Computing in Civil and Building Engineering.

Puchta, C., & Potter, J. (2004). *Focus group practice*. London: SAGE Publications. doi: 10.4135/9781849209168

Rooney, K. (2017). *International BIM Education Report.* NATSPEC BIM, ICIS, 1-15. Retrieved on: November, 3, 2019, from: https://bim.natspec.org/images/NATSPEC_Documents/BIM_Education_Global_2017_Update_Report_V4.0.pdf.

Sabongi, F. J., & Arch, M. (2009). *The Integration of BIM in the Undergraduate Curriculum: an analysis of undergraduate courses.* Paper presented at the Proceedings of the 45th ASC Annual Conference.

Salama, A. M., & Wilkinson, N. (2007). Introduction: Legacies for the Future of Design Studio Pedagogy In A. M. Salama & N. Wilkinson (Eds.), *Design studio pedagogy: Horizons for the future* (pp. 3-8). UK The Urban International Press.

Teymur, N. (2007). Vitruvius in the Studio - What is Missing? . In A. M. Salama & N. Wilkinson (Eds.), *Design studio pedagogy: Horizons for the future* (pp. 91-110). UK The Urban International Press.

UIA (2011). *UIA and architectural education: Reflections and recommendations.* Tokyo: UIA Architectural Education Commission.

Yan, W. (2010). *Teaching Building Information Modeling at undergraduate and graduate levels.* Paper presented at the Future cities: 28th eCAADe Conference Proceedings, Zurich, Switzerland: ETH Zurich.