ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

DEVELOPMENT OF BIM LEARNING SCENARIOS FOR ARCHITECTURAL EDUCATION

Ph.D. THESIS

Hatidza ÇAPKIN

Department of Architecture

Architectural Design Programme

APRIL 2020

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

MİMARİ EĞİTİM İÇİN BIM ÖĞRENME SENARYOLARI GELİŞTİRME

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Hatidza ÇAPKIN, a Ph.D. student of İTU Graduate School of Science Engineering and Technology student ID 502122010, successfully defended the dissertation entitled "DEVELOPMENT OF BIM LEARNING SCENARIOS FOR ARCHITECTURAL EDUCATION", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my family,

FOREWORD

Completing this thesis would have not been possible without the valuable contribution and support from my teachers, my family, and friends.

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October 2019 Hatidza ISANOVIĆ
(Architect)

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ABBREVIATIONS

AE	**:** Architectural Education
AEC	**:** Architecture Engineering Construction
AECO	**:** Architecture Engineering Construction Operation
AP	**:** Architectural Practice
BIM	**:** Building Information Modeling
CAAD	**:** Computer Aided Architectural Design
CAD	**:** Computer Aided Design
HVAC	**:** Heating Ventilation Air Conditioning
ICT	**:** Information Communication Technology
MEP	**:** Mechanical Electrical Plumbing

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DEVELOPMENT OF BIM LEARNING SCENARIOS FOR ARCHITECTURAL EDUCATION

SUMMARY

Nowadays, tending towards the adoption of digital technologies and building information modeling (BIM), architectural education is going through transformation. 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 established culture and associated modes of practice and education.

The inclusion of BIM in architecture, as well as engineering and construction academic curricula 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. While schools in some contries have structured approaches to adopting BIM in education and develop methods for its improvement, in countries like Turkey, many architecture educators still ask: 'What is BIM and why do we need it?'.

In past two decades, there has been a visible increase of publications in the area of BIM teaching in architectural education and signs that it is becoming a growing field of research. However, there is a lack of agreement among scholars and educators on how should it be done. While some see it as an opportunity to improve the existing education, others consider it a threat to the creative development of students and the disruption of long-established models of educating architects. In addition, there is a lack of agreement on whether BIM should be approached in architectural curricula as a tool/skill issue, a new form of design practice or a professional organizational method. As a consequence, the question of *how* and *when* to introduce BIM into architectural education remains to be opened and exploring innovative approaches is needed. Furthermore, this issue has not been studied with a significant level of depth locally. In order to improve the current practice in Turkey and better respond to the emerging requirements, there is an urgent need to raise the BIM awareness and knowledge in local AEC firms and schools.

To address this need and to contribute to the aforementioned discussion, this thesis explores the ways of introducing BIM in architectural education with a specific focus on Turkey. In doing so, this study accomplished the following objectives: it provided an overview of global and local perspectives on BIM in architecture education; it conducted a multi-level case study to develop and test three BIM learning scenarios; assessed the case study results and discussed their contribution to the future development of a model for BIM adoption in architectural education in Turkey.

This thesis proposes different 'BIM learning scenarios' for architecture schools without 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). It proposes a strategy for introducing BIM in architectural education which 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.

To accomplish the main research goals, this study used a mixed-method research approach that combined quantitative and qualitative methods, such as literature review, survey, focus groups, interviews, and case study. The exploratory nature of the study necessitated a flexible research approach. Thus, action research strategy was adopted to design the research development process. Following the logic of action research, the development process of the case study was designed in three consecutive levels.

This study provides valuable insights into the local perspectives on BIM which is generally lacking in the research literature. Data collected from observations, surveys, and interviews with local practitioners and educators can inform future initiatives for planning BIM in architectural education. The three BIM learning scenarios, developed and tested in this study, represent flexible structures for organizing objectives, contents, methods, and people involved in the learning process. They propose a strategy for introducing BIM in architectural education which is defined by the means of an exchange of experience between the academic world and practice to simulate professional practice in the university. This made the basis for creating a new culture in education which promises that the divergence between what is taught in architecture schools and what is practiced in real life can begin to transform into convergence through collaboration between education and practice.

A practical implication of the research findings is the development of a strategy for BIM integration into the architectural curricula of the ITU Faculty of Architecture graduate program which is planned for the future. We hope that this will establish the basis for the formation and development of a new educational model for architectural education in which BIM will have the central role.

MİMARİ EĞİTİM İÇİN BIM ÖĞRENME SENARYOLARI GELİŞTİRME

ÖZET

Teknolojik yenilikler, küreselleşme, sürdürülebilirlik ve akıllı eserler, bir mimardan yeni bir beceri ve bilgi seti gerektiren çağdaş mimari uygulamanın yeni koşullarını oluşturdu. Yapı bilgi modellemesi (bundan böyle BIM), kitlesel özelleştirme, parametrik tasarım, hızlı prototipleme, dijital üretim, her yerde bilgi işlem ve prefabrikasyon gibi teknolojiler, bir mimarın ortaya çıkan bu bağlamda bilgi tabanını ve becerilerini yeniden tanımlaması için fırsatlar sunmaktadır.

BIM, bina modelleri oluşturmak, paylaşmak ve analiz etmek için bir dizi yöntem ve teknoloji olarak tanımlanmaktadır (Sacks, Eastman, Lee ve Teicholz, 2018). Bina modelleri proje bilgileri veritabanıyla bağlantılıdır. BIM'in arkasındaki ana fikir, tasarım, inşaat ve proje yönetimini yeniden entegre etmek, proje teslim süresini ve toplam maliyetleri azaltmaktır (AIA, 2007). Araştırma literatüründe kapsamlı bir şekilde rapor edilen BIM'in sayısız faydaları, BIM'in mimarlık, mühendislik, inşaat ve işletme (AECO) uygulamasındaki en etkili son gelişmelerden birini temsil ettiğini göstermektedir. BIM'in tasarım-yap-işlet süreçlerine dahil edilmesi disiplin sınırlarını bulanıklaştırır ve geleneksel rolleri, organizasyonu ve çalışma yöntemlerini güçlü bir şekilde etkiler. Bu nedenle, birçok yazar tarafından AECO uygulamasında bir paradigma değişikliği olarak kabul edilmektedir (Foqué, 2010; Azhar, 2011; Garber, 2014; Sacks ve diğerleri, 2018).

BIM'in çağdaş uygulamalardaki artan önemi ve kullanımı, eğitimcilerin öğrencilerin buna hazırlanma şeklini yeniden düşünmeleri için bir görev oluşturmaktadır. BIM'in akademik müfredata girişi, uygulama-eğitim ilişkisini yeniden gözden geçirerek ve AEC eğitimindeki parçalanmış disiplin yapılarını yeniden düzenleyerek geleneksel eğitim yaklaşımlarının dönüşümüne duyulan ihtiyacı güçlü bir şekilde göstermektedir. Mimari eğitim, sosyal ve çevresel değişimlere, yeni teknolojilere ve özellikle mimari uygulama ve inşaat endüstrisindeki değişikliklere karşı yetersiz duyarlılığı nedeniyle geniş ölçüde eleştirilmiştir (Nicol & Pilling, 2005).

Kullandığı yöntemler ve araçlar, izlediği rol modelleri ve sunduğu bilgi, geçmiş dönemin eğitim modellerine dayanmaktadır ve mevcut uygulamadan ziyade geçmişin gereksinimlerine daha fazla yanıt vermektedir (Clayton, 2006). Çeşitli araştırmalar, mimarlık okullarının öğrencileri uygulamada yaşamın gerçekleri için yeterince donatmadığını göstermektedir (Dobson, 2014; NCARB, 2013).

Ayrıca, bilgi teknolojilerinin geliştirilmesi çeşitli medya ve teknoloji tabanlı ortamlar yoluyla yeni öğrenme fırsatları yaratmıştır (Niemi, 2009). Bu, bilgiyi almak, iletişim kurmak ve işlemek için teknolojiyi rasgele kullanan bir öğrencinin yeni bir profilini getirdi. Bu tür bir öğrenci esnek öğrenme yapıları arar ve kendi ilgi ve ihtiyaçlarına göre kendi kendine öğrenme paketlerini oluşturur (Foqué, 2010). Dijital öncesi yaş için tasarlandığından, mevcut eğitim sistemi artık dijital çağda öğrenme gereksinimlerine cevap veremez (Prensky, 2001).

Muhtemelen, mimari eğitim radikal değişiklikler ve paradigmatik olarak yeni yaklaşımlar gerektirmektedir. Çağdaş mimari araştırmalardaki etkili sesler, mimarlık eğitiminin altında yatan teori ve yöntemlerin köklü bir şekilde yeniden düşünülmesi ve 21. yüzyıl mimarisinin ortaya çıkan bağlamının gereksinimlerini karşılayacak yeni eğitim modellerine duyulan ihtiyacı vurgulamaktadır (Buchanan, 2012b; Chong, Brandt, & Martin, 2010; Findeli, 2001; Foqué, 2010; Salama & Wilkinson, 2007b). BIM'in son yirmi yılda artan kullanımı ve gelişimi, BIM'in mimari eğitimin aradığı paradigma değişikliğinin en güçlü itici güçlerinden biri olduğuna dair güçlü argümanlar sunmaktadır. BIM, öğrencilerin uygulama zorlukları için daha iyi hazırlanmasını sağlayacak çağdaş mimari müfredatların oluşumuna temel sunarak mimari eğitimdeki devrimci değişiklikleri ön görmektedir.

Son yıllarda, mimari eğitimin dönüşüm süreci, yeni dijital teknolojilere yer açmaya ve mimari tasarım ve bina yapımı için getirdikleri fırsatları benimsemeye başladı. Dünyadaki çeşitli üniversiteler mühendislik ve inşaat akademik müfredatının yanı sıra mimaride BIM'i tanıtmanın en iyi yollarını arıyor. BIM'in ne zaman ve nasıl tanıtılacağı soru programları farklı yaklaşımlardır (Becerik-Gerber, Gerber ve Ku, 2011).

BIM çok boyutlu, karmaşık ve gelişen bir kavramdır. Mimarlık eğitimine girişi, çeşitli açılardan ele alınması gereken karmaşık bir konudur. BIM, mimarlık öğretiminin sadece aracın anlaşılmasını değil, aynı zamanda amaçlanan profesyonel uygulamanın, kullanılan malzemelerin ve kullanılan yapım yöntemlerinin bilgilerinin de kavranmasını gerektiren yeni öğretim yollarına işaret etmektedir (Cheng, 2006). Öğrenciler sadece BIM'in teorisini ve işlevselliğini öğrenmek ve mevcut etkilerini anlamakla kalmamalı, aynı zamanda uygulamanın değişen gereksinimlerine cevap verebilmek için 'öğrenmeyi öğrenmeli' ve pratik becerilerini ve bilgilerini sürekli olarak yükseltmelidir.

BIM'in mimariye dahil olmasının yanı sıra mühendislik ve inşaat akademik müfredatları son yıllarda önemli bir hız kazanmıştır (Barison ve Santos, 2018). Bu alandaki yayınlarda gözle görülür bir artış olsa da ve bunun giderek büyüyen bir araştırma alanı haline geldiğine işaret ederken, BIM'in akademik müfredata nasıl dahil edileceğine dair bir anlaşma eksikliği var. Mimarlık eğitiminde hala BIM'in çözülmemiş statüsünün önemli nedenlerinden biri, mimari eğitimde BIM'e karşı açıkça zıt tutumların varlığında bulunabilir. Bazı eğitimciler (Clayton, M., Ozener, O., Haliburton, J., & Farias, F., 2010; Ambrose, M. A., & Fry, K. M., 2012; Ambrose, 2007; Aksamija, 2017; Cheng, 2006) BIM'i 21. yüzyıl eğitiminin kaçınılmaz bir parçası olarak ve onu geliştirme fırsatı olarak görürken, diğerleri bunu öğrencilerin yaratıcı gelişimi ve mimarların uzun süredir yerleşik modellerinin bozulması için bir tehdit olarak görmektedir. (Denzer and Hedges, 2008). Ayrıca, mimarlık eğitimcileri BIM'in bir araç / beceri meselesi, yeni bir tasarım uygulaması biçimi mi yoksa profesyonel bir organizasyon yöntemi mi olarak ele alınacağına karar veremezler. (Deamer, 2011). Bu konumların her biri farklı içeriklere, pedagojik yaklaşımlara ve müfredatta konumlandırmaya yol açar (Becerik-Gerber et al., 2011). Sonuç olarak, BIM'in mimari eğitime nasıl ve ne zaman dahil edileceği sorusu açık bir soru olmaya devam etmektedir ve yenilikçi yaklaşımların araştırılması gerekmektedir.

Buna ek olarak, BIM'in ilgi ve farkındalığının yanı sıra uygulama ve akademi'deki uygulama düzeyi ülkeden ülkeye önemli ölçüde değişmektedir (Rooney, 2017). Türkiye gibi ülkelerde BIM'in önemi henüz uygulayıcılar ve eğitimciler arasında yeterince tanınmamıştır. Bu nedenle, Türkiye'deki mimarlık eğitimi topluluğu arasında daha geniş bir şekilde benimsenmesine yol açacak olan BIM'in yerel farkındalığının artırılmasına ihtiyaç vardır.

Bu ihtiyacı gidermek ve yukarıda bahsi geçen tartışmaya katkıda bulunmak için bu tez, BIM'i mimarlık eğitimine Türkiye'ye odaklanarak tanıtmanın yollarını araştırmaktadır. Bunu yaparken, bu çalışma aşağıdaki hedefleri gerçekleştirmiştir: mimarlık eğitiminde BIM hakkında küresel ve yerel bakış açılarına genel bir bakış sağlamıştır; üç BIM öğrenme senaryosunu geliştirmek ve test etmek için çok seviyeli bir vaka çalışması yürütülmüştür; örnek vaka sonuçlarını değerlendirmiş ve Türkiye'de mimarlık eğitiminde BIM'in benimsenmesi için bir modelin gelecekteki gelişimine katkılarını tartışmıştır.

Bu amaçları gerçekleştirmek için bu çalışmada literatür taraması, anket, odak grupları, görüşmeler ve vaka çalışması gibi nicel ve nitel yöntemleri birleştiren karma yöntem araştırma yaklaşımı kullanılmıştır. Araştırmanın keşif niteliği esnek bir araştırma yaklaşımı gerektirdiğinden, araştırma geliştirme sürecini tasarlamak için eylem araştırma stratejisi benimsenmiştir. Eylem araştırması mantığını takiben, vaka çalışmasının gelişim süreci birbirini izleyen üç düzeyde tasarlanmıştır.

Bu çalışma, genellikle araştırma literatüründe eksik olan BIM hakkındaki yerel bakış açılarıyla ilgili değerli bilgiler vermektedir. Yerel uygulayıcılar ve eğitimciler ile gözlemler, anketler ve görüşmelerden toplanan veriler, mimari eğitimde BIM planlaması için gelecekteki girişimleri bilgilendirebilir. Bu çalışmada geliştirilen ve test edilen üç BIM öğrenme senaryosu, öğrenme sürecine dahil olan amaçları, içerikleri, yöntemleri ve insanları organize etmek için esnek yapıları temsil eder. Akademik dünyaya BIM'i tanıtmak için, akademik dünya ile üniversitede profesyonel uygulamayı simüle etme pratiği arasında deneyim alışverişi yoluyla tanımlanan bir strateji önerilmektedir. Bu, mimarlık okullarında öğretilen ve gerçek hayatta uygulananlar arasındaki farklılığın, eğitim ve uygulama arasındaki işbirliği yoluyla yakınsamaya dönüşmeye başlayabileceğine söz veren yeni bir kültür kültürü yaratmanın temelini oluşturmaktadır.

Araştırma bulgularının pratik bir sonucu, gelecekte planlanan İTÜ Mimarlık Fakültesi lisans programının mimari müfredatına BIM entegrasyonu için bir stratejinin geliştirilmesidir. Bunun, BIM'in merkezi role sahip olacağı mimari eğitim için yeni bir eğitim modelinin oluşturulması ve geliştirilmesine temel oluşturacağını umuyoruz.

1. INTRODUCTION

Technological innovation, globalization, sustainability, and intelligent artifacts formed new conditions of contemporary architectural practice that require a novel set of skills and knowledge from an architect. Technologies like building information modeling (henceforth BIM), mass customization, parametric design, rapid prototyping, digital fabrication, ubiquitous computing, and prefabrication offer opportunities for an architect to redefine his knowledge base and skills in line with this emerging context.

BIM is defined as a set of methods and technologies to create, share and analyze building models (Sacks, Eastman, Lee, & Teicholz, 2018). Building models are linked with a database of project information. The main idea behind BIM is to reintegrate design, construction, and project management, reducing project delivery time and overall costs (AIA, 2007). The numerous benefits of BIM, extensively reported in the research literature, indicate that BIM represents one of the most influential recent developments in architecture, engineering, construction and operation (AECO) practice. The introduction of BIM into design-build-operate processes blurs the disciplinary boundaries and strongly affects the traditional roles, organization, and work methods. As such, it is considered by many authors, as a paradigm shift in AECO practice (Foqué, 2010; Azhar, 2011; Garber, 2014; Sacks et al., 2018).

The growing importance and utilization of BIM in contemporary practice creates a task for educators to rethink the way students are being prepared for it. The introduction of BIM into academic curricula strongly indicates the need for transformation of the traditional educational approaches, reconsidering the practice-education relationship and re-arranging the fragmented disciplinary structures in AEC education.

Architectural education has been widely criticized for its insufficient sensitivity for social and environmental changes, new technologies, and specifically for changes in the architectural practice and construction industry in general (Nicol & Pilling, 2005). The methods and tools it uses, the role models it follows and the knowledge it offers, are based on the educational models of the past era, responding more to the requirements of the past rather than the current practice (Clayton, 2006). Various research show that architecture schools are not sufficiently equipping students for the realities of life in practice (Dobson, 2014; NCARB, 2013).

In addition, the development of information technologies has created new opportunities to learn through various media- and technology-based environments (Niemi, 2009). This brought a new profile of a student who casually uses technology to acquire, communicate and process information. This type of student seeks flexible learning structures and creates his own self-learning packages according to his own interests and needs (Foqué, 2010). Since it was designed for pre-digital age, the current educational system can no longer respond to the requirements of learning in the digital age (Prensky, 2001).

Arguably, architectural education requires radical changes and paradigmatically new approaches. The influential voices in contemporary architectural research call for a fundamental rethinking of the underlying theories and methods of architectural education and emphasize the need for new educational models that will meet the requirements of the emerging context of 21st century architecture (Buchanan, 2012b; Chong, Brandt, & Martin, 2010; Findeli, 2001; Foqué, 2010; Salama & Wilkinson, 2007b). The growing utilization and development of BIM in the last two decades provide strong arguments that BIM is one of the most powerful drivers of the paradigm change that architectural education is searching for. BIM foreshadows revolutionary changes in architectural education by offering the basis for the formation of contemporary architectural curricula which would enable preparing students better for the challenges of practice.

1.1 Problem Definition

Over the last decades, the transformation process of architectural education has already begun to make room for new digital technologies and to embrace the opportunities they bring for architectural design and building making. Various universities around the world are searching for the best ways to introduce BIM in architecture, as well as engineering and construction academic curricula. When and how to introduce BIM are questions programs approach differently (Becerik-Gerber, Gerber, & Ku, 2011).

BIM is a multi-dimensional, complex and evolving concept. Its introduction into architectural education is a complex issue that needs to be considered from various perspectives. BIM points to the new ways of teaching architecture that requires understanding not only of the tool but also grasping the requirements of the aspired professional practice, knowledge of materials and construction methods used in it (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 a professional organizational method (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 an open question and exploring innovative approaches is needed.

In addition, 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). In countries like Turkey, the importance of BIM has not yet been sufficiently recognized among practitioners and educators. Therefore, there is a need to increase the local awareness of BIM which will open the way to its wider adoption among the architectural education community in Turkey.

1.2 Research Aim

This study aims to build on the ongoing discussion of *how* and *when* BIM should be integrated into architectural education. It is difficult (and probably inappropriate) to recommend any model or curricular change that could be applied to all schools in all countries similarly. Instead, this thesis explores how architecture students respond to different *BIM learning scenarios*. In the context of this study, the BIM learning scenario is proposed as a flexible structure for organizing objectives, contents, methods, and people involved in the learning process. Such a structure aims to promote a learner-centered approach which is one of the requirements of 21^{st}-century learning.

The literature review of articles on implementation of BIM in education show 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 approach to BIM introduction 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 introducing different BIM learning scenarios 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.

The development of BIM learning scenarios throughout three-level case study was informed by how students responded to them. Not to congest their minds with the complexity of BIM software and concept, the learning scenarios consisted 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 three BIM learning scenarios represent a learning approach that focuses on improving and broadening the competence of architecture students to:

a) Understand the role of BIM in achieving better, more efficient, sustainable, socially and environmentally conscious design solutions;

b) Recognize the changing role of an architect and the importance of BIM knowledge and skills in contemporary practice;

c) Learn the main principles and methods of BIM functionality;

d) and learn how to develop BIM knowledge and skills in the future.

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.

1.3 Research Objectives

This study has four main objectives:

1) To identify the approaches to BIM adoption in architectural education, discuss their strengths and weaknesses and highlight some of the important issues and challenges using relevant research literature;
2) To identify the current state of BIM adoption in architectural education in Turkey;
3) To develop and test different BIM learning scenarios with a carefully designed multi-level case study;
4) To assess the case study results and discuss their contribution to the future development of a model for BIM adoption in architectural education in Turkey.

1.4 Methodology

This study adopts a mixed-method research approach that is aligned with the research objectives and the complexity of the research problem. Various quantitative and qualitative methods were used to support the development of research, such as literature review, survey, focus groups, interviews, and case study.

To understand how students respond to different ways of introducing BIM into architectural education proposed through three BIM learning scenarios, the case study is used as primary research methodology which incorporates qualitative and quantitative research methods and techniques that align with the main research aim (Creswell, 2014; Yin, 2003).

Since the study is exploratory in nature, the development process necessitated a flexible research approach. Therefore, the study adopted an action research strategy to design the research development process. Action research is a practical research methodology that proceeds through a spiral of cycles of action and research consisting of four major moments: planning, acting, observing, and reflecting in a systematic and documented study (Kember & Kelly, 1993; Mertler, 2019; Zuber-Skerritt, 1992).

Following the logic of action research, the development process of the case study was designed in three consecutive levels. All three levels were conducted under the common methodological framework and present complementary components of a single case, instead of separate cases (Creswell, 2014).

The study was conducted in the following methodological steps (Figure 1.1):

1) Literature review to identify *the state of the art* and research gaps;
2) *Research in practice* to understand the current state of BIM in AEC practice in Turkey;
3) Survey to define the current trends of BIM adoption architecture programs in Turkey;
4) Multi-level case study to develop and test three BIM learning scenarios;

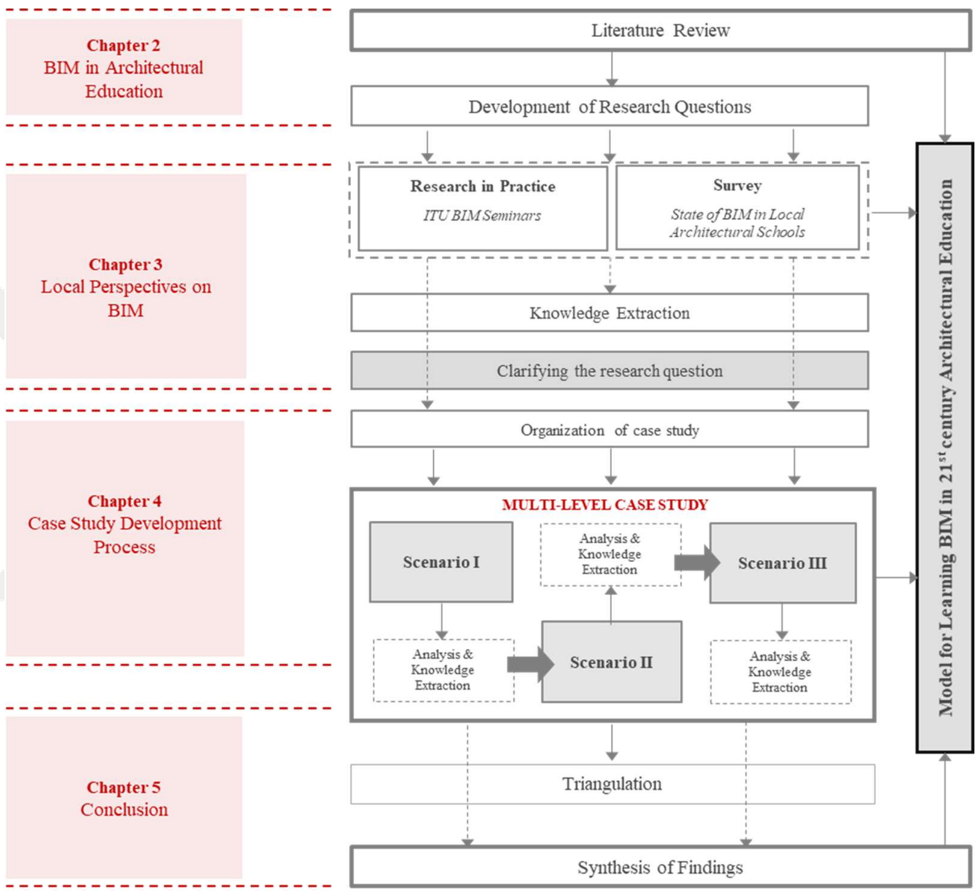

Figure 1.1 : Research development process map.

1.5 Significance

Considering that BIM adoption in Turkish AEC practice and education is in its early stages, the research study is timely. To prepare the process of BIM adoption in architecture programs in Turkey it is essential to investigate this issue from a local point of view. The thesis provides valuable insights into teaching-learning process based on structured multi-level case study from exemplar architecture school in Turkey. We believe that this thesis can increase the awareness and the sensibility of the academic environment for the need for BIM adoption in contemporary architectural education in Turkey. Furthermore, we expect that the contribution made by this study will enhance the process of BIM adoption and stimulate its future development. Finally, we hope that our findings will be valuable contributions to the formation and development of a strategy and a model for learning BIM in architectural education in Turkey.

1.6 Thesis Overview

This thesis is organized into five main parts:

a) Chapter 1 provides the background information and the general context of the study, defines the research problem and research objectives;

b) Chapter 2 describes BIM and its role in contemporary architectural practice; highlights its importance for architectural education and identifies the main benefits and challenges related to its adoption based on relevant research literature;

c) Chapter 3 describes the local perspectives on BIM by analyzing the relevant literature, research in practice and results from the survey;

d) Chapter 4 describes the development process of a multi-level case study;

e) Chapter 5 provides the main conclusions and suggestions for further research.

2. BIM IN ARCHITECTURAL EDUCATION

This chapter describes building information modeling and outlines its importance for architecture, in general, and current architectural education, in particular. Furthermore, it considers the most important issues related to BIM in architectural education, defines its state-of-the-art, and evaluates the current approaches to introducing BIM in architectural education. The main findings from this chapter will be used for the development of the research study described in the chapters that follow.

Given the large body of literature on the subject and the diversity of educational approaches to BIM, only the most relevant studies on BIM in architectural education published in the past two decades will be considered. The resources for the literature search were key journals obtained from electronic databases of the publishers such as ISI Web of Science, Science Direct, American Society of Civil Engineers (ASCE), ITCON, Emerald and CUMINCAD.

2.1 Why BIM?

Considered from the general historical perspective, three major paradigm approaches to architecture, and accordingly three approaches to architectural education can be recognized:

1. Medieval, in which the master-builder mentality, uniting the process of 'designing' and 'building', was dominant.
2. The modern approach which was based on *the Albertian model*[1]. Its meaning was that everything was reduced to theory, drawing, and numbers. It divided the design and building, representation and actualization (Carpo, 2014).
3. The postmodern approach is searching for re-joining of the processes of design and building.

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[1] Albertian model refers to Leon Batissta Alberti's proposition that the architect's role is to design, not to build. This proposition dates back from Renaissance and is considered the origin of the modern profession of architecture (Garber, 2014).

The *medieval* macro paradigm combined the experiences of design and construction, that is, the architect's idea and its realization. The architecture building making here is nothing but a craft activity, and the architect is a craftsman directly involved in building the building with his own hands (Garber, 2014).

The *modern* macro paradigm introduced a fundamentally new approach to architecture and its understanding. Unlike the medieval macro paradigm, it separated design and craftsmanship and instead of directly engaging in construction practice, it preferred good ideas and drawing, prioritizing representation over the actual making of the building. The interest in meeting the results of builders, craftsmen and contractors, that is, those who translate a drawing into a physical object was lost (Carpo, 2014). Here, the role of an architect was to represent the building, without participating in its construction.

The rapid changes in society, environmental issues and imperatives for sustainability, the exponential advances of science and technology, the development of new materials and new modes of manufacture, assembly and construction management, as well as growing complexity of buildings and demand for closer collaboration of multiple experts in interdisciplinary teams, posed new challenges for architecture that the modern paradigm cannot properly answer to. Speaking in Kuhn's language (Kuhn, 1962), the modern paradigm loses the ability to accurately identify problems in architecture and construction and to solve it effectively. Therefore, it is very clear, especially in the last two decades, that the need for the constitution of a new macro paradigm able to provide answers to the new demands placed in front of architecture and construction, emerges. Much of this indicates that its constitution has already begun and that building information modeling (BIM) could be at its very core. Along with other technologies such as mass customization, parametric design, rapid prototyping, digital fabrication, ubiquitous computing and prefabrication, BIM offers an opportunity for architects and builders to respond to the abovementioned demands.

2.2 What is BIM?

Although the origins of the idea of BIM can be found long back in history, its first clear formation and basic elaboration were introduced in the text of Eastman (1975). In this text, Eastman described the concept of 'Building Description System'(BDS) which contained all the elements of BIM as we know it today. These elements are parametric design, high quality computable 3D representations, with a “single integrated database for visual and quantitative analyses”. In this concept, Eastman had envisioned a database-led design (Eastman, 1975).

BIM is defined as a set of methods and technologies which provide new ways of planning, designing, building and operating buildings (Sacks et al., 2018). Various other definitions of BIM exist. Some of the most frequently used are provided in Table 2.1. It is critical to understand that BIM is not only about technology, even less about software. Understanding BIM implies two of its major components: ‘big BIM’ and ‘little BIM’ (Jernigan, 2008). *Big* BIM refers to collaborative processes for creating, sharing and managing information and complex relationships between the social and technical resources, while *little* BIM refers to interoperable software applications from BIM platform[2].

[2] BIM platform contains various BIM tools that support different tasks in the building lifecycle. The widespread providers are Autodesk, Nemstech, Tekla, and ArchiCad, Bentley. Each modeling tool is connected with a variety of other tools that support different tasks in the project lifecycle.

Table 2.1 : BIM Defintions.

BIM Definition	Source
"A rich information model, consisting of potentially multiple data sources, elements of which can be shared across all stakeholders and be maintained across the life of a building from inception to recycling".	National Building Specification (NBS) (Url-1)
"A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward".	National Institute of Building Science (NIBS) (Url-2)
"Building Information Modelling is digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition".	Royal Institute of British Architects (RIBA) and Construction Project Information Committee (CPIC) (Url-3)
"BIM is a process that involves creating and using an intelligent 3D model and enables document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance)".	Autodesk (Url-4)
"Building Information Modeling (BIM), a digital, three-dimensional model linked to a database of project information…because BIM can combine, among other things, the design, fabrication information, erection instructions, and project management logistics in one database, it provides a platform for collaboration throughout the project's design and construction".	American Institute of Architects (AIA) (Url-5)
"BIM is a digital model of a building with information structured and shared in a 3D, 4D or even 5 dimensions integrating components of time and cost".	BuildingSMART (Url-6)

Unlike computer-aided drafting (CAD), which simply allowed documentation to be drawn in the computer, building information model merges three-dimensional geometry with real-time databases. Geometry represents form and building components, and visually describes a design solution. The database extends geometry by adding a wide range of real-time information about the building; from materials, structure, cost and energy usage, scheduling, fabrication details to formal and spatial conditions. This ability to associate data with geometry allows project team members to integrate technical and performance criteria from the early stages of design while testing various design alternatives and making predictions about their performance through environmental analysis, daylight studies, energy analysis, solar access studies, etc. (Goldman & Zarzycki, 2014). For an architect specifically, this provides an opportunity to include life-cycle assessment as part of the design process when considering design alternatives.

In addition, BIM provides a well-structured system for collaboration and management of people, processes, and information in the building lifecycle (Figure 2.1). A variety of digital information from architectural, structural, and mechanical, electrical and plumbing (MEP) are stored, organized and shared through a common system. As such, the BIM model is a comprehensive database of all information contained in conventional building documents, like drawings, specifications, and construction details. Compared to the fragmented information in the drawings, this represents a significant improvement in design-build processes where project participants have to use and communicate complex, accurate and interrelated project information (Kiviniemi & Fischer, 2009).

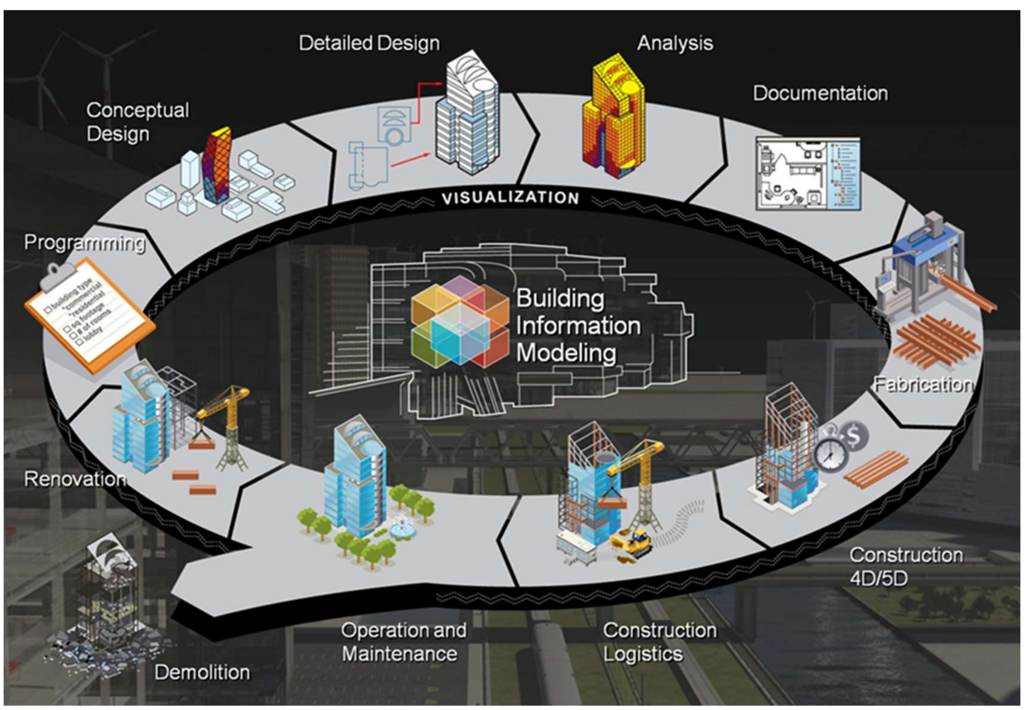

Figure 2.1 : BIM and building lifecycle.

The fundamental purpose of BIM is to facilitate business processes in the building industry by organizing information flows throughout the building lifecycle (Scheer, 2014). BIM is based on a different strategy of information sharing that aims to reduce the gap between design intentions and project delivery. By comprising all essential information domains like 3D modeling, project database, interoperability, and simulation, it allows the designers to experiment on digital prototypes of buildings, and builders to simulate construction virtually before heading to the field (Bernstein, 2010).

Different perspectives of scholars and key industry initiatives have been well documented in the literature for the past couple of decades which address the theoretical and practical implications of BIM. For example, Sacks et al (2018), presented case studies of projects in which BIM played a significant role. They represent the experiences of a wide range of project participants, from owners, architects, engineers, contractors, fabricators, to even construction crews and facility maintenance teams. The case studies also cover various types of projects in terms of function, including medical, residential, office, museum, exhibition hall, multicultural complex, airport, and railway station projects from different regions including Asia, Europe, North America, and the Middle East (Sacks et al., 2018).

In addition, as evidence of how widespread BIM adoption has become, the British Government's BIM Task Group has outlined a set of mandates that enforced a minimum level of BIM requirements for all government projects starting from 2016 (Ganah & John, 2014). This is followed by the European Commission, who recently awarded the EU BIM Task Group funding to deliver a common European network aimed at aligning the use of BIM in public works (EU BIM Task Group, 2017).

2.3 BIM in Architecture

Some authors see the opportunity for the reincarnation of the idea of master builder with the appearance of BIM (Garber, 2014). BIM extends the design into new dimensions, of architectural design and architecture building making, which does not only focus on representation and geometry but on the richness of information embedded computationally in the design. BIM's intelligent modeling approach is fundamentally changing the way architects used to produce and communicate design information (Kocaturk & Kiviniemi, 2013). BIM models contain an inherent design intelligence that plays an important role in spanning the gap between design and making facilitating collaboration between designers and contractors. This represents an opportunity for an architect to reconnect with the network of project team members.

Nowadays, BIM is becoming an inseparable component of contemporary architectural design practice. Many world-leading architectural firms such as Ghery Technologies, Zaha Hadid Architects, BIG (Bjarke Ingels Group), SHoP, MVRDV, Morphosis, UNStudio, SOM, Arup, have recognized the benefits of BIM and have integrated them into their work processes (Garber, 2014). The creative potential of BIM which enables architects to produce novel possibilities and generate new types of architecture have been revealed through using BIM for different tasks in the lifecycle, from conceptual design, analysis and simulation, optimization, planning the construction and coordination, better performance prediction and analysis.

However, architects still have divided opinions about BIM. Design is transformed from individual to collaborative activity in which an architect is no longer a ‘creative genius'. However, an architect will always be responsible for the creative and innovative building design. No one is ever going to expect from a mechanical engineer to propose a creative design of a building but will surely expect it from an architect.

The architectural design process is not a rule-based rational system, but a complex mixture of intuition, skills, experience, and personal and cultural values, and according to Kivniemi and Fisher (2009), this situation has a significant impact in adopting new design tools and practices (Kiviniemi & Fischer, 2009). Architectural design and building making have always demanded a high level of different types of skills and knowledge. The fear of many architects is that they might have to sacrifice design innovation, a formal and spatial expression for procedural clarity and building efficiency prioritized in the BIM approach (Briscoe, 2016). BIM supports the practical aspects of construction such as standard documentation, project management, and sustainability. It is believed that BIM is suppressing this creative act by congesting the architect's mind with a large amount of information and complex tools. It is important to remember that the main purpose of BIM is not to serve as architect's design tool by itself, but rather as a common medium for collaboration in various tasks of the design-build process (Bernstein, 2010).

However, design does not have to be sacrificed, only expanded to another dimension for which an architect needs to be equipped with new knowledge and skills. Although there is still resistance towards BIM caused by its misunderstanding and lack of recognition of the necessity to change, BIM's importance in architectural practice and AEC industry continues to grow and the pressure on education to address it properly in curricula will increase. BIM provides an opportunity to reconsider the way architects and engineers should be educated and trained. In the following, BIM in the context of architectural education will be discussed. Before that, we will look at some of existing issues in architectural education.

2.4 The Weaknesses of Architectural Education

Avant-garde theorists of architectural education consider current education to be in serious crisis, requiring radical changes and paradigmatically new approaches (Buchanan, 2012a; Findeli, 2001). Much of architectural education is largely based on traditional models, according to which architecture is regarded as an artistic discipline. Architectural education has been widely criticized for its insufficient sensitivity for social and environmental changes, new technologies, and specifically for changes in the architectural practice and construction industry in general (Nicol & Pilling, 2005). According to some authors, the methods and tools it uses, the role models it follows and the knowledge it offers, are based on the educational models of the past era (Clayton, 2006). As such, academic architecture education belongs more to the modern rather than the postmodern educational paradigm.

The influential voices in contemporary architectural research call for a fundamental rethinking of the underlying theories and methods of architectural education and emphasize the need for new educational models that will meet the requirements of the emerging context of 21st century architecture (Buchanan, 2012b; Chong et al., 2010; Findeli, 2001; Foqué, 2010; Salama & Wilkinson, 2007b).

Moreover, many practicing architects from the world's leading architectural firms such as Patrik Schumacher (ZHA), William and Christopher Sharples (SHoP), Reinier de Graaf (OMA), Winy Maas (MVRDV), are also criticizing today's architectural education. Schumaher (2019), the principal of Zaha Hadid Architects, explicitly express concerns about its relevance, as he considers that "the current architecture education is disconnected from the profession and it doesn't pursue societal realities or needs as expressed in real (public or private) client briefs "(Schumacher, 2019). The architect specifically emphasized the global crisis in which architecture is found today “cannot be fixed by universities alone as it reflects the fragmentation and disorientation of our discipline” (ibid).

Furthermore, the results of a recent survey undertaken by RIBA Appointments indicates that architecture schools are not equipping students for the realities of life in practice (Dobson, 2014). Another recent survey conducted by the National Council of Architectural Registration Boards (NCARB, 2013) defined the knowledge/skills architecture graduates must possess and the tasks they must be able to perform at the time of licensure. Practitioners listed BIM as the second-highest professional development need. In addition, licensed architects identified gaps in the business of architecture including construction management, project and practice management. Moreover, Phillip Bernstein, a technology thinker, educator, and architect, also suggests re-aligning the models of practice present in current architectural education. According to his observations “two dimensions of being an architect aren't sufficiently developed in education. One is the nature of the practice. What do architects actually do, where do they connect to the overall systems, and what is the future of architecture? Second, the emphasis on design training, just one portion of the architect’s responsibilities, tends to warp the student’s perspective about the most important thing they’re doing and the context in which they operate” (Bernstein, 2017).

In addition to the gap between practice and education, Nicol and Pilling (2005) suggested other problematic aspects of architectural education which are related to the conception of the design studio, collaboration and teamwork and lifelong and self-learning development. The current conception of design studio mainly emphasizes the issues, roles, methods, tools, and processes from the past century (Clayton, 2006). It places much more emphasis on the way design ideas are represented rather than on understanding how they are translated into the actual architecture building. The lack of real-life aspects results in students' proposals focused on ‘good looking' design that considers only the one-dimensional context of a building, usually only formal. Thus, many design studio instructors complain about ‘visually appealing but unbuildable student projects’ (Balfour, 2001).

In addition, the design studio is still strongly based on drawing as the primary tool for expressing and communicating design ideas. Students are not only taught to make drawings but to think through them as well. In learning by drawing, students learn to dissect building into plans, sections and elevations which contributes to disintegrated thinking about building. Students fail to understand the building as a system of interrelated components and the way they get connected into the whole.

Although architecture building making has always been the act of interdisciplinary contribution from architects, engineers, constructors, and other sub-disciplines, architectural education has never cherished enough the culture of collaboration. The perception of design as the result of one individual creative act is rooted in architecture training and deeply embedded in their practice, knowledge, and tools (Lawson, 2006). The abovementioned drawing-based education prioritizes the individual skills of a single designer, a ‘solitary genius', rather than the ‘21st-century collaborator'.

In addition, the constant growth of technology poses the requirement for continuous learning and upgrading of our knowledge and skills. Educators become aware that the role of university education increasingly becomes providing the guidelines on an approach of ‘learning how to learn’ and teachers become moderators in the learning process, like scaffolding for a new building (Niemi, 2009).

Architectural education is based around the development of formal skills which are, and always will be, essential for architectural education. As a design tool, the drawing will preserve its important place in the work and thinking of many architects. However, for the competent architects of the future, they need to be expanded and combined with other knowledge and skills.

2.5 BIM in Architectural Education

Over the last few decades, the transformation process of architectural education has already begun in order to make room and adopt new technologies and opportunities they bring for architectural design and building making. The various examples found in research literature demonstrate that academic education is cognizant of the key role that BIM can play in more sustainable, efficient and collaborative practice. The inclusion of BIM in academic architecture, engineering and construction (AEC) programs has gathered significant pace over recent years.

While there is a visible increase of publications in the area of BIM in academic education and signs that it is becoming a serious area of research, there is a lack of agreement on how should it be done. Various universities around the world such as Georgia Tech, MIT, Southern California (USC), Virginia Tech, Harvard, PennState, Texas, Cal Poly, are searching for the best ways to introduce BIM in architecture, as well as engineering and construction academic curricula. When and how to introduce BIM are questions programs approach differently (Becerik-Gerber et al., 2011).

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 (Figure 2.2.) (Barison & Santos, 2018). 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.

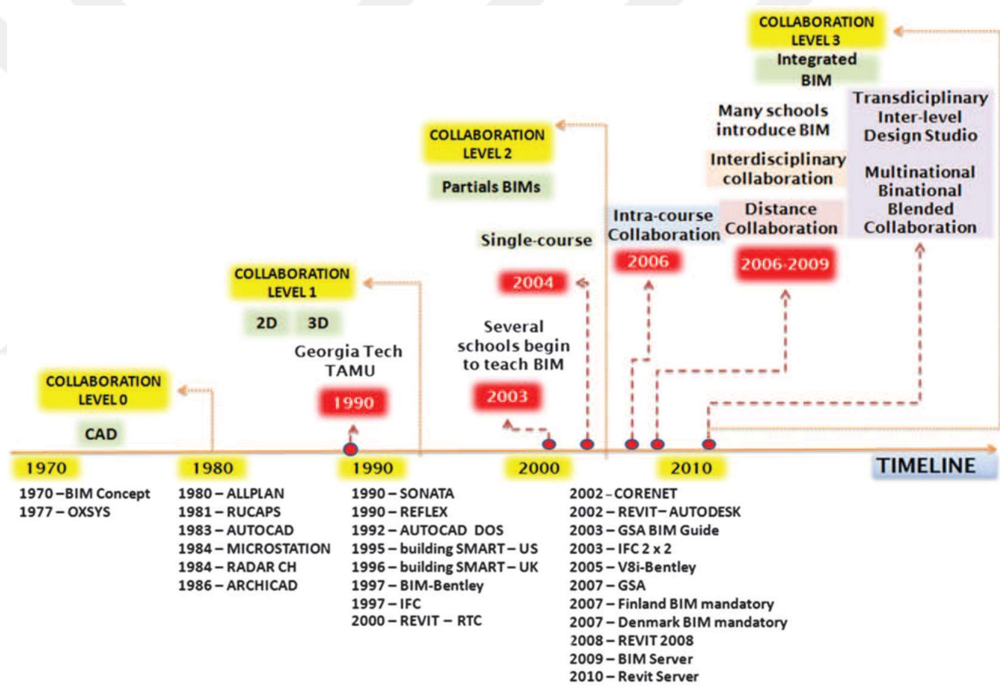

Figure 2.2 : Timeline of evolution of BIM education.

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. 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). The question of *how* and *when* to introduce BIM into architectural education remains to be an open question and exploring innovative approaches is needed.

2.5.1 Main approaches to BIM in architectural education

BIM education has been widely explored in the literature over the past two decades. Various authors have discussed BIM curricula models from program to course levels. Barison and Santos (2018) and Abdirad and Dossick (2016) provided a comprehensive analysis and systematic review of research literature on BIM curriculum design in AEC education (Abdirad & Dossick, 2016; Barison & Santos, 2018). However, their focus is majorly on construction and engineering curricula. Although both share some common characteristics and contents with architectural curricula, the introduction of BIM in architectural education needs to be considered as a separate case. The design studio centered curricula and the explorative nature are unique for architectural education.

Three dominant approaches to the introduction of BIM into academic architectural curricula can be extracted from research literature:

a) BIM education frameworks

b) Stand-alone BIM courses

c) BIM in the design studio

a) BIM education frameworks are usually developed on the national level, based on the requirements of a specific country. For example, the UK BIM Academic Forum proposed a set of learning outcomes to address strategic, management and technical industry needs to facilitate knowledge, understanding, practical skills and transferable skills (Underwood et al., 2015). BAF also produced a useful BIM teaching impact matrix, which described the following four levels of engagement: absent, aware, infused and embedded. The learning outcomes framework indicates the knowledge required from construction industry practitioners in order to implement BIM level 2 successfully. However, since the framework is aligned with UK BIM standards and policies, it can only be completely followed in the UK and in countries where UK BIM standards have been adopted.

In Australia, the "Collaborative Building Design Education using BIM (CodeBIM)" proposed a framework for collaborative building design teaching using BIM entitled as IMAC (Illustration, Manipulation, Application and Collaboration) (Mills, Tran, Parks, & Macdonald, 2013). IMAC framework provides a strategy for how BIM education should be provided in AEC education. Firstly, an introduction of BIM in the discipline the students belong to should be given where students acquire technical skills, according to their discipline, and start getting knowledge about BIM principles. Thereafter, students develop the capacity to solve problems in their disciplines, to be able to work collaboratively later on with other disciplines in a BIM process.

Kelly, O'Connor, Costello, & Nicholson (2015), Thomas (2013) and Coates, Arayici, & Koskela (2010) focused on the development of frameworks through collaboration with professional practice. Kelly et al (2015) proposed a reciprocal learning framework where industry best practice, curriculum development, and research activities are coordinated and utilized to address the educational challenges posed by the interdisciplinary nature of BIM (Kelly, O'Connor, Costello, & Nicholson, 2015). The framework is based on the utilization of real-world local construction projects (as case studies). Academic industry partnership has enabled the development of industry orientated multi-disciplinary Higher Diploma in BIM. Within this framework, a set of modules were developed: BIM Virtual Modelling Fundamentals, BIM Architecture, BIM Structure, BIM Infrastructure, BIM Mechanical, Electrical and Plumbing, BIM Collaboration and BIM Project. A similar approach was adopted by Thomas (2013) for collaborative BIM learning through academia-industry partnership.

Coates et al (2010) suggested the knowledge transfer partnership approach (KTP). KTPs are projects between universities and companies through which academia share knowledge and assist in the development of the industry (Coates, Arayici, &

Koskela, 2010). Knowledge transfer seeks to organize, create, capture or distribute knowledge and ensure its availability for future users. This concept of knowledge sharing forms the basis of the KTP schema. Using the knowledge gained from the KTP the University can develop course material. Through the KTP the academic supervisors gain industrial experience allowing them to become more knowledgeable tutors.

A framework that specifically focuses on architectural education was proposed by Kocaturk and Kivinemi (2013). The main premise of this framework is that BIM impacts on two major realms of architectural curricula: representation and modeling; and collaborative working. The focus of the first realm is on the ways of modeling, embedding and sharing geometric and non-geometric information during the entire project life cycle. The second one is proposing ways of collaboration between design and project partners. Accordingly, they proposed two core modules:

- Modeling and representation that focuses on the process of design creation, development, coordination, communication and negotiation through building models.
- Collaborative working and co-creation considers the timing of involving each 'disciplinarity' in design and clarifying the role of an architect in a team. By acknowledging the differences between individual and collaborative teamwork, this module covers cultural, social and technical issues in collective design activity.

They suggested that the integration of BIM should be gradual and progressive change rather than the "add and stir" approach. It should be founded on a deep understanding of other disciplines and their contribution to design. "It needs to be connected with the rest of the curriculum, and the new method and technology of BIM should make sense in a continuum and by identifying our frames of references in relation to how things were in the past, how they are now and how they are changing with new tools and working methods" (Kocaturk & Kiviniemi, 2013).

b) Stand-alone BIM courses - the introduction of BIM into the curriculum initially took the form of single courses (Barison & Santos, 2018) and represents the most widespread way of introducing BIM into architectural education. This approach is typically practiced by those who believe that the introduction of BIM should be decoupled from design studios, and taught in other courses such as building technology (Aksamija, 2017; Ibrahim, 2014). Early examples of this group focused on making a transition from teaching CAD to teaching BIM, and exploration of affordances of BIM tools over CAD tools (Denzer & Hedges, 2008). As stand-alone, BIM is introduced in the form of specific BIM course, or as part of digital graphics representation, building technology, environmental courses, professional practice, the workshop or as part of research courses in master or doctorate programs (Barison & Santos, 2018; Deamer & Bernstein, 2011).

This approach can involve a single course or a group of multiple courses addressing different topics, such as basic BIM concepts and modeling, parametric design or building lifecycle applications of BIM. When BIM is taught in just one or two courses, BIM tools are usually taught at the beginning of the programs (freshman or sophomore) and at the end (junior or senior). When BIM is taught in several courses, the BIM model is used as a teaching resource to improve students' understanding by visualizing certain issues. However, according to a recent survey, many programs around the world still focus mostly on software skills (Rooney, 2017).

The disadvantage of this approach is that offering standalone BIM courses without any follow-ups in other courses do not support students' long-term learning because students rarely find the opportunity to re-use BIM skills in different courses, and they do not retain software skills after learning and using them for a single course (Clevenger, Glick, & del Puerto, 2012). In addition, a standalone BIM course can be disruptive because students experience a learning environment very different from other AEC courses (Wu & Issa, 2013).

c) BIM in the design studio – for a design studio-centered curricula, positioning BIM in relation to design studio in architectural education deserves careful consideration. As in the previous two approaches, there are a variety of attempts to introduce BIM through the design studio. They can be divided into three main groups:

- *An intradisciplinary* studio is a form of teaching BIM to students from the same discipline (architecture, engineering, etc.). This approach is typically employed to create, develop and analyze BIM models or even teach more subjective BIM concepts and simulate collaboration in a real project (Ambrose, 2007; Ambrose & Fry, 2012)
- *An interdisciplinary* studio where students from different programs at the same university learn BIM concepts and simulate real collaboration by experiencing practical situations in a design studio (Holland et al., 2010; Poerschke, Holland, Messner, & Pihlak, 2010).
- *Distance collaboration* which can be on a local or global level is a variation of interdisciplinary collaboration in which students from collocated teams collaborate and are exposed to typical situations and technologies involving remote collaboration, which is increasingly important in the current world of globalization (Fruchter, Katz, & Grey, 2018)

Guidera (2006) proposed a reductionist approach to the integration of software used in professional practice with course activities associated with the design studio (Guidera, 2006). This prescriptive strategy emphasizes the use of task-specific software features to support specific aspects of design project activities and learning outcomes. This study illustrated that computation, specifically computer modeling using BIM software, can be effectively introduced at the early stages of the curriculum through the use of an exclusive and prescriptive approach to software features and commands. It developed an understanding of the conceptual underpinnings of object-based modeling, thus providing a foundation for the use of more advanced applications of BIM later in the design curriculum as well as in the profession.

Clayton et al. (2010) introduced the Studio 21 approach that takes advantage of twenty-first-century information tools. The study compared conventional and BIM approaches (Studio 20 and 21) in the design studio(Mark Clayton, Ozener, Haliburton, & Farias, 2010). The results of the study show that Studio 21 approach radically changes the design process in terms of time devoted to particular tasks, definitions of schemes, and decision warrants. Furthermore, Studio 21 can produce designs with higher performance by enabling the designer to rely upon objective measures of performance rather than tacit knowledge. It can be taught more quickly as it relies less on the slow acquisition of tacit knowledge through experience and more on explicit knowledge that can be transferred in a classroom setting or through written documents. In Studio 21, decisions are based upon objective, even quantified measures of performance that derive from simulations and analytical calculations. The designer chooses a scheme among several alternatives based on the examination of the performance.

One of the most representative and successful examples of interdisciplinary BIM studios are collaborative BIM studios at Penn State (Holland et al., 2010; Poerschke et al., 2010). BIM began to be taught in the interdisciplinary design studio which brought together students from six different AEC programs and was developed in various levels of development where students were taught to use BIM technology not only for design integration and analysis but also Integrated Project Delivery (IPD) processes for collaboration(Solnosky, Parfitt, & Holland, 2013). In addition, they are characterized by interdisciplinary collaborative design teams; practitioner/client involvement which exposes students to real-world practitioners and client expectations. This gives the students a unique opportunity to learn from and interact with practitioners as well as be exposed to a real client; design benchmarking – as the students develop their own designs they are required to benchmark their work against the real project design in terms of function, cost, schedule, site logistics, and energy consumption. In a collaborative BIM studio, students learn the lexicon of their allied fields. Whether they know how to calculate the variables is not important, the knowledge of what the controlling factors are and how their designs might optimize that variable.

Pihlak and Deamer et al (2011) reported a study of three integrated studios where they observed design exploration and how it adjusts to BIM protocols(Poerschke et al., 2010). They noted that collaboration is productive when architects are strong and confident about their field, and when engineers are flexible to fit into the creative process. Their specific focus was on design collaboration, formal possibilities, and engineering integration into design. Key findings of this study show that minimizing conflict between team members from different disciplines leads to decreased innovation in design. Furthermore, Teams that made too much compromise offered less than optimal solutions. In addition, design emphasis gets lost in the field where design is loaded with numbers, time and money.

Within these approaches, BIM was introduced both, in undergraduate and graduate courses, each having its advantages and disadvantages (Nakapan, 2015; Sabongi & Arch, 2009; Yan, 2010). For example, in integrated studios at the undergraduate level, there are many pre-BIM design fundamentals that need to be covered such as form, composition, spatial hierarchy, architectural vocabulary, and grammar. In contrast, Denzer and Hedges (2008) demonstrated that BIM provides significant advantages even at the undergraduate level (Denzer & Hedges, 2008). These are: fostering integrated thinking about architecture, structure and mechanical systems; considering materiality and construction at earlier stages of design than the conventional model; 'shifts the curve to the right' – the proportion of time dedicated to developed design increased when compared to schematic design. While in the conventional model, students commonly work only in the schematic level, not even considering detailed design, working with BIM allows students to easily deal with questions related to developed design. This also encourages students to pursue more complex designs. However, according to Aksamija (2017), integration of BIM with design studio classes (after mastering the basics and understanding software capabilities) is highly recommended, since this allows students to advance their knowledge and skills (Aksamija, 2017).

2.5.2 Potentials of BIM

BIM accommodates opportunities for fundamental changes and improvements not only for architectural practice but also for architectural education. One of the most valuable potentials of BIM is that it allows exploration of various aspects of architecture buildings through realistic 3D digital prototypes of designs - BIM virtual models, while in the classroom (Bernstein, 2010). BIM models can be used to mimic reality, and explore it to a higher level of detail considering various design criteria. Furthermore, performance simulations allow addressing issues of environmental performance and sustainability and support green building design (Krygiel & Nies, 2008). This can significantly improve students' understanding of the environmental consequences of their design decisions.

Another important potential of BIM in education is the improvement of understanding how different systems integrate into the design. As BIM modeling resembles the actual constructing of a building, creating the model necessitates knowledge of the way buildings are built and understanding of how systems go together in a building (Sacks et al., 2018). In the BIM model, geometry is loaded with additional, non-geometric information which makes architectural representation, not just sophisticated but 'information heavy' (Poerschke et al., 2010). The BIM model becomes the source of all information, including the classical plan-elevation-section representational package contained in sets of drawings. To be able to design with intelligent BIM objects, students need to know how to create its content, not only geometrical but other numerical information to be able to extract the desired information. Once the intelligent model is created, drawings are automatically produced and can be extracted from whenever needed. Drawing became not an end product, but reports from the model. The need for the displacement of emphasis from the reproduction of drawings has long existed in architectural education.

Furthermore, BIM enables students to consider materiality and construction at earlier stages of design (Denzer & Hedges, 2008). While in the conventional model, students commonly work only at the schematic level, working with BIM allows them to easily deal with questions related to developed design. This can encourage students to pursue more complex designs and to consider other aspects such as energy consumption or the financial impact of design decisions (Ozener, 2009).

2.5.3 Challenges and obstacles to BIM adoption

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 et al., 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.

Further, 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.

Putting forward modeling and simulation instead of drawing in learning design represents a significant challenge for architectural education. Modeling and simulation prioritize the building logic and systematic thinking of how things are built, how do they perform, not only how they are represented. Cheng (2006) has warned on the threats and risks of applying BIM without changing the pedagogical model. If BIM is carelessly introduced within the architecture curriculum design thinking and its central role in architectural learning could be overshadowed (Cheng, 2006).

If BIM tools are not introduced properly, they tend to be confused for another CAAD (computer-aided architectural design) tool. The traditional CAAD tools are usually used within a representational domain and for the exploration of formal possibilities. The truth is, BIM essentially is a tool that can aid design, but in a different way than the conventional CAAD tools. Architecture programs mostly teach BIM with a focus on design for purposes of visualization and 3D modeling (Becerik-Gerber et al., 2011). Students usually get fascinated by the representational capability of the tool and usually ignore the constructional and functional requirements of buildings in their projects. As such, BIM use may negatively impact students' creativity and design solutions may become mere outputs of the functionality of BIM tools instead of emerging from students' creativity.

If the student does not understand the underlying principles and what drives their tools, there is a threat to students' disengagement with the tool. In addition, automation of functions and ready-made downloadable libraries possible with BIM can 'disguise' an underdeveloped design by giving it an appearance of resolution making it difficult to distinguish between a conscious design decision and the one automatically created by the BIM software.

One of the concepts that BIM introduces is collaboration, which requires the integration of different subject areas. For an educational setting traditionally based on silo logic such as architectural education, this is a challenging task. Moreover, it is difficult to coordinate the schedules, classrooms, and laboratories of all the units involved since this includes many students studying at the same time. Although it is useful to mimic the actual design practice by bringing students from different disciplines together (each drawing on their disciplinary knowledge) at certain point in their formal education, the timing of such an interaction is of vital importance and could only be useful if the students have already gained a certain degree of maturity in their own specialization.

3. LOCAL PERSPECTIVES ON BIM

Due to the developments and issues summarized in Chapter 2, BIM in architectural education deserves further inquiry. Research literature indicates a lack of agreement about how should BIM be integrated into academic curricula. Furthermore, various examples demonstrate that every school approaches differently to BIM adoption. The literature review gave a broad framework that is required to be analyzed contextually.

A recent report by NATSPEC (2017) provided a comprehensive overview of various BIM educational programs around the world. Their observations show that BIM awareness and BIM uptake are on the rise. However, this is not strictly a consistent global trend, with BIM being widely adopted, and even required by governments in some countries, whilst still only being considered in others. While there is a general interest and awareness of BIM, it differs from country to country (Rooney, 2017). Furthermore, Barison & Santos (2018) demonstrated that the patterns of BIM adoption in academic curricula in general, and architectural, in particular, vary significantly from country to country having different approaches, strategies, methods, and challenges associated with professional and academic environment (Barison & Santos, 2018).

This variety in adoption patterns can be explained by the existence of different social groups in terms of their innovativeness and technology adoption (Rogers, 1983). According to Rogers (1983), the five major social groups are: innovators, early adopters, early majority, late majority, and laggards (Rogers, 1983). While *innovators* seek out new technologies and implement them to their business models by accepting the associated risks, *late majority* adoption occurs because of a contextual pressure and where adoption becomes business vitality. When it comes to BIM, the late majority are the countries that did not develop the BIM tradition in the professional and academic environment. Here, BIM adoption is being newly discussed as the pressure from the AEC industry at local and global levels grows to require an increased number of practitioners who are able to work on BIM-based collaborative projects.

As outlined, the paradigm shift triggered by BIM adoption is not following the same pattern in all countries. While in some countries, such as the UK and the USA, the majority of the industry has already adopted BIM, others have just recently begun to recognize the importance of BIM. In addition, education in many countries is lagging behind industry and BIM is absent from academic curricula. Therefore, an investigation into the local context is needed for the development of a research study. This motivated us to explore the current state of BIM in the AEC industry and its adoption in architectural programs in Turkey. The findings from this chapter informed the development and planning of the case study which will be described in Chapter 4.

3.1 BIM in Turkey

Turkey has one of the largest construction industries in the world. The growth of large-scale complex projects creates a demand for more efficient collaborative processes using the most advanced technologies. In this sense, the benefits of BIM and the need for its adoption becomes increasingly recognized among leading AEC companies such as Enka, TAV, GMW Architects, Arup Istanbul, Ronesans Holding, Tekfen Engineering, Professional Construction Solutions (PROCS), Dome+Partners, etc. It is also important to notice the growing number of public projects initiated by governmental institutions such as Turkish Housing Developing (TOKI) (Url-7). For example, the Kabataş-Mecidiyeköy-Mahmutbey Metro line is the first BIM-implemented project in public and the pilot project for Istanbul Metropolitan Municipality ("Kabataş-Mahmutbey Metro Project Became a National Pride for Turkey," 2017). This extremely demanding and complex project of 635 km metro line included over 200 stakeholders and 3850 people. Utilization of BIM was essential for achieving efficient collaboration and coordination between numerous participants, and tasks like 4D phase planning, cost studies, CFD analysis, parametric tunnel design, visualization, and sustainability.

In addition, the Istanbul Grand Airport, one of the largest airport projects in the world, was planned and executed using BIM and IPD approaches. According to Koseoglu et al (2018) "BIM enabled the intelligent interrogation of design; provided a quicker and cost-effective design production; better co-ordination of documentation; more effective change control; less repetition of processes; a better quality constructed product; and improved communication both for IGA and across the supply chain"

(Koseoglu, Sakin, & Arayici, 2018). This points to growing BIM awareness in the public sector of benefits and the importance of the new way of working methods and advanced technologies offered by BIM. These are essential for its development and adoption in the local construction industry and architectural practice.

A study by Ezcan et al (2013) investigated the level of BIM adoption in Turkey by comparing it with the level of BIM adoption in the UK, as a representative example of a developed country (Ezcan, Goulding, Kuruoglu, & Rahimian, 2013). The findings of this study reveal that BIM implementation, in parallel with the adoption levels is very low in the Turkish construction industry when compared with the UK. Although there is individual awareness of BIM, organizational use is still immature. BIM is a familiar aspect for more than half of the professionals from the AEC industry. However, only a few had experienced it and nearly half of them do not believe that they will experience it within the coming five years' time (Ezcan et al., 2013).

In addition, a study by Sarı (2017) reveled that BIM adoption is not widely recognized and accepted in the Turkish AEC industry which makes it difficult to implement and sustain BIM adoption efficiently. This study also provided a summary of research studies conducted by year 2017 including various aspects of BIM and BIM implementation in the Turkish AEC industry (Sarı, 2017). This study also questioned whether there are any existing official BIM documents (protocols, standards, and guides) that were released by Turkish authorities. Although the necessity for BIM implementation and the tendency of the technical consultancy firms for BIM adoption in the coming future were outlined in governmental reports (TCKB, 2013 ; TMMMB, 2015), the local official BIM documents are still non-existent. This handicaps the BIM implementation process. In this sense, the study identified two types of BIM adoption in Turkey. One of them is not applying an official BIM document due to its non-existence and thus, implementing BIM with adopting BIM practices to available conditions. The other one is implementing BIM by adopting other countries' BIM documents such as AIA and CIC BIM documents. The study concluded that it is an immediate necessity to develop and prepare official BIM documents such as BIM standards, protocols, and guides which will compensate the regulatory, contractual, product and services BIM maturity areas in Turkey (Table 3.1) (Sarı, 2017).

Table 3.1 : The List of the research conducted in Turkey published until 2017.

Reference	Research Area
(Sow, 2016)	The study focuses on sustainability analysis model proposal for Doha.
(Gercek, 2016)	By reviewing BIM implementation standards and guides released in different countries, the study was aimed to help the construction firms during the implementation of BIM in construction phase of projects. By taking a case study of a large construction firm's quantity take off and cost estimation studies in Turkey, the study argued the unique challenges of BIM implementation in Turkish AEC industry
(Alkawi, 2016)	The study give credit to take benefits from interdisciplinary working environment of BIM by proposing a T-model education model during the education of architecture student.
(Akgun, 2016)	The study examines the progress payment applications in contractor firms and the use of BIM technology in progress payment process.
(Doser, 2016)	The study focus on integration of BIM to facility management. By proposing a model consisting of BIM promises, new workflow was compared with traditional workflow.
(Oktem, 2016)	Considering the needs of Turkish AEC industry practitioners in terms of BIM implementation, the study establishes a BIM implementation framework to help the firms newly started to adopt BIM concept.
(Muratoglu, 2015)	The study investigates the contribution of BIM on design phase related disputes in traditional project delivery methods (Design-Bid-Build).
(Kopuz, 2015)	The study aimed to find out necessary items and terms that a BIM protocol shall include in order to efficiently implement BIM practices.

Due to its increasing importance in local professional practice, the growing number of educators recognize the importance of BIM and each year more programs begin to introduce BIM in their curricula. Leading universities in Turkey (METU, Mimar Sinan Fine arts University, Bogazici University, Yildiz Technical University, Hasan Kalyoncu University, Medipol University), have already started the introduction of BIM tools and concepts into various undergraduate and graduate courses. According to their syllabuses, some courses only mention BIM as one of the topics, while others have several courses devoted to teaching BIM methods and tools. However, examples of greater significance that demonstrate a well-structured strategy or educational plan do not yet exist.

In addition, there are several student-initiated attempts to increase interest and awareness of BIM among students. Some of the examples are 'Design Together'(ITUMHK) organized for architecture and engineering students each year and 'BIM 4 Turkey'(BIM4Turkey). Furthermore, a number of local symposiums such as MSTAS(MSTAS), 'BIM and Beyond'(ProtaMuhendislik, 2018), Eurasian BIM Forum (MSGSU, 2019), were organized in order to discuss various topics related to BIM implementation in practice and academic curricula in the present and in the future.

3.2 ITU BIM Seminar

For the purpose of this study, a research in practice seminar titled "Intelligent modeling and simulation supported design" (Url-8) was organized in February 2017 at Istanbul Technical University, Faculty of Architecture, under the supervision of Prof.Dr.Birgül Çolakoğlu. The main purpose of this seminar was to bring together AEC practitioners, architects, and educators to discuss how adopting BIM has changed the AEC industry and architectural practice in Turkey and the ways these changes should be reflected in AEC education.

Participants of the seminar were asked to prepare presentations about the BIM adoption process and accompanying transformations and their recommendations for the future. The study began with discussions focusing on the role, the ways of utilization and the key benefits of BIM in professional practice. Through the presentations, a range of areas such as the role of BIM strategy in the organization, the reasoning behind its utilization, and barriers to the successful implementation of BIM were investigated (Figure 3.1).

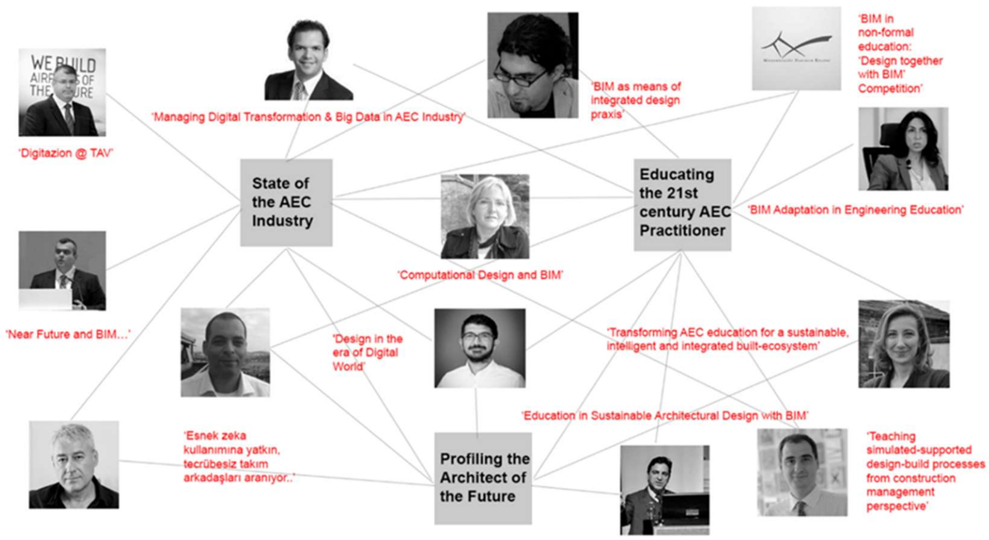

Figure 3.1 : Seminar participants.

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). A focus group study is a structured discussion with a small group of people to generate qualitative data on a precise topic of interest. According to Krueger and Casey (2014), the use of focus group can help a researcher to identify trends and patterns in a specific subject through a systematic analysis of the focus group discussions (Krueger & Casey, 2014).

As argued by Flick (2009), 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). 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.

The use of focus group in this study falls under two categories described by Greenbaum (1998). The first category is "habits and usage studies," used to obtain information from the participants about their usage of different products and services. The second category is "idea generation," which is frequently employed to obtain preliminary information about problems and needs in a particular field (Greenbaum, 1998).

The industry participants were purposely selected from local firms that were known to the researcher to have had significant experience with BIM for implementing in building design and construction projects. Faculty participants were selected according to their experience in teaching BIM in architecture and engineering education. In addition, all seminar presentations and discussions were opened for architecture and engineering students from Istanbul Technical as well as other universities.

In order to extract the information relevant for the development of this research study, the topics for seminar presentations and questions for discussions had to be carefully selected and prepared. The seminar consisted of three sessions and post-session discussions which were organized around three main themes:

- BIM implementation in AEC industry in Turkey;
- The changing role of architect in BIM team;
- Educating future AEC practitioners.

The details of the seminar sessions are given in Table 3.2.

Table 3.2 : Seminar sessions.

Session	PARTICIPANTS	NUMBER OF PARTICIPANTS	DURATION
Session 1 AEC Industry	Engineering design director, BIM director, BIM manager and MEP engineer from large AEC firms.	3 participants	2 hours 20 minutes
Session 2 Architectural Practice	Principal architects and BIM managers from large and mid-size architectural offices.	3 participants	2 hours 5 minutes
Session 3 AEC Education	Instructors in architectural design, performance-based design, engineering and construction management from local architecture and engineering faculties. Engineering students' club from local university.	6 participants	3 hours 50 minutes

3.2.1 Lessons learned

All seminar sessions and post-session discussions were videotaped and transcribed for content analysis. The collected data consisted of transcribed text and related material such as participant presentations. Content analysis is a research technique for making replicable and valid inferences from texts and other meaningful matter (Krippendorff, 2018). This method of analysis provides new insights, increases a researcher's understanding of particular phenomena, or informs practical actions. The qualitative content analysis of seminar sessions revealed several important findings which are used for the development of research study.

The BIM implementation process in the Turkish AEC industry is at its early stages. The industry lacks strategic planning, standards, and guidelines that would lead the BIM implementation process. In addition, industry participants emphasized the lack of understanding and BIM expertise among local firms. BIM utilization typically stays in tool/software domain. Furthermore, it was also discussed that the Turkish AEC industry is lagging behind world construction industries. Turkey does not have government-push which would oblige local practices to go under the common delivery system and to adopt common standards. The pressure for Turkish companies to utilize BIM comes mostly from international projects. Although successful examples of BIM-supported construction projects exist in Turkey, there are still many issues and challenges for the wider BIM adoption in the country. One of the major issues is a lack of awareness of BIM and a lack of educated people who can work in BIM projects. Another major issue related to BIM implementation in Turkey is the non-existence of common standards and strategies. In this sense, industry practitioners emphasized the need for the Government, industry professionals, and educators to collaboratively approach to planning the future BIM implementation process in Turkey.

Practitioners also expressed disappointment with the lack of BIM awareness among new graduates from architecture and engineering schools. The major current deficiencies in BIM education, as emphasized by seminar participants, include the lack of teamwork and communication skills, analytical thinking and understanding interdisciplinary collaboration in BIM. They emphasized the pivotal role of the university in shaping students' mindset that is required to work in a BIM environment. Some of the most important skills of future AEC practitioners outlined by industry practitioners are the capability to think in multiple dimensions, open-mindedness and ability to continuously learn. The recommendation for education is to teach students the main logic and principles of the BIM approach. The advanced levels of knowledge and expertise can be acquired through working in practice. However, in their opinion, academic programs should be synchronized with the requirements of practice for students to be able to continue their development in practice.

Just like the industry, AEC education lacks a strategy and a common approach to BIM adoption. Several experiments that utilize BIM in teaching performance-based design, construction management and simulation in construction were demonstrated in seminar sessions. However, the majority of courses are still focusing on teaching BIM software. Discussions also revealed that any transformation and development of current AEC curricula requires closer relations and collaboration between practice and education and more involvement in hands-on real-life cases from AEC practice. Educators also outlined the emerging ways of BIM training outside the university which might put in question the credibility of university education if it continues to show resistance to the adoption of BIM. As these forms of training develop more rapidly, they are more responsive to current changes and provide a more flexible structure for the learning process. In addition, it was emphasized that there is generally more interest from students in BIM than offered in curricula, that learning BIM is mostly initiated by students. It was concluded that education should develop in an intradisciplinary direction addressing more lifecycle aspects of building. However, numerous obstacles to this process were identified such as large curricular changes for which education is not yet ready; interdisciplinary education is not a casual blurring of the boundaries, but requires deeper understanding and research; curricula are incompatible for collaborative education and there are difficulties in arranging time and place of various programs.

Finally, industry participants and educators have jointly invited for the creation of a common strategy for BIM implementation in practice and education. Both should be developed in parallel and the content should be synchronized and compatible. Furthermore, it was specifically emphasized that this strategy should be approached collaboratively, by industry, academia, and governmental body. In order to improve the current practice and better respond to the emerging requirements, there is an urgent need to raise the BIM awareness and knowledge in local schools and AEC firms.

Some of the most important quotes from seminar participants were extracted as the following:

“One of the first challenges we faced with when we started Istanbul Grand Airport was to find people competent to work on BIM-supported IPD process. So we had to invent our own ways to provide education for everyone in the project, from new graduates to experienced construction workers. BIM is about people and processes followed by technology. We aimed to create a culture of collaboration and a fully digitalized process in which a smooth flow of information is absolute imperative. For such a process, we need practitioners who are capable to think in 360°. An open mindset and learning skills are what we value the most”, session 1 participant, BIM director.

“BIM architect/engineer, BIM coordinator, and information manager are roles that did not exist a few years ago. They need to be properly addressed in the AEC education. The form no longer follows only function, but also performance. For complex systems like airports, building and human performance are of enormous importance. These aspects should be more emphasized in education”, session 1 participant, engineering and design director.

“Working with BIM requires new logic and mindset, flexibility, using mind and hand at the same time. Making the BIM model is 1+1=3. Making the model requires more information. You put less effort but gain more value, if you know which information, when and for whom should the information be produced. But why are we producing more information? To make value from it, to have a better project and more efficient work. The role of an architect is to produce value from BIM”, session 2 participant, architect.

“An architect is an orchestrator of information and mechanisms that drives the form. Education should be addressing both, the transforming and enabling function of technology. Teachers are no longer teaching, but curating the information and knowledge”, session 3 participant, faculty member.

“For students, it is easy to learn how to use BIM tools. There are many out-of-the-school programs which are effectively providing up-to-date software skills. What is important for them to understand is the BIM logic which has always been present in an architect's mind. I think BIM existed ever since architect exists. Maybe not as a technology, but as a way of thinking”, session 3 participant, faculty member.

3.3 Survey

The next research step aimed to explore the state of BIM adoption and common trends in teaching BIM in architecture academic programs in Turkey. In order to collect educators' attitudes towards BIM as part of architecture education, types of courses that teach BIM, strategies, and methods used to teach it, and visions for future development, this study used a survey as a primary method for data collection. An online questionnaire was made accessible to invited respondents by using an online survey tool Google Forms (Url-9). The survey questionnaire was sent to contacts from 33 universities with architecture programs in Turkey. The list was created using official internet webpages and personal contact lists. The questionnaire was sent to deans, program coordinators, and faculty members. Instructions for completing the survey requested the survey link to be forwarded to the faculty member who would be able to answer questions about the current use of BIM in the curriculum in the case that the initial recipient of the survey did not have the knowledge to answer the questions.

The first email with questions was sent on December 13, 2017, and the process was repeated 4 times in the period of four months. The questionnaire consisted of 20 questions with multiple choice and open-ended answers. The questions were from the following areas:

a) Demographics;

b) type and level of BIM courses;

c) strategy for BIM adoption;

d) main obstacles to BIM adoption;

e) suggestions for the future development of BIM in architectural education.

3.3.1 Results

Responses were received from 17 institutions, indicating a response rate of 51%. Respondents by institution are shown in Appendix A. The majority (82 %) of respondants answered that they adopted BIM in some way to their program, while 12% responded that they did not adopt BIM but are planning to in the future (Figure 3.2). In this answer, a high percentage of positive answers could be related to the fact that mostly schools interested in BIM gave responses to the questionnaire. Those who are not familiar with the topic did not even accept to participate in the survey.

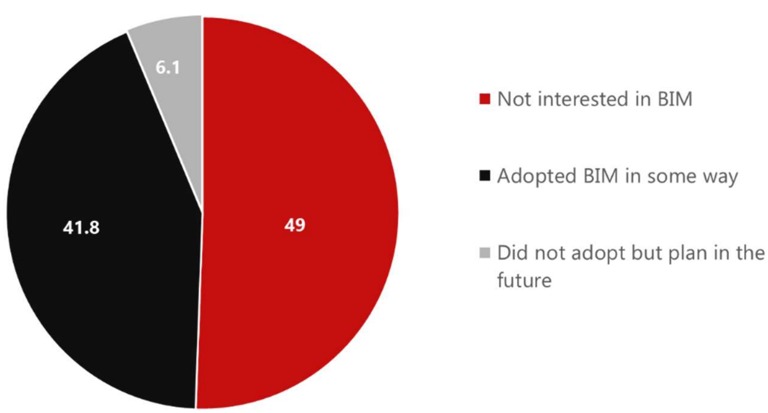

Figure 3.2 : BIM adoption rate in architecture programs in Turkey.

When asked about the reasons for implementing BIM into their curricula, the majority replied that they see BIM as important for the future of the profession (53%) and that BIM can increase the employability of the future graduates (47%)(Figure 3.3).

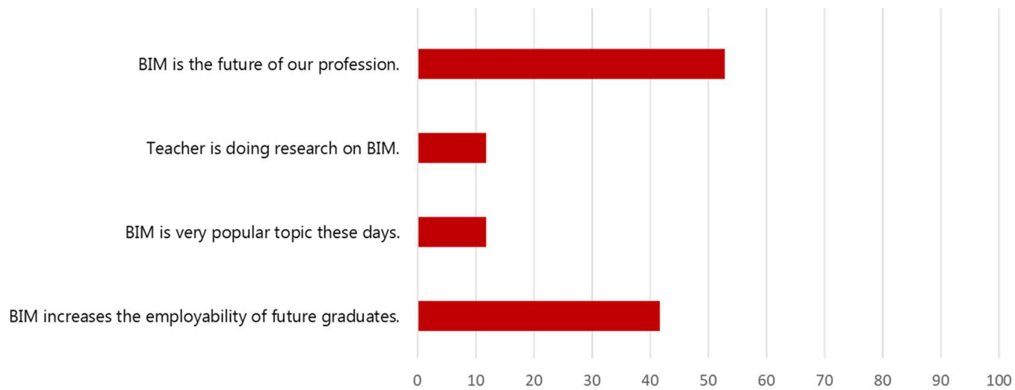

Figure 3.3 : Reasons for implementing BIM in curricula.

When it comes to the major obstacles to BIM adoption, 58% answered that the main issue is in the fact that BIM requires new content and methods. Another major issue that represents the obstacle for BIM adoption is insufficient BIM-related expertise of faculty (53 %). Other issues include lack of industry involvement (35%), the structure of existing architecture curricula (30%) and misunderstanding of BIM concepts (18%). It is interesting to notice that none of the respondents listed a lack of interest from students as an existent issue (Figure 3.4).

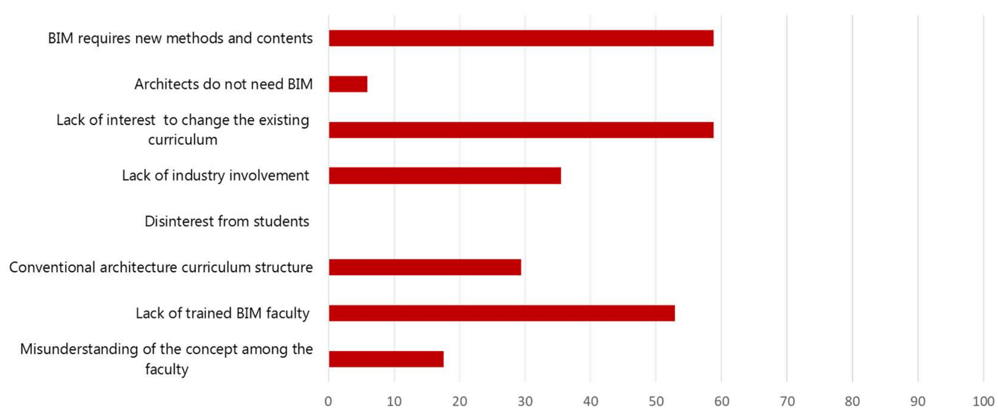

Figure 3.4 : Obstacles to BIM adoption.

The profile of faculty teaching BIM in architecture programs is architecture faculty (87.5%) and educators outside university (12.5%). It is interesting to notice that BIM is being taught more in undergraduate (81%) than graduate programs (19%). BIM-related classes are mostly elective (67%), stand-alone courses, such as Building

Information Modelling, Project Management, Building Construction Management, Sustainable Design, Acoustics and Simulation, Computer Applications in Architecture.

As a part of theory and building technology courses, BIM-related courses are mostly focusing on teaching BIM tools (62.5%) followed by BIM concepts (44%) and performance-based design (37.5%) (Figure 3.5).

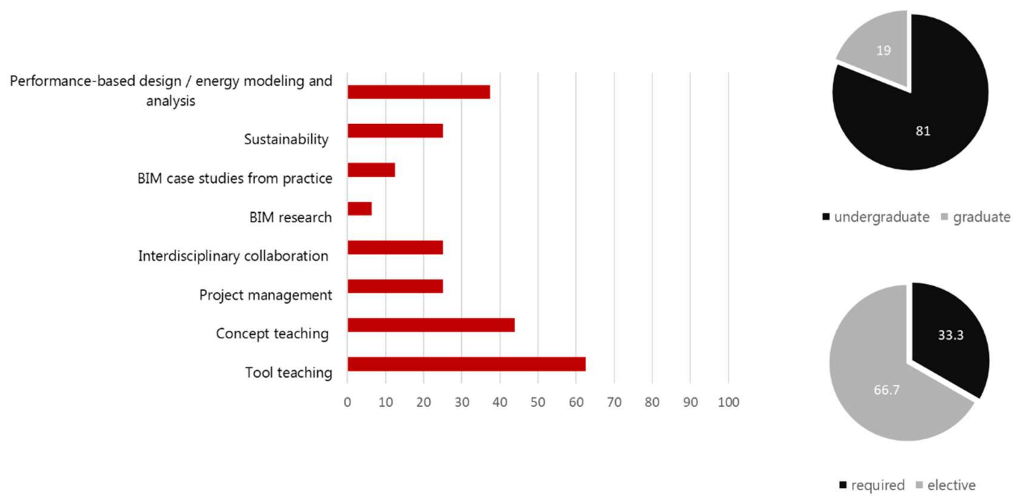

Figure 3.5 : BIM course content and place in curricula.

When it comes to BIM tools, the majority is using Revit (47 %) followed by Archicad and AutoCAD. BIM is still mostly introduced as a part of the experimental process (41.2%) without having a strategy for BIM adoption in the future (53%) (Figure 3.6).

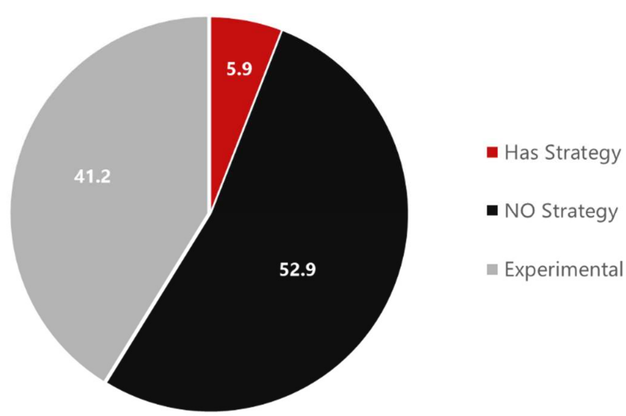

Figure 3.6 : BIM adoption strategy.

Respondents consider BIM as a very important topic that should be part of architecture curricula (94.5%). The general opinion is that schools will be forced to integrate BIM in the near future (70.6%), but also students will learn about BIM outside university

(23.5%). This adoption process depends mostly on skills and knowledge of educators (70.6%), pressure from the AEC industry (58.8%) and interest of students (47.2%)(Figure 3.7).

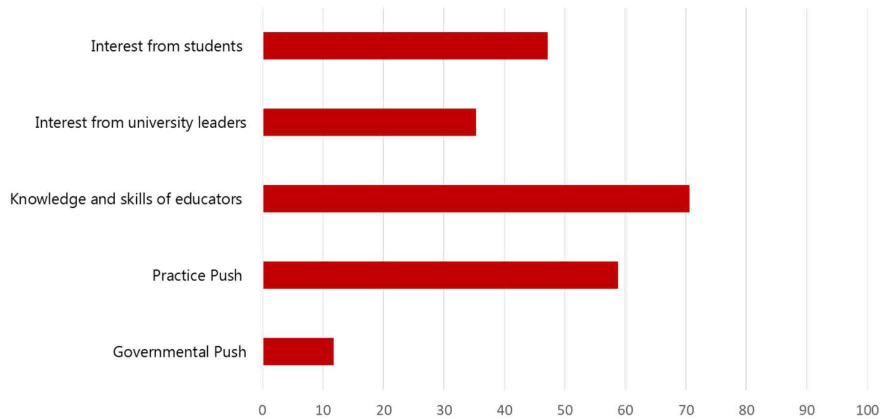

Figure 3.7 : Reasons for implementing BIM in curricula.

When asked about future plans regarding BIM adoption, 37.5% of respondants plan to teach BIM as modeling/management tool, 18.8 % plans to completely adopt BIM into their curricula, while 18.8% do not plan to adopt BIM in the future (Figure 3.8). This process will take a few years in the next decade according to responses.

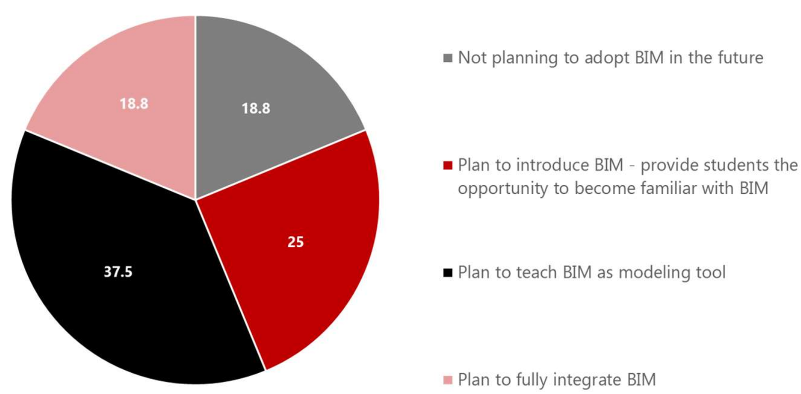

Figure 3.8 : Future plans for BIM adoption.

When asked how BIM should be adopted to architecture education, 82.4 % responded that BIM should be combined with the content of existing courses, 29.4 % think it should be done through workshops and 23.5% think it should be a stand-alone course. In addition, 50% think that BIM should be taught as a modeling/simulation tool, a design tool (43.8%) and a collaboration tool (31.3 %) (Figure 3.9).

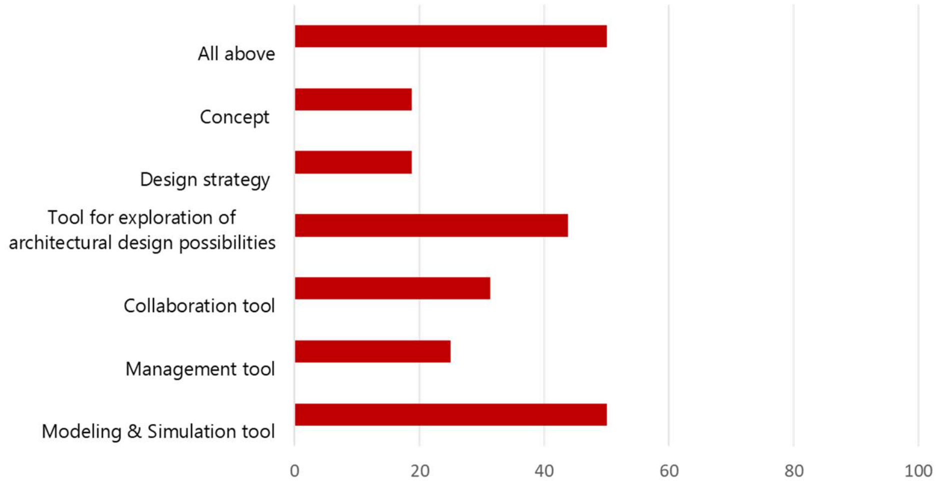

Figure 3.9 : How should BIM be adopted.

3.3.2 Lessons learned

The main finding of this step is that there is a lack of a common approach to BIM in architectural education in Turkey. This is followed by the non-existence of educational standards and well-defined requirements for BIM education. Many schools are not teaching BIM in any way, some are teaching BIM through stand-alone experimental courses and there is generally no strategy for adoption, nor plan for implementation into the various areas of architectural curricula.

However, the results indicate that the interest among architecture programs in Turkey to adopt BIM is on the rise. The major driver for adopting BIM is the recognition of the importance of BIM for the future of the profession and the fact that BIM can increase the employability of future graduates. Respondents felt that BIM was important to industry and that knowledge of BIM was important in meeting industry demands. A greater percentage of the architecture schools implemented BIM at the undergraduate level than the graduate. Autodesk Revit was the most commonly taught BIM software. The majority of the schools were interested in fully integrating BIM, and very few schools felt that BIM implementation was not important. However, the major obstacles to BIM adoption lie in the fact that BIM requires new content and methods, as well as insufficient BIM-related expertise of faculty, lack of industry involvement and misunderstanding of BIM concepts. However, the results show the lack of a common approach to how BIM should be taught, course structure, content, type, and level.

Respondents see BIM as a very important topic that should be part of architecture curricula. However, BIM is still mostly introduced as part of the experimental process without having any strategy for BIM adoption in the future. The general opinion is that schools will have to integrate BIM in the near future. This adoption process depends mostly on the skills and knowledge of educators, pressure from the AEC industry and interest of students. In addition, the standards and requirements for BIM education (on the national level) have not yet been discussed/defined. This makes BIM education in architecture schools provisional and left to the will of each separate school or teacher. Future studies should investigate the strategies for BIM adoption and methodologies for teaching BIM as well as defining the learning outcomes and establishing a relationship with the industry.

As the interest in the implementation of BIM into the education curriculum grows, schools in Turkey are searching for ways to adopt BIM in order to better prepare students for the growing demand for BIM knowledge and skills by the industry. However, what is missing is the guiding strategy and a common approach to this issue and models for adoption that are focusing on local schools and conditions.

4. CASE STUDY DEVELOPMENT PROCESS

The findings outlined in previous chapter determined the development direction of the case study. Findings from the previous chapter show that although the BIM adoption process in Turkey is in the early stages, there are strong indications that the demand for professionals with BIM skills and knowledge will grow in the future. Local architecture schools are showing more interest in introducing BIM, but are doing so without a well-defined strategy or a model that would guide this process. This motivated us to further explore this issue by conducting a case study. This chapter will present the research process of exploratory multi-level case study. The case study observes different ways of introducing BIM in real-life learning settings organized in three levels. The first part of the chapter describes the case study design, methodological approach, strategy and data collection, and analysis procedures. The second part describes the three levels of the case study by describing the framework, setup, analysis and major findings of each level. The final part summarizes the findings of the case study and discusses its contributions to the formation and development of a model for learning BIM in architectural education in Turkey.

4.1 Case Study Design

As this research study was concerned with gathering students' perceptions of their BIM education and the way they respond to the introduction of BIM, a qualitative approach was considered appropriate. To understand how students respond to different ways of introducing BIM into architectural education, this research uses the case study as primary research methodology which incorporates qualitative and quantitative research methods and techniques that align with the main research aim (Creswell, 2014).

As defined by Yin (2003), a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context (Yin, 2003). The theoretical framework of the case study relies on the philosophy of constructivism which acknowledges the learner's active role in the personal creation of knowledge based on prior learning experiences (Yin, 2003). In recent years, case study research has become a widely used methodology in education research (Creswell, 2014; Merriam, 1998; Yin, 2003).

Since the study is exploratory in nature, the development process necessitated a flexible research approach. Therefore, the study adopted an action research strategy to design the research development process. Action research is a practical research methodology involving research strategies whose goals are not only oriented towards data collection but also towards creating some change found in real-life settings (Dick, 2000; O'Leary, 2004). Action research has been applied extensively in teaching practice (Gibbs et al., 2017; Mertler, 2019).

Although there are various ways to conduct action research, most researchers agree that action research should proceed through a spiral of cycles of action and research consisting of four major moments: planning, acting, observing, and reflecting in a systematic and documented study (Kember & Kelly, 1993; Mertler, 2019; Zuber-Skerritt, 1992). The plan includes problem analysis and a strategic plan; action refers to the implementation of the strategic plan; observation includes an evaluation of the action by appropriate methods and techniques, and reflection means reflecting on the result of the evaluation and on the whole action and research process. This reflection process can ultimately lead to the identification of a new problem or problems and hence new levels of the inquiry cycle.

Both case study and action research are concerned with gaining an in-depth understanding of particular phenomena in real-world settings. Following the logic of action research, the development process of the case study was designed in three consecutive levels as shown in Figure 4.1. All three levels were conducted under the common methodological framework and present complementary components of a single case, instead of multiple separate cases (Creswell, 2014).

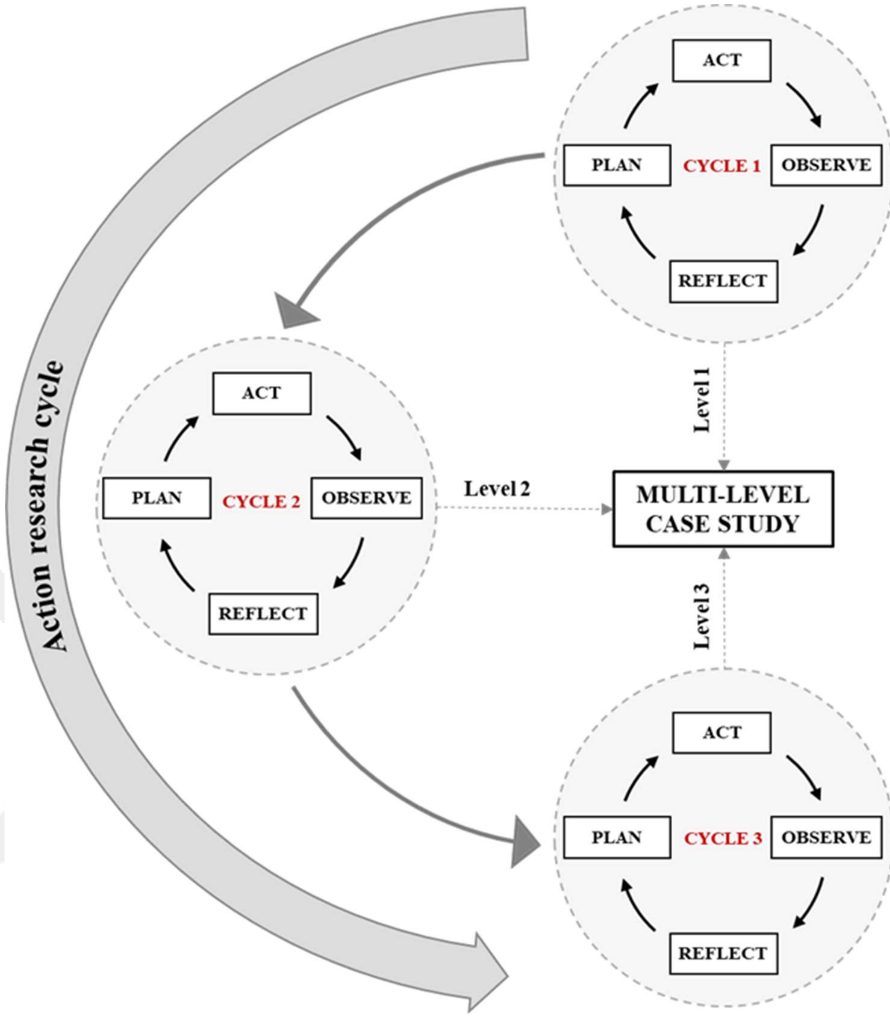

Figure 4.1 : Case study development process.

4.1.1 Case study preparation

Istanbul Technical University (ITU) Faculty of Architecture was selected for conducting the case study. As one of the leading architecture schools in the country, it has a great influence on other schools and spreading the adoption process and development of educational programs. Another reason for its selection as the case study school is based on the opportunity to conduct research provided by Prof.Dr. Birgül Çolakoğlu.

ITU has been internationally accredited for its 23 programs by ABET (Accreditation Board for Programs in Engineering and Technology) since 2011, which enables the students to have their diplomas accepted internationally. ITU Department of Architecture has also been certified as an "equivalent" institute by NAAB (National

Architectural Accrediting Board) in 2007, both for its undergraduate and graduate programs.

The mission of the School, as stated in Faculty website (Url-9), is “to equip the students with environmental sensitivity, historical consciousness, aesthetic values as well as the concern of social and individual well-being and technological innovation”. The program consists of a four-year undergraduate program referred to as Bachelor of Architecture, a two-year graduate degree programs - Architecture Thesis and Non-thesis programs.

Architecture curricula is design-focused whose structure is primarily based on design studio and design-related courses (Url-10). Considering the non-existence of exchange and collaborative courses with engineering departments, the interdisciplinary aspects are not covered in undergraduate programs. The graduate program is more flexible, as it contains experimental courses such as special topics in architecture which typically introduce new topics into the architectural curriculum.

To better understand the BIM culture of the selected school, and the level of BIM awareness, the attitudes, understanding of BIM concepts and related plans for its adoption, semi-structured interviews were conducted with the faculty from March 17, 2017, to June 6, 2017. Selected responses are given below:

"BIM is a new popular technology that is being developed. Students will experiment with it and finally learn it on their own, just like CAAD tools. I don't think we need to give it a special place in curricula" (faculty member).

"Architectural design education should cherish creativity. BIM is a standardized method that is efficient for building construction, less for creative work. It could be part of architectural curricula, as a special topic course" (faculty member).

"If you read anything about the architecture profession today, you can understand that the field is being transformed completely. And BIM is a very important player in it. Although I do not have much knowledge about it myself, I think it should become an important part of architecture education” (faculty member).

“From my personal experience, any attempt to teach BIM ends with teaching Revit as there is no supporting infrastructure to develop it in curricula” (faculty member).

"BIM knowledge and skills are a must for every future architect and engineer. Without BIM knowledge, future generations of architects might have a hard time finding the desired jobs. Education has to respond more quickly than it used to. We do not have the strategy currently and the problem in this is that we need to work more collaboratively. But education is already under transformation, and we hope to see the changes very soon" (faculty member).

Responses show that the school does not have developed BIM tradition. The faculty is divided between those who strongly support BIM and recognize it as an important part of architectural education; and those who consider it a passing trend which does not deserve a special place in the curriculum. In addition, BIM is absent from the current curriculum. Currently, the only course dedicated to BIM is elective BIM course 'Building information models' in doctorate program (Url-12). In such conditions, the important question is: "How to approach BIM introduction in the architecture program of ITU?"

4.1.2 Data collection and analysis

The case study combined four data collection methods:

a) Questionnaires were used to determine students' profiles, their BIM knowledge, and previous experiences as well as their attitudes towards its introduction into architectural education.

b) Observations including note-taking and recording the work sessions were used as the main method for data collection about students' responses to new content during the research process. To get more thorough data, students were encouraged to get actively involved in class discussions and ask questions about the presented contents.

c) Focus groups were conducted at the end of each case study level to draw upon students' attitudes, experiences, and evaluation of several course aspects, as well as their recommendations for the future. The researcher prepared a script for the capturing of the data which was then circulated to the other participants in the study – instructor and practitioners for comments before the focus sessions were conducted. An external moderator of the focus group was engaged to get realistic answers from students. In order to increase explanatory value of focus group data, we conducted multiple focus groups with different participants enabling thus comparison of students' perceptions.

d) Artifacts comprising BIM models, 3D visualizations, 2D documentation, simulations and presentation materials created during the case studies were used as an additional source of data.

The collected data consisted of text and related material such as visual documents and digital artifacts. The study utilized a content analysis method for the analysis of the collected materials. Content analysis as described by Krippendorff (2004), is a research technique for making replicable and valid inferences from texts and other meaningful matter. In his terms, this method of analysis provides new insights, increases a researcher's understanding of particular phenomena, or informs practical actions (Krippendorff, 2018). Texts were coded by highlighting the statements of interest. Coded texts were examined and conclusions were drawn based on the patterns, trends, and relationships that emerged in the transcribed texts. This analysis process relies on selective reduction where transcribed texts are reduced into categories consisting of a word, a phrase or a concept.

Reports of the study include quotes from the focus groups, visual materials from students' assignments as well as important observations made by the researcher. As previously mentioned, the development process of the research study follows an action research strategy. Much of the action research process involves cycles of reflection and interpretation, so the "collect everything and then analyze at the end approach" does not apply here. Instead, we will present the initial setup of each level, then the description of the continual gathering of data, analysis, and reflection which are essential for the research development process. The direction of research also changes as the new reflections and conclusions emerge.

4.1.3 Validity of the study

To ensure that the approach is not biased and the findings are valid, apart from the researcher, one faculty member and two practitioners from the local AEC firm also participated in the study in the role of instructors. At the end of each level, they were asked to review the development process, evaluate students' results and discuss the future development of the course. Observation notes, opinions, ideas and recommendations were combined into case study findings.

4.2 BIM Learning Scenarios

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). The important part of such educational landscape is self-learning or self-directed learning. According to Knowles (1975), self-learning is defined as: “a process by which individuals take the initiative, with or without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, and evaluating learning outcomes”. An instructional process where a learner assumes primary responsibility for the learning process; and as a personality characteristic centering on a learner’s desire or preference for assuming responsibility for learning (Zuckerman-Parker, M., 2008). Thus, 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).

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. The term “scenario” [3] is typically used to describe possible actions or events in the future. In the context of this study, using the term scenario to describe the organization of the learning setting was considered convenient for the flexible nature of the research process.

4.2.1 Framework

As a basis for organizing BIM learning scenarios, this research uses a theory of architectural education proposed by Teymur (2007) and adopted and further elaborated by the International Union of Architects (2011) (Teymur, 2007; UIA, 2011). This theory suggests that planning, proposing and analyzing new programs, courses, or

[3]The word "scenario" is derived from the Latin *scaena*, meaning scene which was originally used in the context of performing arts like theatre and film to describe a sequence of events.

projects into architectural education should be organized within the framework of four basic questions:

a) Contexts and objectives (i.e. why) - refers to the rationale behind 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) – refers to the contents that should be taught and their place in the curricula. These can be analyzed by considering the organization of specific course in terms of their specific content and teaching modes or in terms of the whole study program (numbered years, stages, parts, degrees, etc.)

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

d) Management and structure (i.e. who) – as an organized form of learning and teaching, education is managed. This refers to the management of knowledge, people, time, space and financial resources in educational contexts. It is also considering the question of who delivers the knowledge, who are admitted as students and who evaluates and validates courses.

All these components are linked. The objectives, contents, methods, and management of education determine and influence 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, 2007a), this framework represents a unique and legitimized approach. Although the need for formation of common framework for architectural education has been pointed out by many architectural researchers and educators (Tzonis, 2014; Roaf and Bairstow, 2008; Nicol and Pilling, 2001), to our knoweldge, there is no other framework specifically elaborated for architectural education.

Within the abovementioned components, we have also taken into account the influence of additional factors that can affect the introduction of BIM into architectural education including professional practice, curricula of related disciplines such as engineering and construction as well as learning in the 21st century. 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 (Figure 4.2).

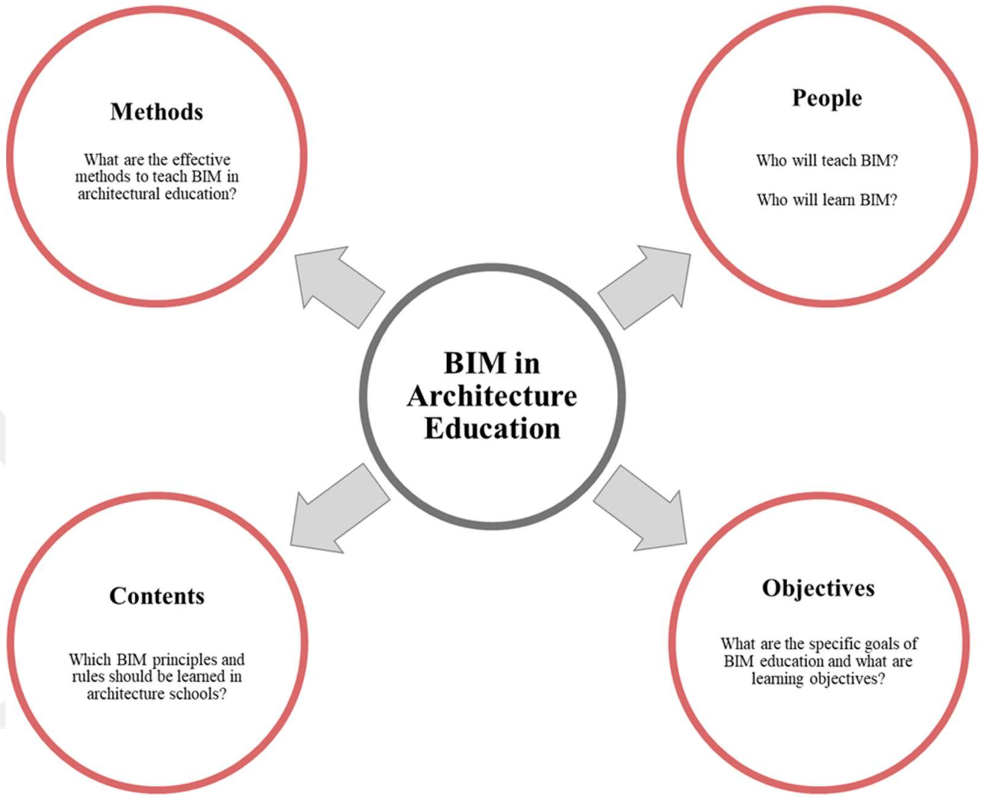

Figure 4.2 : Framework for BIM learning scenarios. Based on: Teymur, 2007; UIA, 2011.

4.2.2 Description

The organization of three BIM learning scenarios was composed considering the four components of the abovementioned framework, namely: objectives, contents, methods, and people. Each scenario represents one of the ways to introduce BIM to architecture students new to BIM concepts and tools. The succeeding scenario incorporates elements of the previous one and introduces new elements based on the findings from the previous level.

The general lack of support for BIM at ITU Faculty of Architecture indicates that BIM adoption in the curricula is in the early stage and immature. Due to this situation, the opportunity to introduce BIM was through experimental course. This type of courses are typically placed in graduate, rather than undergraduate program until some level of maturity is being reached. For the purpose of the case study, three courses were developed and taught under the supervision of Prof. Dr. Birgül Çolakoğlu and in collaboration with BOLD Architecture, a local architecture-engineering firm. As part of the non-thesis academic program at Istanbul Technical University (ITU) Faculty of Architecture, the courses were part of Special Topics in Architecture, an experimental course which is typically used for the introduction of new topics into the practice-oriented graduate program of the Faculty. This program is typically opened for enrollement of students who have graduated from other universities. Thus the profile of students is not from ITU only, but from a wide range of schools from Turkey. The program aims to provide an 'understanding of the praxis, relevant issues of design generation in a variety of implementation scales, ease in decision making and evaluation of alternatives, and agility regarding potential means of representation' (Url-13).

The study was conducted in the period of three academic semesters from Spring 2017–Spring 2019. Consequently, BIM was introduced in Special Topics in Architecture (MTZ508E), a graduate course for architecture students as a 3-credit course named "Introduction to Building Information Modeling in Architecture". The limited-time of the course, 3 hours per week, required careful planning of contents that would be introduced to students new to BIM.

The three learning scenarios had a common goal to propose and test a learning approach that focuses on improving and broadening the competence of architecture students to:

e) Understand the role of BIM in achieving better, more efficient, sustainable, socially and environmentally conscious design solutions;

f) Recognize the changing role of an architect and the importance of BIM knowledge and skills in contemporary practice;

g) Learn the main principles and methods of BIM functionality;

h) and learn how to develop BIM knowledge and skills in the future.

The proposed scenarios are based on learning by doing pedagogical approach which combines top-down and bottom-up approaches. It also involves a combination of various methods with an emphasized student-centered approach. Pedagogically, the courses were designed as a series of lectures, workshops, and demonstrations introducing new skills and techniques, followed up by hands-on exercises which give students an opportunity to apply those skills to specific tasks. As our understanding of how students responded to new BIM contents matured, the nature of BIM learning scenarios also evolved - from a series of instructor-led theoretical lectures and discrete procedural modeling tasks to student-defined modules and collaborative learning environment. The effectiveness of various instructional methods was examined through the study, including rapid software introduction, directed self-learning modules, engagement of industry mentors, and virtual instructional methods.

To actively involve students in learning and to support self-learning, a blended approach that integrates in-class and out-of-class learning was adopted from the beginning. Self-learning term used in this study referes to learning done by oneself, without a teacher or instructor where the learner has the primary responsibility for learning. A substantial amount of out-of-class time was required for directed self-learning using various online resources. Google classroom (Url-14) was used as a common platform for sharing the class materials, uploading students' assignments and for class-related discussions. Moreover, all additional references, links, and questionnaires were shared through this platform. This enabled a consistent common database of all class-related data.

Based on the proposition that the role of university class is to provide guidelines on *learning how to learn*, the role of the instructor was more of a coordinator of learning activities, rather than a teacher. Students were encouraged to express their opinions and attitudes about the course and to actively engage in its design and development. As the research developed, the professional practice was gradually involved, from partial involvement at the beginning to equal participation in planning and teaching the course.

4.2.3 Pre-study Survey

Although we started with the assumption that students have no knowledge about BIM, we decided to conduct a pre-study survey before the beginning of each level of the case study. Each student was asked to fill in the questionnaire which contained questions regarding three domains:

a) Previous education and work experience;

b) Familiarity with BIM technology and concepts, and related experience;

c) Opinions and attitudes towards BIM.

The pre-study survey provided evidence about the preferences, knowledge and skill level and attitudes of students regarding the research focus (Table 4.1).

Table 4.1 : Case study participants' information.

Case study level	Level 1	Level 2	Level 3
Number of participants	11	13	17
Undergraduate education	Architecture: 11 Other: 0	Architecture: 13 Other: 0	Architecture: 17 Other: 0
Work experience	No experience: 7 Some experience or currently working: 4	No experience: 8 Some experience or currently working: 5	No experience: 12 Some experience or currently working: 5
Tools typically used	AutoCAD: 11 Sketchup: 9 3Ds Max: 6 Rhino: 2 Grasshopper: 2	AutoCAD: 13 Sketchup: 9 3Ds Max: 6 Rhino: 2 Grasshopper: 2	AutoCAD: 17 Sketchup: 14 3Ds Max: 5 Rhino: 4 Grasshopper: 4
Familiarity with BIM concepts	Not familiar: 9 Basic knowledge: 2 Advanced knowledge: 0	Not familiar: 11 Basic knowledge: 2 Advanced knowledge: 0	Not familiar: 17 Basic knowledge: 0 Advanced knowledge: 0
BIM skills	Revit: 2 ArchiCAD: 3 Microstation: 1 Navisworks: 0	Revit: 1 ArchiCAD: 2 Microstation: 0 Navisworks: 0	Revit: 0 ArchiCAD: 3 Microstation: 0 Navisworks: 0
Experience in BIM-supported project	No experience: 9 Worked on BIM-based project: 2 Role: Revit modeler	No experience: 12 Worked on BIM-based project: 1 Role: Revit modeler	No experience: 17 Worked on BIM-based project: 0 Role: None

In total, 41 students participated in the case study. Level 1 had 11 students, level 2 had 13, and level 3 had 17 participants. All students have completed undergraduate education in architecture that primarily focuses on architectural design. According to their answers, the majority of students do not have any work experience. Some are working in architectural offices in parallel with education. In addition, all students answered that they're using AutoCAD actively. Among other tools, students use: Sketchup, 3Ds Max, Rhino, and Grasshopper.

The three groups of students had a homogenous profile, regarding their BIM knowledge and related experience. The majority of students answered that they are not familiar with BIM concepts and that they do not have any BIM skills. Only few students answered that they have basic knowledge about BIM and basic knowledge in using one of the BIM tools such as Revit, ArchiCAD, and Microstation. Those who have been working on BIM-supported project previously, answered that their role was of "Revit modeler", mostly focusing on development of 3D geometry.

In the final part of the questionnaire, students were given open-ended questions to encourage them to describe more thoroughly their attitudes and opinions about BIM and motivation to learn it. Some of the characteristic answers are given below:

"If BIM was so important for an architect, why nobody taught us BIM before?" (case study participant).

"BIM looks too complicated. I think architects don't like it too much. It looks like it's more for engineers" (level 1 participant).

"I know some architects who tried to use BIM, and they say it is too expensive and not so useful for architects" (level 3 participant).

"In the firm where I worked, we tried to start BIM, but we didn't succeed because we had to pay too much and, honestly, did not see any benefits for the price" (level 2 participant).

"I am working in an office that is struggling to adopt BIM. I think it is very useful, especially Revit. But it is very hard to implement it fully, like collaboration and information-rich models" (level 1 participant).

The results of the pre-study survey confirmed our assumption that students are new to BIM concepts and tools. They also demonstrate a lack of confidence in the necessity for learning BIM in architectural education. This indicates the absence of interest and low level of awareness of BIM's importance, which represented a specific challenge for the researcher in implementing the educational program. In the following, the setup, analysis and major findings of each case study level will be presented.

4.3 Scenario I – Introduction of BIM Theory and Tools

In line with the propositions of the action research strategy, each scenario development process went through several cycles of planning and preparation, action, observation, and reflection. The preparation process for the scenario I involved the following steps:

a) Analyzing the BIM syllabus employed in some of the leading architecture schools in the world and in Turkey to understand how and in what ways these programs introduced BIM in their curriculum. These were presented in Chapter 2.

b) Compiling a list of BIM topics using handbooks, guidelines, standards and high-quality online resources. Some examples of used resources are: BIM Handbook (Eastman et al, 2013); AIA (Url-5) and RIBA documents (Url-15), Penn State BIM Execution Planning (Url-16); National BIM Standards (NBS) website (Url-17), BIM Object (Url-18), Autodesk University and Autodesk Knowledge (Url-19).

4.3.1 Setup

After the analysis of the abovementioned resources, Scenario I was arranged in the following way (Figure 4.3):

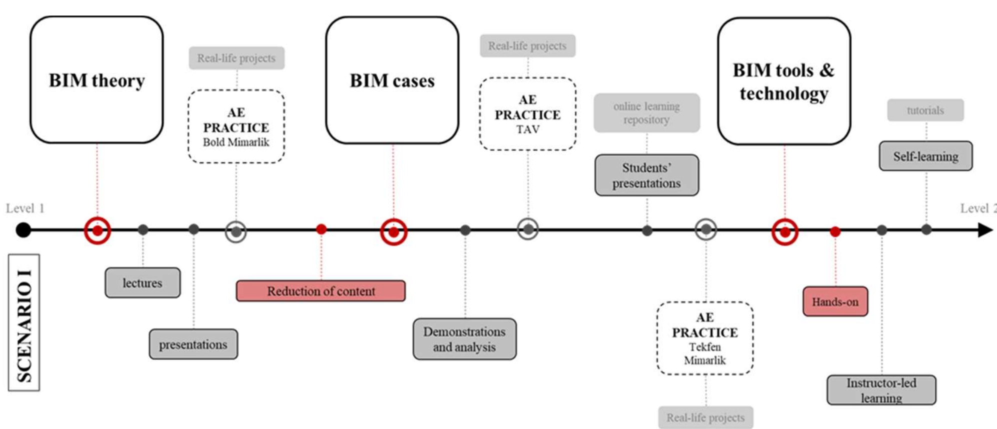

Figure 4.3 : The setup of Scenario I.

The central learning objective of scenario I was to open the way to shift students' mindset from conventional to BIM approach, develop a positive attitude towards BIM and increase students' awareness of BIM's importance for contemporary architectural practice. Thus, the course mainly focused on the main benefits and functionalities of BIM; understanding the differences between BIM and conventional approaches to design; learning the main principles of BIM tools and understanding the difference between BIM and non-BIM tools through application in hands-on exercises.

The content of the first scenario was organized around three main themes:

a) BIM theoretical concepts

b) BIM cases

c) BIM tools and technology

Although common tendencies in introducing BIM in architectural education are through teaching the tools, we started from the assumption that understanding the underlying theory is more important than acquiring practical skills. Thus, the Scenario I started with presenting the theoretical concepts. The first part presented short history of BIM and the motivation for its development; benefits and importance for contemporary architectural practice; the difference between conventional BIM approach to architectural design and building making; and introduced the main concepts and terminology such as: information modeling, collaboration, BIM levels and dimensions, BIM standards, integrated project delivery (IPD), BIM execution plan, BIM roles and responsibilities.

As our understanding of how students learned BIM matured, the initial scenario proposition also evolved and made us engage professional practice in learning BIM. The students were gradually introduced to the application of BIM in real-life projects. The second part of the course focused on "BIM cases", representative examples of BIM utilization in contemporary architectural projects. Professionals from local firms were invited to share some of their experiences of working on national and international BIM-based projects. The final part of the course was designed as a series of hands-on workshops introducing new skills and techniques, followed up by multi-level BIM exercises which gave students the opportunity to apply those skills to model buildings.

The teaching methods combined instructor-led and self-learning approaches. The format of the course was divided into theoretical lectures presenting BIM concepts with extensive discussion sessions, demonstrations, analysis of real-life examples, and hands-on BIM exercises. To actively engage students in learning, the instructor presented only the most important lessons in the class, while students had to extend their knowledge on their own by using additional materials provided through a common learning repository. A variety of texts, links, and visual materials from BIM-related literature and websites were provided as well as tutorials and videos about BIM as an extension of contents presented in lectures. Students were required to read and analyze different texts and to prepare presentations about the selected topics. In addition, students were constantly encouraged to get actively involved in discussions and to interact with the instructors.

4.3.2 Development

To provide theoretical basis for understanding BIM and its importance, the first part of the course focused on BIM theory, such as the role of BIM in the transformation of AEC practice, evolution of representational methods and delivery approaches, BIM standards, BIM dimensions, integrated project delivery (IPD), BIM execution plan, parametric BIM objects. After three lectures, we noticed a general lack of motivation for learning BIM, except for a few students who were enthusiastic about learning something new through the course. As there was a general confusion about the presented concepts, students were seldom getting involved in discussions. They were also skeptical about BIM's importance for architecture. We found that one of the reasons for this lack of appreciation and motivation to learn BIM might be in the fact that BIM was introduced to students without reference to the actual real-life building projects.

Due to the evident absence of interest and motivation to learn BIM from the side of students, after the set of lectures focusing primarily on BIM theory, we decided to invite an architect from the local architecture-engineering firm, BOLD Architecture. The architect was asked to present successful examples of BIM application on firm's projects and how using BIM led to the improvement of their practice. The architect presented BIM utilization on three project of different scale and complexity; a primary school, a hospital, and a family house. He presented the process of development of the projects and the way BIM helped in achieving better communication between disciplines, fitting in the required time and cost frames, coordination with the construction site and a more sustainable design solution. This served as a kind of confirmation of what was presented through theoretical concepts using real-life examples.

According to attention during the lecture, the way they interacted with the architect, the comments and questions they asked, it was noticed that students show a higher level of interest in practical examples than in BIM theory. For example, one of the students said: "now I see that BIM is not only about standards. It is about making real buildings". Another student, who was working in practice, in paralell with taking the classes, said that "all these boring jobs that I have to do manually, like correcting drawing mismatches between plans and sections, schedules and reports, you got automatically. Can you show me how you did it?”. In addition, one of the students asked: "if I knew how to work with BIM, would you hire me in your office?”.

To avoid further congestion in next stages, we also decided to reduce the content. Many of the planned content was not presented as we noticed that students have troubles in comprehending them. Instead, from this point on, we decided to continue the introduction of BIM by using more practical examples. Several representative examples of BIM utilization in contemporary architectural projects were selected from the research literature. These examples were demonstrated and analyzed in the class. Students were then asked to select a "BIM case", analyze it and present it in the class in front of other students. In addition to the lectures and student presentations, we invited practitioners to demonstrate exemplary projects of BIM utilization in Turkey on large scale projects such as: Medina Airport presented by Ahmet Citipitioglu, Engineering Design Director at TAV and Mahmutbey Metro Project in Istanbul presented by Mehmet Polat Diker, BIM manager.

One of the reasons they showed interest to participate in lectures was a desire "to contribute to educating the future generations of architects and increasing the awareness and knowledge of BIM in the academic environment." (Ahmet Citipitioglu, TAV). Another reason to participate was their recognition of the "urgent need for educating architects and engineers to work in a BIM-based project. Lack of people who can work together to create and share information using BIM technology is one of the major challenges we have to deal with in the practice." (Mehmet Polat Diker).

The discussions with the professionals revealed many gaps in students’ knowledge about many aspects of real-life practice that were essential to understanding BIM properly. For example, data management and coordination of different groups of project participants. However, students again demonstrated increased interest in the presented projects and in learning about BIM's application in real-life practice. Many students said that they were not aware of BIM's great importance and utilization in the local projects. They also gained more confidence that learning BIM can help them get the job later after they were shown that it is something required in professional practice.

The final component of the course introduced the main characteristics of BIM tools and basic techniques for creating building information models. The skill sessions were, expected to give a good basis for understanding the main logic and principles of the tool, rather than focusing on the development of technical skills. Concepts like BIM objects, parametric relationships, and creation, sharing and organizing different types of information in the models were stressed. Initial applications focused on replicating and recreating tasks done with previous CAD technologies, exploiting the advantages of the new tools. In order to avoid overwhelming students with too many types of BIM technologies, a specific suite of the application was selected, even though the interoperability concept was emphasized. Autodesk (Url-4) solutions were selected based on their growing popularity and widespread utilization in Turkey, where the majority of BIM applications are based on its products. In addition, there is a wide availability of teaching and learning resources (textbooks and video tutorials) provided by the Autodesk community (Url-19). The intent was not to make students completely proficient in these environments, nor did time allow it. Instead, the intent was to demonstrate how design, practice, and process are influenced by the use of these environments.

Students were given two options to learn the software skills: to learn in the class through instructor-led learning. This meant that the instructor would show the commands on the screen and students would follow up. The second option was to learn how to use the tool on their own, using the high-quality tutorials provided through the common course platform created for the purpose of this course. This self-learning approach was led by the proposition that students can learn the technical skills more efficiently in the self-defined learning process.

From the analysis of BIM models, students' questions and general dynamics of learning, we came to important conclusions. The classical instructor-led teaching showed as a time-consuming and notably less efficient method in learning the tool over then the self-learning approach. Students who learned on their own produced more complex and more accurate models that the ones who learned in the class which indicated that this is a more efficient method for learning BIM tools (Figure 4.5, Figure 4.6). The in-class time could be used for more advanced topics and questions students could not resolve on their own.

In this way, 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. 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. This method is also useful in learning how to learn which is important for following up on the constant developments of BIM technology.

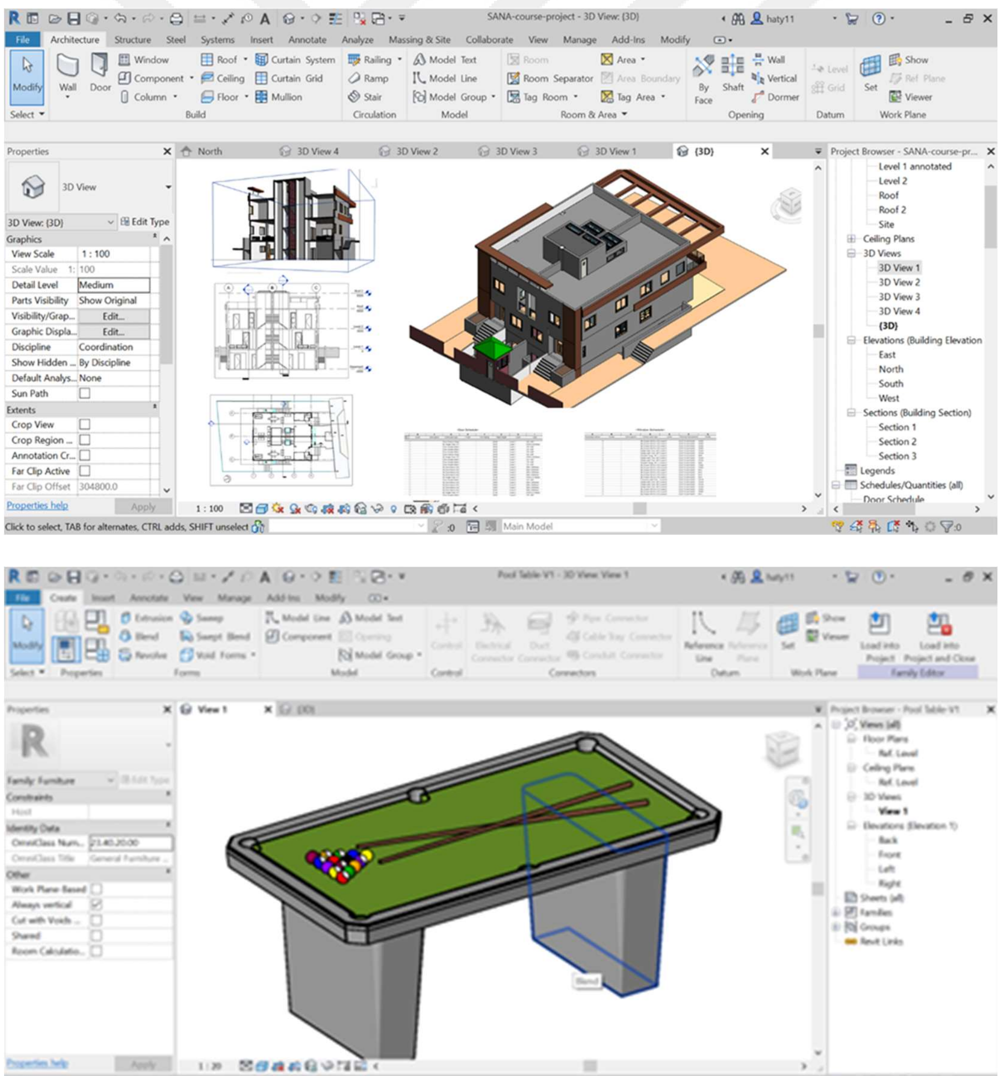

Figure 4.4 : An example of model from student who learned by self-learning.

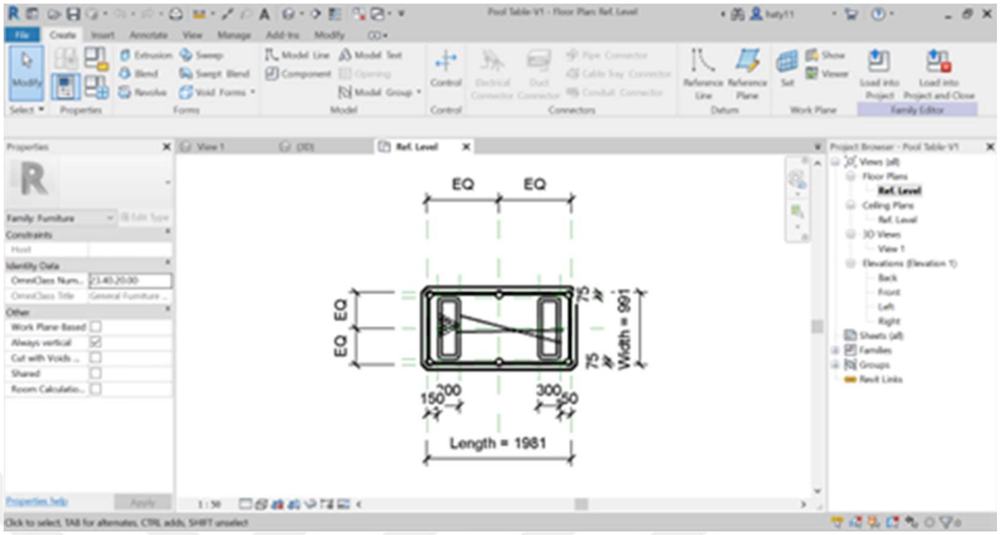

Figure 4.5 (continued) : An example of model from student who learned by self-learning.

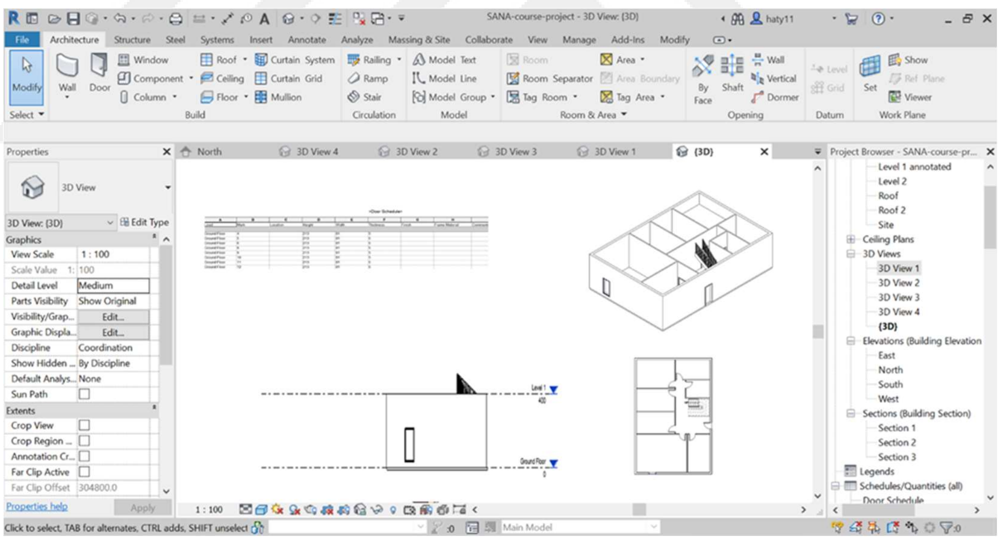

Figure 4.6 : An example of model from student who learned by instructor-led teaching.

In both groups, we noticed a strong influence of conventional tools and the presence of representational logic which made understanding and adoption of the logic of BIM tools more difficult. Many students were using BIM tools with the inhibition created by the long utilization of CAAD tools. Many students used modeling tools with the "drawing" logic: draw lines that represent walls in plan, section and elevation separately. (Figure 4.7).

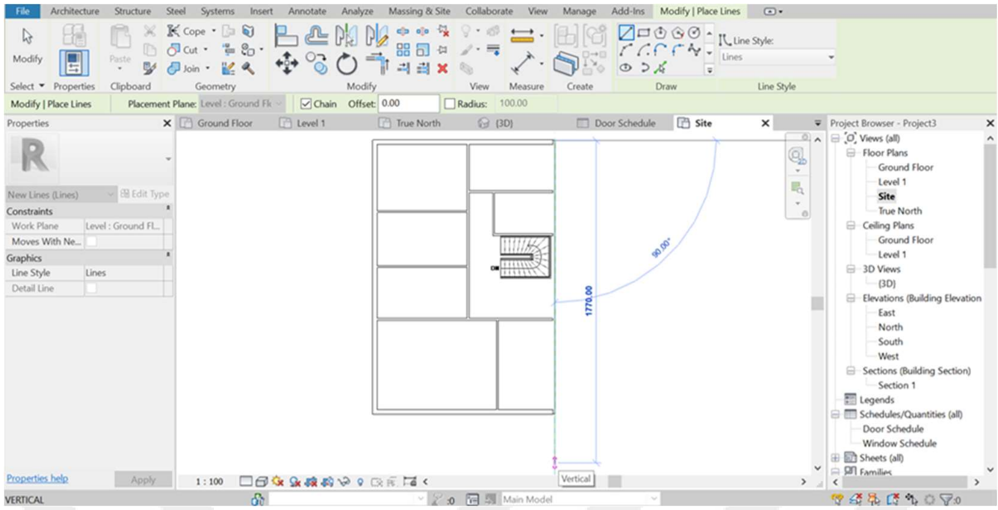

Figure 4.7 : Student using “line” command instead of “wall” to create building element.

One of the typical student’s comments was: “This looks so limiting. If we think about too many rules, we cannot design anything. I cannot put materials before I have the plan. I cannot think of the price if I want to be creative.”

According to the submitted models, students mostly focused on graphical information, to visualize building elements. However, non-graphical information such as element properties were neglected (Figure 4.8). This can be related to their background, in which many architectural programs, prioritize visualization, 2D and 3D aspects. Models were generally using built-in Revit families.

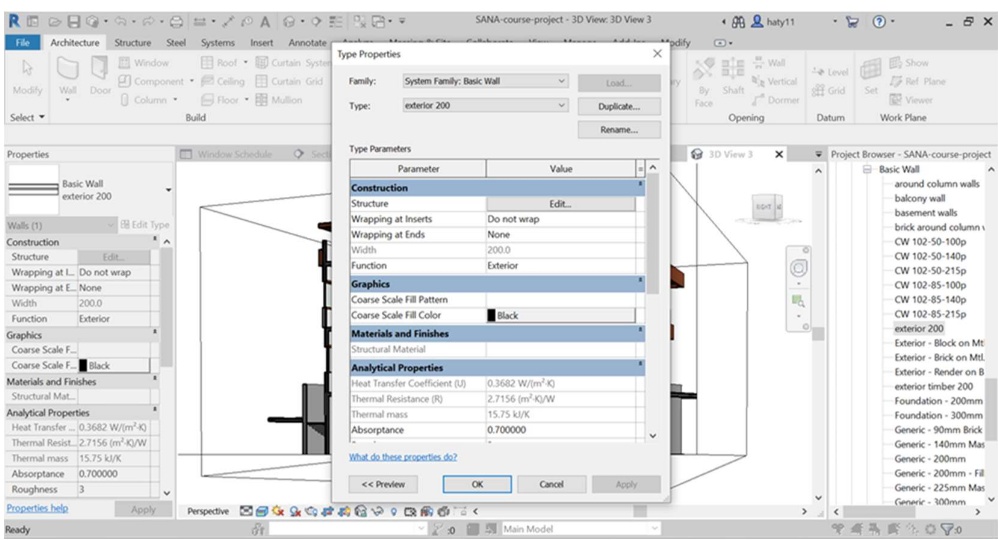

Figure 4.8 : Element properties in student’s model.

4.3.3 Focus group

In the focus group study that was conducted upon the completion of the courses, students were asked to evaluate the course and express their opinions about different aspects of the course, as well as their recommendation for the future. The results were discussed with other instructors and practitioners involved in teaching the course. The focus group findings corroborate with the observations made during the action research process of the first level of the case study.

Analysis of the findings identified several key themes that were critical in the students' opinions about BIM introduction in architectural education to improve BIM teaching and learning. Students were asked to rate as "successful", "partly successful" or "not successful" the effectiveness of their program in improving their understanding of BIM. From 11 participants, 10 said the program had been partly successful and one student said it had been successful. According to students' responses, the most unsuccessful aspect of the course was the theoretical part that was confusing and too broad. The parts that students did not understand at all are related to delivery methods and BIM standards.

In addition, they preferred projects over texts and real-life examples over theoretical concepts. One of the students said: "Looking at examples of great BIM projects in the world is better than reading texts on BIM. But still, it would be more useful to see the process, how is a real building made with BIM." Furthermore, another student said that "theory is important, but it is like story-telling when you don't have any project to see. I think that projects should be shown together with lectures, and I think, it's not all so smooth in real-life as it is written in the books. For example, collaboration". Yet, another student had the opposite attitude by saying that "for me, readings at the beginning of the course, and the theoretical part was very important because it made me think about architecture and my education as an architect. It motivated me to read more about the changes that are happening and of which I was not aware. Everyone can learn the tool, but I think the idea behind all this is important".

Students evaluated the involvement of practice as the most successful aspect of the course. Although only three lectures, it was identified as extremely important. All the students expressed the desire to have practice involved in future classes. These findings are in line with the observations that we made earlier in the process, that the involvement of practice positively influenced students' interest and motivation to learn BIM.

Moreover, all students agreed that instructor-led software teaching was unsuccessful. They preferred learning using tutorials and wished to learn more about how BIM works in real life. As one of the students commented: "For me, it's not a problem to learn how to use the tool. I will open it like any other, if I don't know something, I just type it on the internet. But where to find and how to use the information in a real-life project is a problem. I would like to learn that in the class. For example, if I want to use the specific wall material, how do I put it in, which regulations should I look at, specifications and numbers, costs?". Another student added that "I think BIM should be learned by doing a project. There are so many BIM aspects that you cannot imagine if you don't see how they are used in a project".

Students also complained about the duration of the course and the amount of new contents. Because BIM was completely new to the majority of students, its acceptance and learning the logic takes time. Students agreed that it would be better if the course has more time than only 3 hours per week. They said that "many things get mixed because there are many new contents". The students also found the workload (e.g. too much readings, the difficulty of modeling comparing to the tools they already knew how to use, and related time spent in carrying out each task) was above what is usually required for a similar course.

In the future, the majority of students answered that they would like to learn more about collaboration and how to work with other disciplines, how to add real-life information, and how to create families, how can architect design with BIM and also how to do simulations. They would also like to learn what we can do with BIM and not with other tools.

When asked about their future learning and use of BIM, some of them were determined to use it later. Others were still critical about it, such as the student who said: "Many companies are still using the non-BIM systems. There are many companies where I can find a job even if I don't use Revit". Another student said that "I want to work in a large international company when I graduate. I think BIM can help me find a job more easily. So I will definitely learn more about BIM." Another student clearly expressed the awareness of BIM's importance by saying that "the best part of the course for me was when BIM managers came and presented their projects. I then realized that I am not informed about what happens out there. And it is in Turkey, not just somewhere else in the world. I will definitely keep on learning about this".

4.3.4 What have we learned from the scenario I?

The critical question that we asked at the end of this level was: “What have we learned from level 1 and how do we use what we learned to plan level 2?” The first level had several focus points which were directed towards questions about teaching methods, contents, the involvement of practice, software learning and the relationship between BIM theory and application in the introductory course. The main findings which served as the foundation for developing the next level, are described below:

- The theory is necessary for understanding BIM, but should not dominate over the practical application. Students understand and adopt new BIM concepts more easily when their meaning and application in real-life examples are demonstrated to them. The amount of theory should be reduced in favor of practical examples and hands-on. The introduction of BIM should be balanced between hands-on and theory classes. 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.
- This example confirmed that the involvement of practical examples is more attractive to students than theoretical lectures. The clear positive influence of involving professional practice is an important indicator to intensify the relationship with them and consider their involvement at future levels.
- The model of practice present in schools is far behind the emerging models currently present in practice. There is a need for focusing more on familiarizing students with the developemnts and emerging requirements of current practice.
- Technical software skills should be primarily self-learned. The in-class time should be used for discussing the advanced issues and real-life aspects that students cannot learn on their own.
- Due to students’ experiences with non-BIM tools and the strong influence of their representational logic, in learning BIM tools, the concept of ‘building as system’ and elements as related parts of the whole should be specifically emphasized.

- Software tutorials and online learning repository are valuable supplements to class. In learning BIM, they are an invaluable support to the in-class contents.

4.4 Scenario II – Collaborative Teaching with Practice

In this level, we took a more realistic approach to introducing BIM which involved more intensive engagement of professional practice and real-life BIM project examples. Once we decided to involve practice as an equal partner in preparing, teaching and evaluating the course, the important question that emerged was: "How to transfer experiences from practice and adapt them to education?" Thus, the major focus of this level was establishing an effective collaboration between practice and education that will result in a successful BIM introduction program. Considering the differences between education and practice in terms of the level of knowledge and experience, this represented a challenging task.

The preparation process of this scenario involved the following steps:

a) Selection of practice that would best contribute to BIM teaching involved conducting a series of interviews with professionals to determine their patterns of BIM usage and the ways it transformed their working methods. Among several options, BOLD Architecture, an architecture-engineering firm from Istanbul was selected according to the following criteria:

   - Interdisciplinary approach and collaborative working methods. In the firm, architects, structural and MEP engineers work together in a collaborative environment through the entire project. BIM is used as a catalyst in this interdisciplinary process. The goal was to bring this into the classroom and demonstrate how architectural design gets transformed from fragmented into collaborative activity in current practice.

   - BIM usage and the way information is produced, organized and shared in BIM information models. This was specifically important criteria as many practices in Turkey use BIM only as a modeling tool for faster visualization. However, the selected practice has been consistently using BIM over a period of more than ten years. The processes of planning, management, organization and sharing among project participants have been structured and developed according to BIM standards and protocols.

- Readiness to collaborate and openness to share experiences and knowledge with teachers and students. Without this, the realization of partnership would have not been possible.

b) Once the practice was selected, the next step was interviewing the principal architect and engineers to obtain their suggestions about BIM content and requirements for future architecture graduates.

c) Preparation of the course materials through collaboration between teachers and practitioners. This involved visits to the office, spending time in a real-life setting, observations, and analysis of their working processes and models to find the most convenient way for translating and adjusting these to the educational setting. The AE practice agreed to provide the required project documentation, BIM execution plans, and BIM models.

4.4.1 Setup

After the abovementioned preparation procedure, Scenario II was arranged in the following way:

The main learning objective of this level was to introduce students with the main BIM concepts, principles and tools by having them exposed to real-life BIM projects. The specific challenge was to introduce these without congesting students' minds with too much information and complexity. Thus, comparing to the previous level, the amount of BIM theory was reduced in favor of the practical application. Topics covered the fundamentals of BIM approach, BIM execution planning, collaboration and teamwork techniques, the concept of the information model, parametric BIM objects, 3D, 4D, 5D, building performance, BIM as well as the role of BIM in achieving sustainable design solutions. Only the basics and fundamental principles were provided in the class, while students were required to expand their knowledge by using additional learning resources.

In this level, the hybrid model was introduced as the basis for the scenario structure. The hybrid model combined three complementary components (Figure 4.9):

a) University class, whose role is to provide the supporting structure and guidelines for the learning activities.

b) Architecture-Engineering (AE) practice contributing with expertise and real-life cases from professional practice into education.

c) Online learning repository with carefully prepared learning resources. The main purpose of this component is to serve as a supplement to in-class learning and to support the development of self-learning skills. The repository contained books and course readings, software tutorials, links to websites, documents, templates and reports, project documentation, BIM models and simulations. The content of the repository was continuously updated.

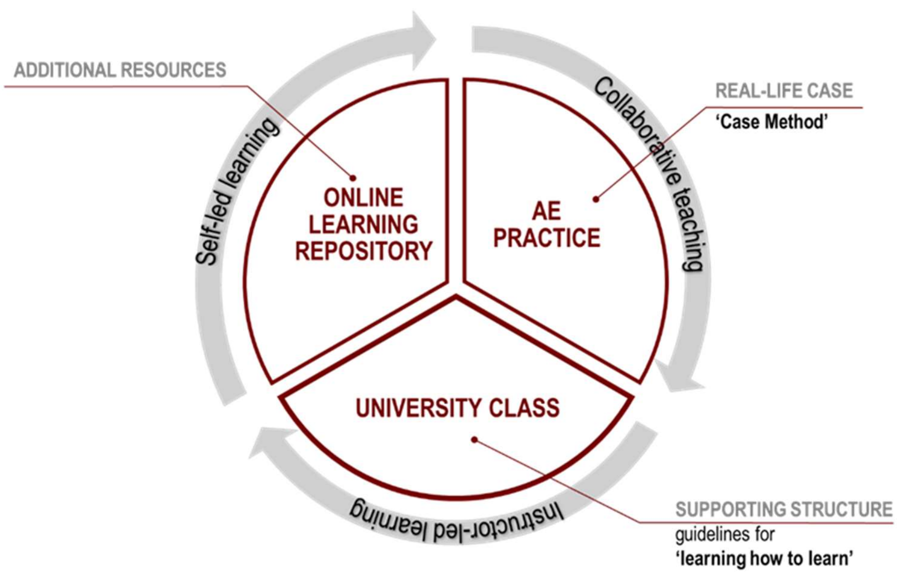

Figure 4.9 : Hybrid model components.

Apart from the lectures and demonstrations, the primary method used to deliver BIM knowledge at this level was the *case method.* Although relatively new in architectural education (McBride, 1984), this method has been used for decades in a wide range of professional schools, such as Harvard's law, business, and medical schools, to teach the skills required for real-world activities (Garvin, 2003). The case method resembles the widely practiced project-based method of architectural design studio. However, the approach of the case method is reversed – it starts from the finished project integrating the application of qualitative and quantitative analysis. The student is actively involved in the exploration of general principals through experience with the case (McBride, 1984).

The main purpose of using this method was to enable students to get directly exposed to real-life BIM projects in learning BIM concepts and tools. The top-down process of case method incorporates elements of analysis of the BIM model, its structure and processes that led to its creation. For this purpose, the AE practice provided a fully realized BIM model and its documentation.

As we learned from level 1 observations, learning the software skills can be achieved successfully through a self-learning process. Thus, learning the basics of how to use the BIM tools was not taught in the class. Instead, students were directed to high-quality online sources with tutorial and step-by-step guidelines. The main idea is that students learn the basic technical skills on their own, and to use the in-class time for the questions about the aspects they could not resolve on their own. Moreover, the in-class time was used for real-life aspects such as which real-time information should be added and how does it impact the overall modeling process.

The courses were taught collaboratively with practice mentors. The presented contents were divided between the instructors presenting the BIM concept theoretically, while the practice mentor explained its application in the real-life project (BIM case). Depending on the content, architect, civil engineer and MEP engineer took the roles of practice-mentors. The scenario required a flexible structure to allow development and the necessary revisions as we gained more understanding of how students respond to specific content.

4.4.2 Development

At the beginning of the process, practice mentors were asked to take notes that would include important observations, comments, and suggestions about the program.

Following the logic of the case method, the learning process started with the exploration of 'BIM case, a fully realized BIM model of already designed and completed building (Figure 4.10). This process involved 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. In this way, the technological and non-technological principles of a model as an integrated system could be analyzed and examined. The aim was to present students the process of virtual architecture building making that integrates design, construction, mechanics and other sub-disciplines of building making.

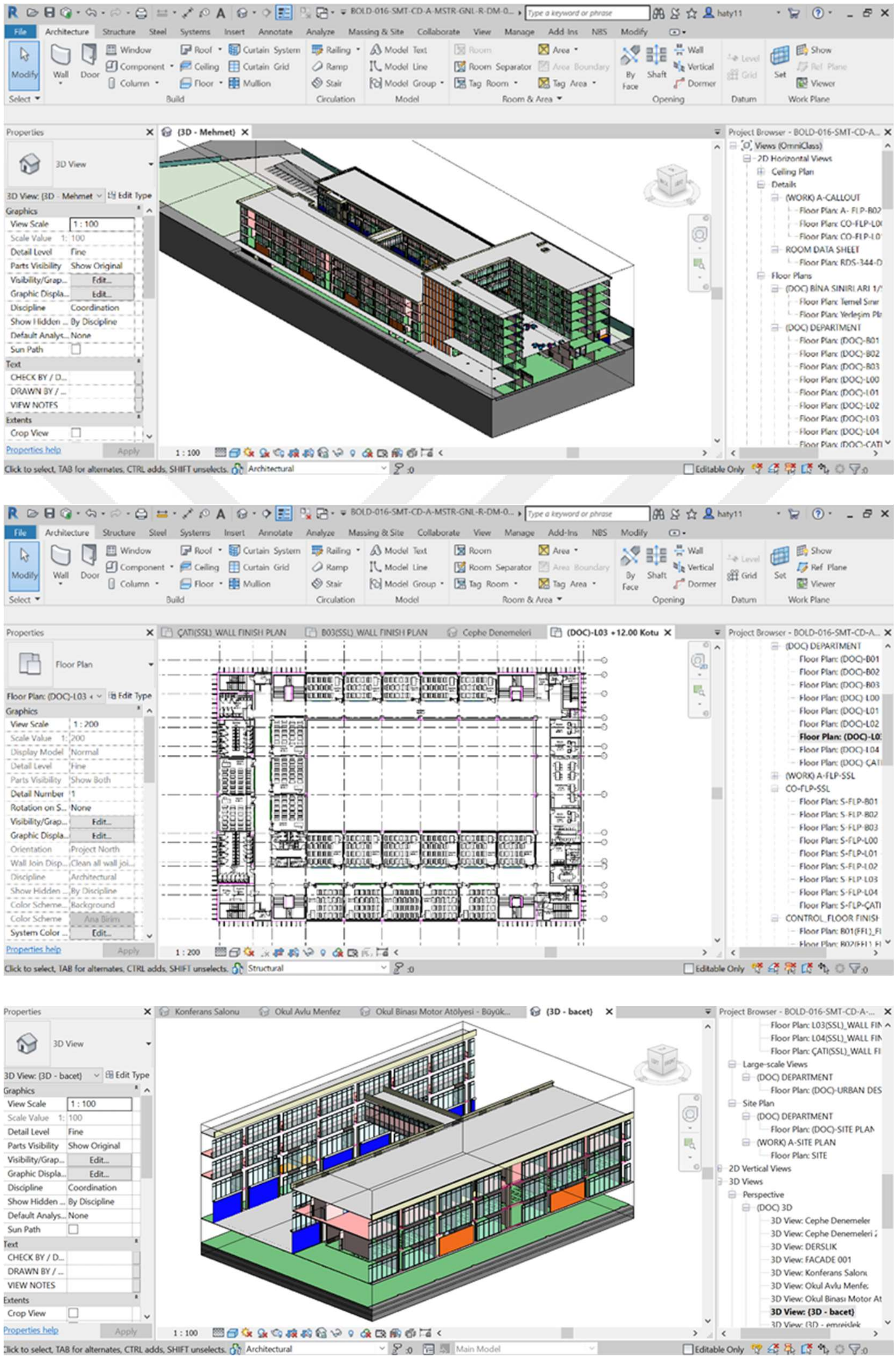

Figure 4.10 : The ‘print screens’ of BIM model provided by BOLD Mimarlik.

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. This approach also stressed the conception of building as a system. This was specifically important in shifting the 'dissection' logic (building as a set of plans, sections, and elevations) and representation through drawings; to real-life building elements as part of one whole.

Different components of the model and stages of BIM process were revealed to students gradually, as the new knowledge was presented through lectures and demonstrations:

a) BIM approach and mindset - the first part of the course provided an overview of fundamental BIM concepts and emphasized its importance for architectural practice. The architect described their utilization of BIM and the benefits of using it. Simple explanations of BIM concepts using dominantly visual descriptions, pictures, diagrams, and videos were used instead of texts.

b) BIM technology – the main logic of BIM tools and the core concepts such as interoperability, information model and parametric BIM object were presented. For example, in explaining the concept of a parametric BIM object, an object from the case BIM model was selected. The types of parameters and information inputs it requires, how does it relate to other objects and to the whole building were demonstrated through the example. A wide range of tools used for different tasks in the project and the interoperability between them were also presented.

c) BIM execution plan – the process of plan development from project requirements, negotiations with clients, required documentation, regulations, and standards used and the role of BIM plan in facilitating the process and communication were presented (Figure 4.11). After the procedure of preparing the plan was explained, students were required to create a simple BEP using the given template.

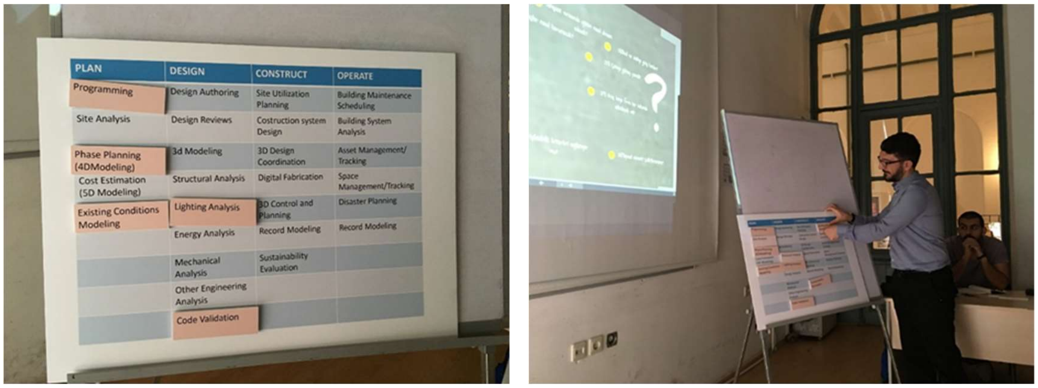

Figure 4.11 : Practice mentor explaining how to create BIM execution plan based on client requirements.

d) Interdisciplinary inputs - relationships between architecture, structure and MEP elements in the model. Structural and MEP engineers from the office were invited to explain the main logic of creating structural and MEP elements and how do they change with the changes in architectural models (Figure 4.12). This was done with the goal to make students aware of the existence of other components in the building model and to emphasize their important contribution to the overall project.

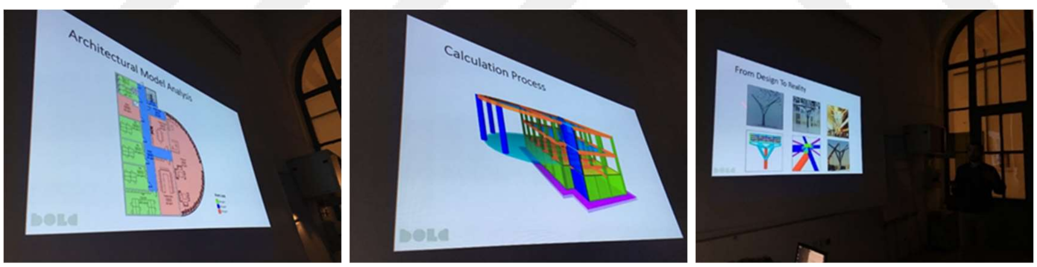

Figure 4.12 : Presentations by structural and MEP engineers from BOLD Mimarlik.

e) BIM uses beyond 3D such as 4D and 5D BIM. Clash detection and construction planning were demonstrated in the class. A civil engineer from the office presented basic information about planning the construction, information inputs, and tools for creating the 4D simulation. Students were required to create simulations and clash detections using Navisworks (Url-20).

f) A one-day workshop in the office was organized for students as a complement to the course. The goal was to familiarize students with the real-life environment and to demonstrate some of the in-house contents and methods for organizing BIM projects that could not be realized outside the office.

The question and discussion sessions with practice mentors (Figure 4.13) during the class typically took more time than we expected. According to students, these sessions were '…an opportunity to learn about valuable experiences from different projects', that practitioners shared with them. However, to fit into the course time frame, we were obliged to reduce the planned contents of the course.

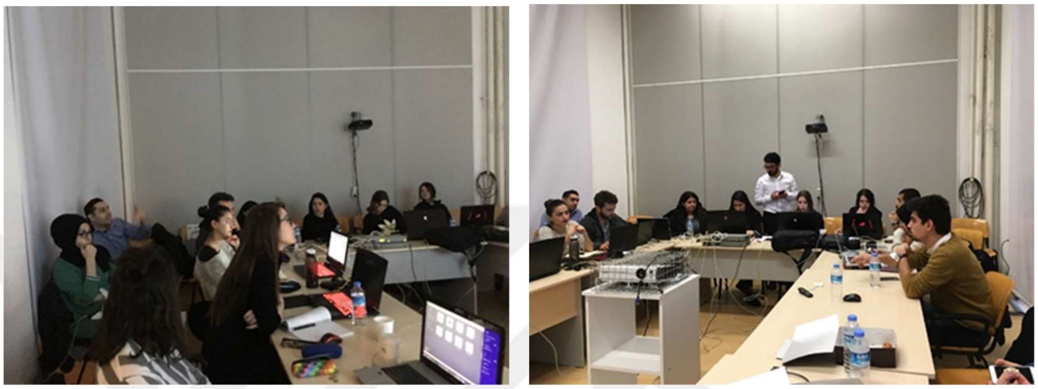

Figure 4.13 : Discussion sessions with practice mentors.

To avoid congestion in students' minds with too much new content, and to meet the course time frame, each topic was explained on the basic level, not going into too much depth and detail. However, the students were encouraged to expand their knowledge by using the learning repository. The hands-on sessions that followed the lectures were also simple procedural tasks that could be completed in a short period of time.

After introducing the main principles of BIM tools at the beginning of the course, students were required to learn the basic skills of BIM modeling tools (Revit). As we agreed with practice mentors that they would not be teaching the tool, nor the time of the class allowed it, students were required to use video tutorials form learning repository. Although it was a self-learning process, students were given the framework to follow, such as the required skills and time to complete. Unlike the scenario I, in which the tools were introduced at the end, in this scenario the tools were introduced at the beginning so the students could follow up on the practical exercises in the course and the continuing analysis of the model.

After completing the set of tutorials, students were required to submit simple models that would demonstrate what they learned. We noticed that the dynamics between students in learning the tool were very different. Some students completed all the tutorials in less than two weeks and produced correct models. They were asking more advanced questions in the class related to model development. The other group of students had difficulties in following up on the dynamics of the course and uploaded their models later than required.

Together with weekly assignments that were simple procedural tasks, usually following what was presented in the course, students were required to submit a final project. The task was to create a BIM project for one of their previously designed projects (in one of design studios). The required contents were: BIM Execution Plan, Revit model with LOD 300 of building elements, quantities file, 4D construction simulation, clash test report, building renders, regulations and standards used.

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. Final projects were presented in front of Prof.Dr. Birgül Çolakoğlu, Mr. Erdinc Çiftçi, and the course instructor. Some of the examples of students' final projects are given in Figure 4.14 and Figure 4.15. After students' presentations of the final projects, the course instructors and practice mentors gathered in a ‘reflection meeting' to review and evaluate the course and discuss future development.

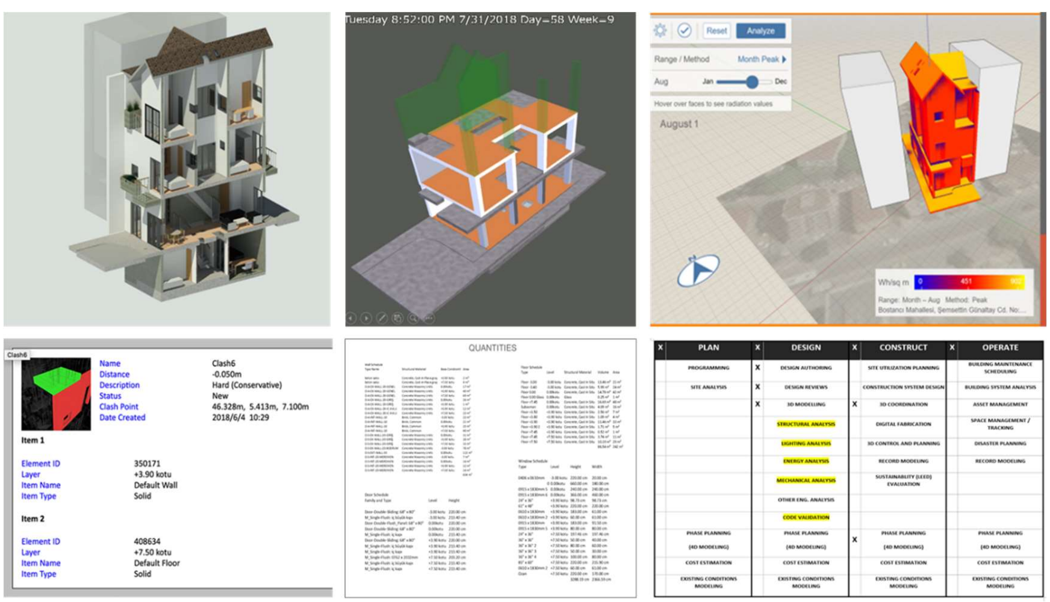

Figure 4.14 : Student work examples.

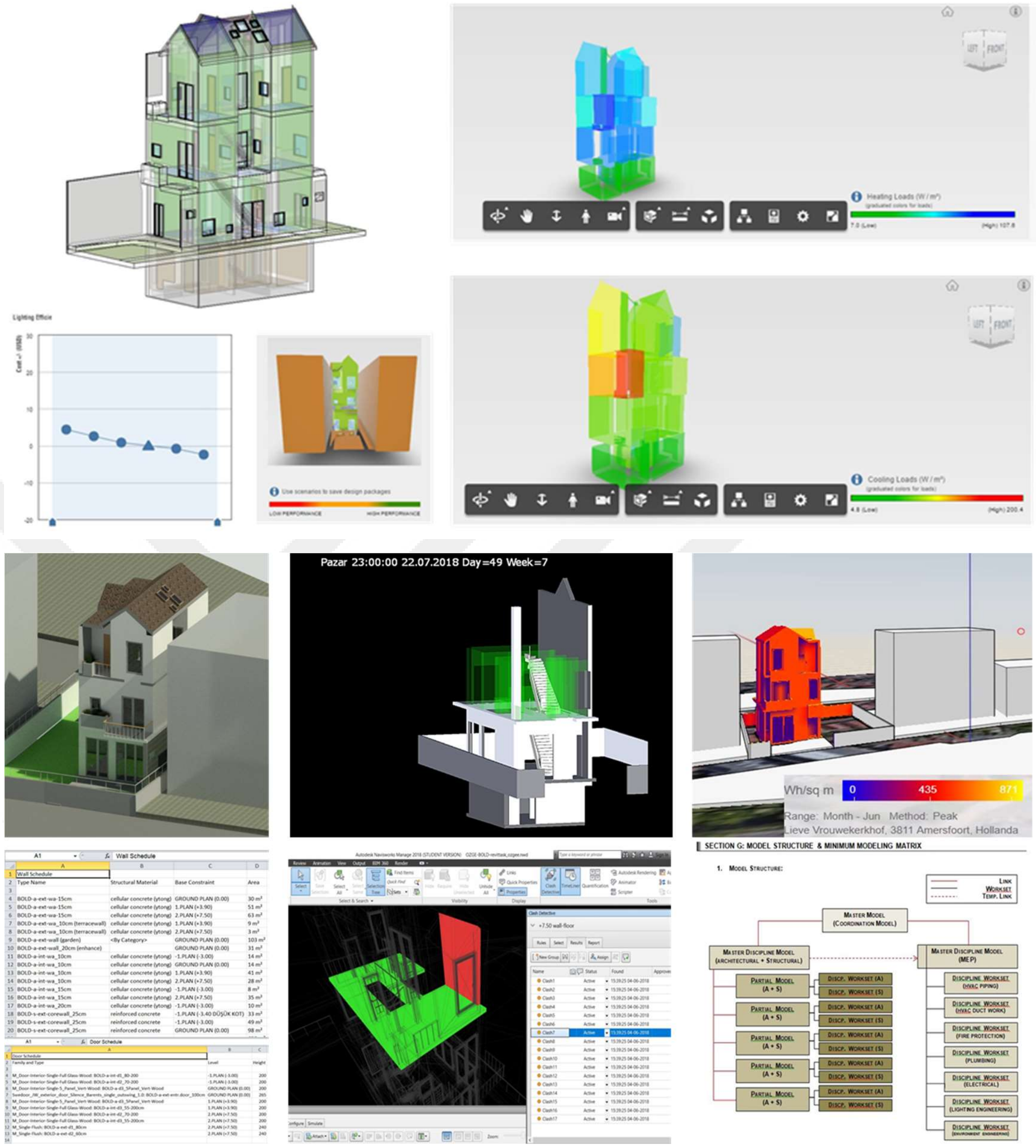

Figure 4.15 : Student work examples.

This was a novel experience for instructors and practitioners. Both sides gained valuable knowledge; instructors gained valuable knowledge about real-life aspects of BIM during the preparation and teaching of the course; practitioners learned about how students think and the dynamics of the classroom. Having to describe and explain different stages of the project development from the beginning made them think in the backward. They said that this was an opportunity for them to reflect on their own processes which might be an opportunity for improvement of some aspects of their practice.

According to our observations and practitioners' opinions, the interaction with students was very successful and motivational. According to the class activities, involvement in discussions, interest in presented contents, students showed a great level of interest to learn in comparison to the previous level. They were also very enthusiastic about the presence of practice and the opportunity to use the real-life BIM model.

In general, the instructors and practitioners were satisfied with the results students demonstrated in the final project. The projects were correct and acceptable for the level of an introductory course. All projects contained the required files and elaborations which demonstrated their understanding of the presented BIM knowledge and skills.

Another important observation was that students show various interests in different BIM areas. For example, some students were more interested in technology, some in project organization while others in the ways BIM can help them in design. Even though their task was not to design, some students continuously tried to make a connection with how to apply BIM concepts in design and whether BIM tools can help them design better and improve their design assignments in the design studio.

In addition, Mr. Ciftci described the importance of task distribution according to one's preferences in real-life projects: “One person in a team can never be at the same time a good architect, successful manager, and great modeler. We select team members for specific tasks according to their preferences and skills. Everyone does a specific job they are the best at. Even in the same task, everyone is not equally successful; some are very creative and propose an innovative design, but are bad in presenting them. So we select another person with good presentation skills when we communicate with the clients”.

Sometimes we noticed that practice mentors are going too fast assuming that students already have some knowledge of presented concepts. As students did not understand many aspects, the instructors had to stop and provide additional explanations. Although it seemed unnecessary to them, due to their different levels of knowledge, students could not understand many aspects if they are not explained in order. Also, there were many new BIM terms that took time for students to adopt and to understand. In addition to not having BIM knowledge and skills, students were also not familiar with many real-life aspects of practice. This gap had to be considered in explaining specific topics. This confirmed our observation from level 1, that important condition for proper understanding of BIM is to know more about the realities of practice.

4.4.3 Focus group

In the focus group study that was conducted upon the completion of the course, students were asked to evaluate the course and express their opinions about different aspects of the course, as well as their recommendation for the future. Analysis of the findings identified several key themes that were critical in the students' opinions about the involvement of practice and using real-life example. Students were asked to rate as ‘successful’, ‘partly successful’ or ‘not successful’ the effectiveness of their program in improving their understanding of BIM. From 13 participants, 11 said the program had been successful and two students said it had been partly successful.

Most students generally expressed positive opinions about the involvement of 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. They also considered very useful to see “…how it all works in real projects with real parameters.” Students also clearly expressed their wish for having practice involved in teaching the course again.

Using learning repositories allowed students the flexibility for learners to choose according to personal interests “…what to learn and when to learn.” Construction planning was also very interesting to students. “It was nice to see in time virtually how the building gets built”.

Students generally complained about the course workload. As one student commented: “After I completed the readings, I had no time left to learn the tool or to analyze the BIM model”. Another student also complained about too many different topics: “I didn’t know what should I focus on, the tool, the BIM plan or the construction planning. I know these are all important parts of BIM, but we could not learn much about any of them, only a little bit, which is not enough I think”.

Other students pointed to this issue: “…at one point it all got mixed. I wish we could learn for example how to develop a BIM execution plan. But learn it really well. We started many topics, but could not go deeply in any of them”. Similarly, another student said: “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?”

They also said that they needed more time to learn the tool to be able to follow up and understand what was demonstrated in the case model in the class. As they were also new in 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 will use Autocad and Max because I use them for five years and I can still do it faster”.

Although students generally thought it is important to have a real-life example, they expressed disappointment about not being able to produce similar ones. 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.

Students also expressed interest to learn further about BIM. “I think we got a good overview of what is BIM in real life. That it is not about making models but also many other aspects. I wish we could learn more about each topic, but I guess that was it…” Among the topic they would like to learn more in the future were: more advanced modeling techniques, design with BIM tools, collaboration with engineers, organization of people in the team and creation of BIM execution plan. Some of them also wished to learn about Revit collaboration techniques, as well as how to communicate with the client about the price and schedule.

4.4.4 What have we learned from scenario II?

The critical question that we asked at the end of this level was: ‘What have we learned from level 2 and how do we use what we have learned to plan the level 3?' This level had two major focus points: the first one was how students respond to the presented scenario; the second was collaboration between practice and education in teaching BIM. In this process, different types of interactions emerged: instructor-practice mentor, instructor-student and student-practice mentor. These interactions are important for the development of practice-education partnership in teaching BIM.

Collaborative teaching process combined pedagogical methods with expertize from practice. The instructor had mostly the role of coordinator between students, practice mentors, and course contents. The findings of this study show that in this process, practice and education have essentially different approaches. On the one side, the practice has a top-down approach; they tend to see the project as finished and they need to go backwards to the beginning level. On the other side, education has a bottom-up approach; trying to explain concepts from the basic levels. 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 most valuable knowledge for educational purposes, the important task of an instructor is to guide them and determine the focus and direction of the course.

The results from this level revealed similar results to level 1 in terms of students' positive opinions about practice involvement. Having practice mentors involved in introducing BIM concepts and explaining their application in real-life BIM case improved students' understanding of BIM and gave them confidence that they are learning skills required in today's practice. The use of real projects makes educational exercises much more meaningful. Students 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 example also allowed exposure to different tasks and roles in a project which helped students reveal their different interests in different BIM areas. Some students were more interested in design, while others in design and management. The general overload of contents and complexity, recognized by the students, points to the need to divide the contents into groups based on BIM areas.

Using additional resources supported the development of self-learning skills. Online repository with tutorials is an important supplement to class and should be a complementary component of BIM-related classes. The use of video tutorials has, in particular, helped to deliver training on practical BIM skills to students.

4.5 Scenario III – Student-Centered Modules

This level presents the further development of the scenario II model and its division into learner-centered modules. The hybrid model was inherited from scenario II. The positive experience from this level made us continue collaboration with AE practice. To create conditions for an interdisciplinary collaborative learning environment, our initial intention was also to pair this course with a similar BIM course from ITU Civil

Engineering Department. However, the issues related to schedules, the compatibility of programs, and the general lack of readiness for change from the side of instructors, this idea had to be discarded at the beginning. We consider important mentioning this effort made by the researcher as it represents one of the obstacles found in real-life educational settings. This is also one of the common obstacles in the attempts of creating more collaborative approaches to BIM education.

4.5.1 Setup

Scenario III was arranged in the following way:

To avoid the congestion with too much content and complexity, the content was divided into modules, each focusing on different BIM areas with more detail. The proposition for modules is based on the observation from the previous level that some students have more preferences in design, some in technology while others can be good team leaders. The BIM case was again used in teaching BIM concepts and tools. As shown in Figure 4.16, the development process of scenario III was organized in the three main stages:

a) Core

b) Modules

c) Collaborative project.

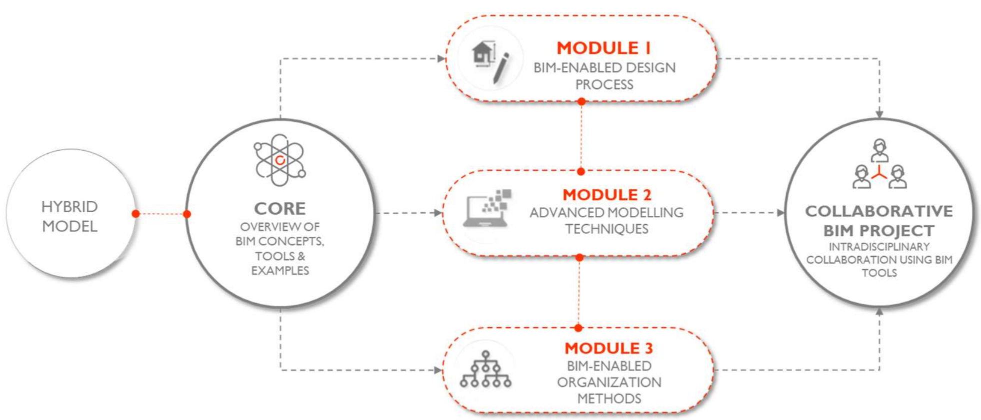

Figure 4.16 : Development process of scenario III.

The three levels were designed to support the gradual development of student's knowledge and skills. The core provided an overview of BIM theory, technology and examples of application in professional practice. It also provided the background for selecting the BIM area students want to study in one of the modules they select. The content of each module was organized around three main themes: BIM technology, BIM organization and design in a BIM environment. The rationale for this division is to enable students to select the BIM area according to their preferences. This is also in line with BIM proposition for task distribution among project participants, each having different contribution to project development. Each group worked with a practice mentor from the AE office. 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. Students would play the role in the team according to the module they selected.

The three-part structure of the learning unit was adopted: one part was devoted to explaining the concept and principles; the other part was focusing on the analysis of real-life project and explanation how the concept was used in it; the remaining time was used for hands-on exercise, student presentations or focused discussions.

4.5.2 Development

The introduction to BIM started with an explanation of BIM approach and an overview of fundamental BIM concepts such as BIM execution planning, collaboration, and teamwork, the concept of the information model, parametric BIM objects, 3D, 4D, 5D, as well as the role of BIM in achieving sustainable design solutions. The practice mentor briefly described the application of these concepts in different stages of real-life BIM case development. Students presented an overview of each module and were asked to choose one of them according to their preferences. The main themes from the core were further extended into modules. Although they were created on the same basis, each module focused on a specific area in more depth. Similarly, different components of BIM case were presented and analyzed according to the module's main focus. For example, the BIM execution plan of the project was explained in an organization module, while building form development, analysis and modifications were presented in design module. The three modules were taught in parallel:

a) **Module 1** focused on design in BIM environment and tools that support design, analysis, and simulations in conceptual design stages. This module aimed to demonstrate the expanded scope of architectural design and the emerging issues architectural design should address. The principles of performance-based design, concepts of sustainability, green building design and zero energy building were also discussed. Students were exploring how building form, its location and orientation, materials and architectural elements influence building performance, its cost, energy consumption and daylighting. The main objective was not to produce any single design but to make students aware of the importance of iterative design development using BIM tools. Students generally had difficulty in understanding the meaning of most performance parameters, numeric values produced in the software (daylight factors, energy usage, and carbon footprint).

b) **Module 2** focused on BIM tools for modeling, coordination, and simulation. The operation of the various software tools in the application of the BIM process was also presented. Students learned the proper application of the tools in correct visualization of different types of BIM objects, the accuracy with which the objects are represented, and the organization of the model parts. Students also learned how to run clash tests and create a 4D simulation. Students were generally producing correct models and simulations. They varied from interesting to less sophisticated.

c) **Module 3** focused on BIM as a method for organizing people, processes and technology. The main principles of the BIM process, BIM execution plan, BIM standards, methods for organization of the team and successful communication were presented. Students learned how to create a BIM execution plan. The major difficulty was in understanding the project standards.

d) **Collaborative learning sessions** in which students from each module presented to other students what they learned in the individual module. This encouraged collaborative learning between students. The major challenge of parallel modules was arranging times and instructors to fit into the course schedule.

e) **Intradisciplinary collaborative project -** students were expected to compile the knowledge and skills learned in individual modules into an intradisciplinary collaborative project. The key to this process was for each team member to build awareness, appreciation, and understanding of their team members. The basic techniques of BIM-enabled collaboration on a project were explained. Students were divided into three teams, each composed of students taking three different modules. The task was to develop the design project using BIM. The design project was developed by students in the design studio which they attended in parallel with the BIM course. The projects were developed gradually, as the new knowledge was presented through the lecture and demonstrations through real-life BIM case. These were presented in front of the course instructors and practice mentors.

In addition, students were encouraged to use the learning repository to expand their knowledge. The first part of the course had the format of workshops with intensive skill sessions combining self-learning and instructor-led learning. The reason for this was to accelerate the tool learning process to fit into the dynamics of the course.

Examples of students' works from module1, module 2 and module 3 and collaborative project are given below (Figure 4.17, Figure 4.18, Figure 4.19, Figure 4.20):

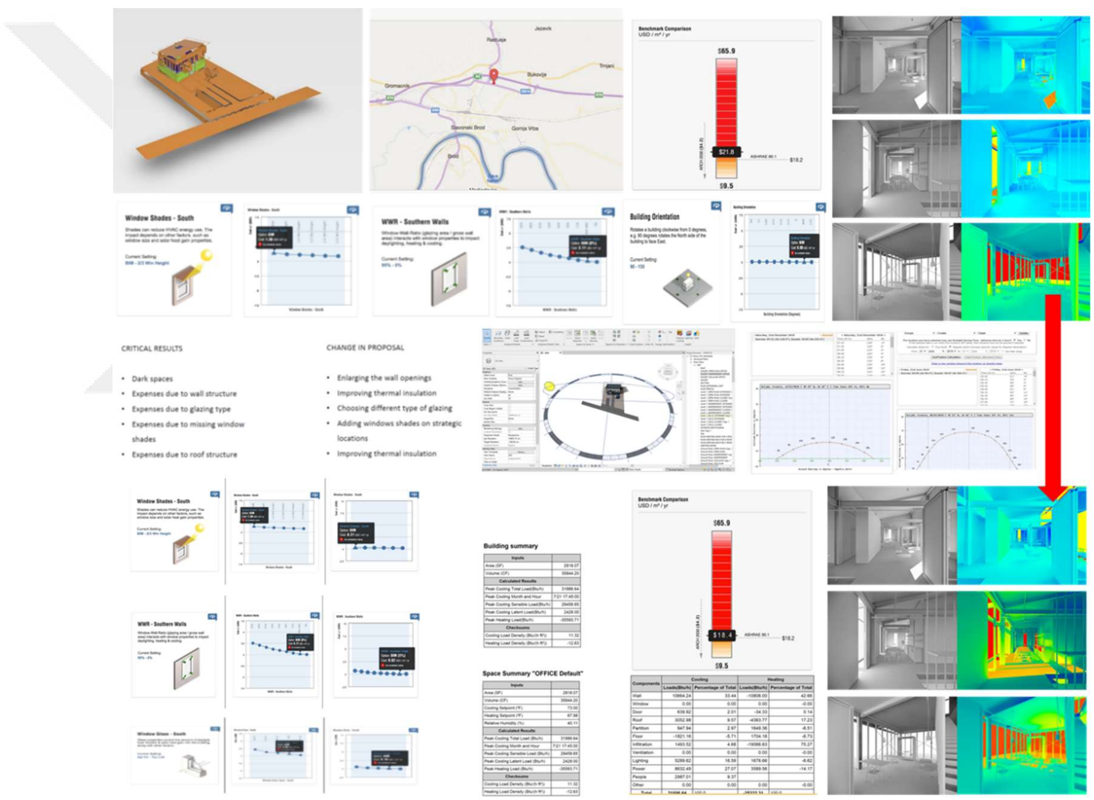

Figure 4.17 : Student work examples from module 1.

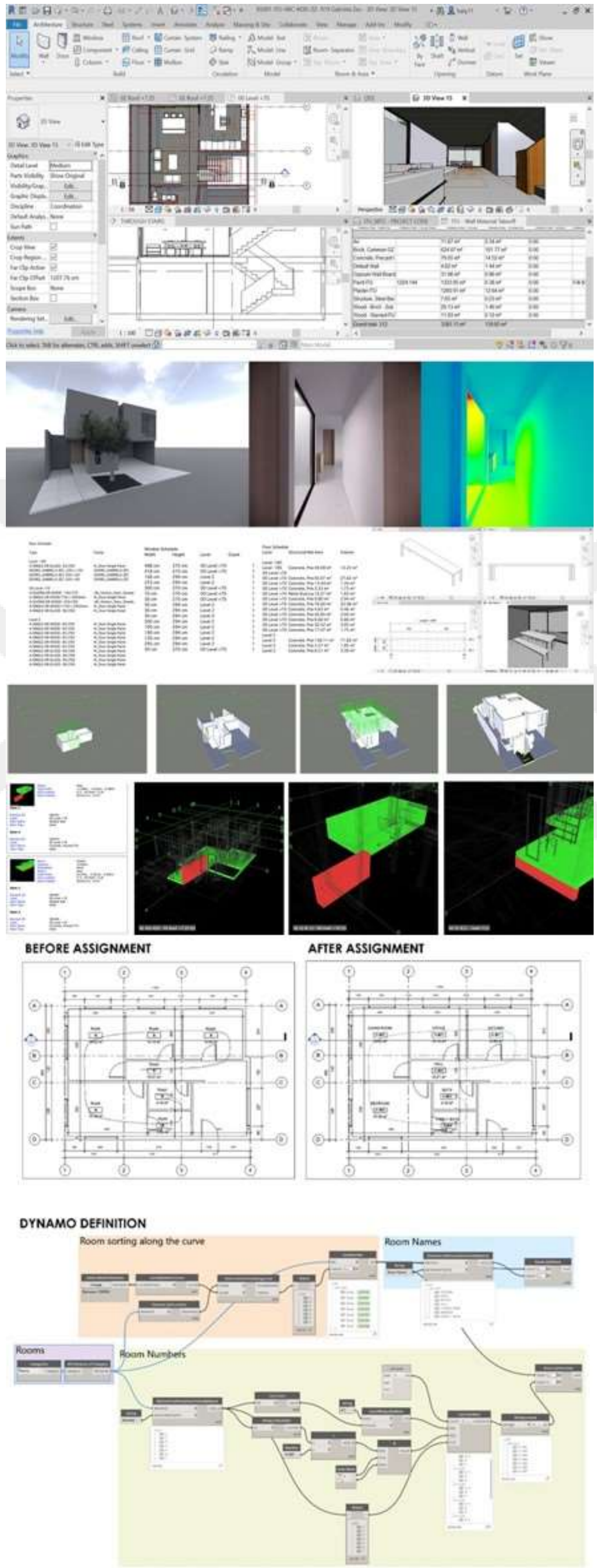

Figure 4.18 : Student work examples from module 2.

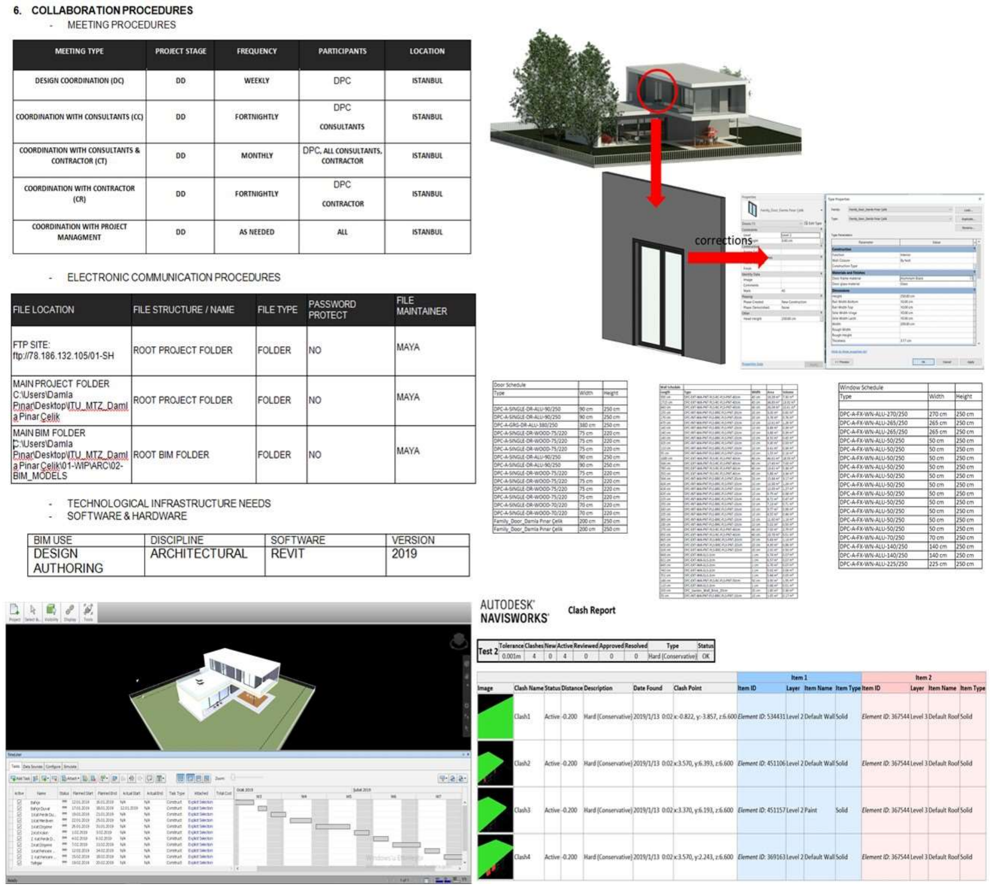

Figure 4.19 : Student work examples from module 3.

Figure 4.20 : Student work example from collaborative project.

4.5.3 Focus group

In the focus group study that was conducted upon the completion of the courses, students were asked to evaluate the course and express their opinions about different aspects of the course, as well as their recommendation for the future. Analysis of the findings identified several key themes that were critical in the students' opinions about the modules and their collaboration experience. Students were asked to rate as ‘successful', ‘partly successful' or ‘not successful' the effectiveness of their program in improving their understanding of BIM. From 17 participants, 11 said the program had been successful, 4 students said it had been partly successful, and two said it was unsuccessful.

We can confirm the results from the previous level, that students are generally very positive about the presence of practice and the ability to see how BIM are concepts applied in a real-life project. Providing an overview of BIM in the core courses was important to all students, as they said it gave them the ‘overall picture of BIM'. 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.'

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.'

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.'

Although they showed relatively good results in individual module assignments, they could not demonstrate it in the 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 then put it all together in the class.’

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 keep to the schedule. Technology will not can give you trust. You have to build it.”

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. In my opinion, it is a process and way of thinking.”

The answers from participants 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.

One of the main topics that students highlighted was the need for more time for learning BIM. Students 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”.

Another student also suggested that: “For a collaborative project 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 a BIM project.”

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 here in the design project.

4.5.4 What have we learned from scenario III?

This level had two major focus points: student-centered modules and intradisciplinary collaboration. The results show that dividing the content into smaller chunks of knowledge and more focused topics is a more efficient way of learning BIM than the compact strucutre. 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 level 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.

In addition, this level also demonstrated that the involvement of professional practice and real-life projects in learning BIM improves students' understanding and general interest and motivation to learn BIM.

4.6 Summary

In this chapter, we presented the development of three BIM learning scenarios in exploratory process of multi-level exploratory case study. The first level presented Scenario I which focused on the shifting students' mindset from conventional approach to BIM and development of positive attitude towards BIM by increasing students' awareness of its importance for contemporary architectural practice. The second level presented the development of Scenario II which focused on utilizing expertize from practice and real-life BIM cases in learning architecture building making that integrates design, construction, mechanics and other sub-disciplines of building making. Finally, the third level presented development of Scenario III which built on hybrid model form previous level and continued collaboration with practice. In this level, learner-centered modules and intradisciplinary collaboration were intrduced. All three proposed scenarios are based on the constructivist approach which proposes active involvement of student and learning by doing.

After analysis of variety of data collected through observations, questionnaires, focus groups at the end of each level and artifacts which represent students assignemnts and projects. Notwithstanding the limitations of case study method and action research design, our results lead us towards the following conclusions which are presented in Table 4.2:

Table 4.2 : Summary of Scenarios.

Case study level	Main Conclusions
Level 1 (Scenario 1)	• Introduction of theory before the tools – theory was dominant • Gradual involvement of practice • Students understand and adopt new BIM concepts more easily when their meaning and application in real-life examples are demonstrated • The involvement of practical examples is more attractive to students than theoretical lectures • Lack of knowledge about many aspects of real-life practice which are essential for proper understanding of BIM • Technical software skills are more effectively self-learned • The strong influence of representational logic represents the greatest obstacle in adopting the logic of BIM tools • Students frequently used online learning repository - valuable supplements to class
Level 2 (Scenario 2)	• Introduced collaboration with ae practice - equal partner in preparing, teaching and evaluating the course • Case method – hands-on real-life BIM cases • Hybrid model - three complementary components • Collaborative teaching - combined pedagogical methods with expertize from practice. • Practice and education have essentially different approaches - the practice has a top-down approach; they tend to see the project as finished and they need to go backwards to the beginning level. Education has a bottom-up approach - trying to explain concepts from the basic levels. • 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.

Table 4.2 (continued) : Summary of Scenarios.

Case study level	Main Conclusions
Level 2 (Scenario 2)	• To make their contribution effective and to extract the most valuable knowledge for educational purposes, the important task of an instructor is to guide them and determine the focus and direction of the course. • The use of real-life projects makes educational exercises much more meaningful: a) It helped students understand what happens after the design stage b) Improved their understanding of the process of development of building projects as an interdisciplinary activity, c) Allowed exposure to different tasks and roles in a project d) Helped students reveal their different interests in different BIM areas.
Level 3 (Scenario 3)	• Demonstarted that dividing the content into smaller chunks of knowledge and more focused topics might more efficient way of learning BIM than the compact structure. • The majority is still primarily interested in BIM as technology as they believe it can help them in future practice. • Student thought that BIM is too complex to be introduced in one course and complained about the course overload • Student-to-student relationship - 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. • Many aspects of intradisciplinary collaboration should be learned before moving to interdisciplinary collaboration.

4.7 Limitations

The characteristic of case study research is exploring the case in its original real-life environment. 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.

The real-life conditions imposed several limitations to the study such as:

- Due to the lack of support for BIM in the academic environment and rigid structure of architectural curricula, BIM introduction was limited to one course per semester. Exploring BIM and learning to more significant levels of depth would need more than a single course. In addition, as the course is organized as one-semester course the three levels of the study could not include the same sample of students.
- Every student has his/her own learning patterns and dynamics. It is difficult, if not impossible to extract the explicit information or make generalizations about the learning process of each student. Exploring the individual learning patterns is beyond the scope of this study.
- Learning process is difficult to observe and the consistency and coherence decreases as the timeframe expands. In addition, various factors influence learning, not only what is taught in the class. Many of them cannot be controlled by the teacher.

However, the study provides important findings which contribute to improvement of understanding of the research issue.

5. CONCLUSIONS AND DISCUSSION

To build on the ongoing discussion of how and when BIM should be integrated into the architectural education, this thesis explored the ways of introducing BIM in architectural education in Tukey. This study had four main objectives:

1) To identify the main approaches to BIM adoption in architectural education and extract the lessons learned;
2) To identify the current state of BIM adoption in architectural education in Turkey;
3) To develop and test different BIM learning scenarios with carefully designed multi-level case study;
4) To assess the case study results and discuss their contribution to the future development of model for BIM adoption in architectural education in Turkey.

Being formative and exploratory, the study employed a mixed-method approach combining qualitative and quantitative methods such as: literature review, survey, interviews, focus groups and case study. After the analysis of a variety of data gathered in research process, our results lead us towards five main conclusions which are presented and discussed below as following:

1) Current attitude in academic environment in turkey towards bim adoption is rather ambivalent reflecting divide between the actual capacities and orientations of architectural schools, from one side, and global trends and the demands of industry, from the other.
2) The analysis of case study results indicates that introduction of BIM into architectural education would require non-traditional learning forms and re-establishing the connection between education and professional practice.
3) The results also indicate that the introduction of BIM in architectural education in the initial stages of its implementation in Turkish architectural schools requires new structure of university class based on hybrid approach that combines different components.

4) Considering the main pedagogical approach of learning by doing in architectural education, learning BIM should be balanced between hands-on and theory classes.

5) The introduction of BIM should be gradual to avoid congestion with BIM complexity and to make progressive transition from drawing to model-based logic.

6) BIM knoweldge and skills can be developed in learner-centered modules where students can choose to study a specific BIM area in more depth according to their preferences.

1) BIM in Architectural Education in Turkey

Literature review, conducted at the beginning of this research, gave us a broad framework that was necessary to explore further from local perspective. The research in practice, realized through ITU BIM Seminar that gathered local AEC professionals and educators, gave us a deeper insight into the current state of BIM implementation and general awareness of its importance. The BIM implementation process in Turkish AEC industry is at its early stages and significantly lags behind world construction industries. Practitioners consider that the major reasons to these are to be found in: lack of strategic planning, standards and guidelines; insufficient level of BIM awareness; and lack of educated people who can work in BIM projects. Practitioners also expressed disappointment with the absence of BIM knowledge and skills among new graduates from architecture and engineering schools.

The situation from practice is reflected in education. The survey results outlined in chapter 3 demonstrate that architectural education lacks a strategy and common approach to BIM adoption. Many schools are not teaching BIM in any way, some are teaching BIM through stand-alone experimental courses and there is generally no strategy for adoption, nor plan for implementation into the various areas of architectural curricula. Several experiments that utilize BIM in teaching performance-based design, construction management and simulation in construction exist. However, the majority of courses is still focusing on teaching BIM software. BIM is still mostly introduced as part of experimental process without having any strategy for BIM adoption in the future. The common obstacles to BIM adoption are BIM-related expertize of faculty, lack of industry involvement and misunderstanding of BIM concepts. In addition, the national standards and requirements for BIM education have not yet been defined. This makes BIM education in architecture schools provisional and left to the will of each separate school or teacher.

Although BIM adoption in industry and education on local level is in early stages, there are strong indications that development of BIM and its utilization in professional practice will continue to increase. It will be difficult, if not impossible to respond to the demands of practice and prepare students with required knowledge and skills if education does not start to more pronouncedly address these issues in curricula. In order to improve the current practice and better respond to the emerging requirements, there is an urgent need to rise the BIM awareness and knowledge in local schools and AEC firms. Both, practitioners and educators emphasize the need for creating a common strategy for BIM implementation in practice and education. Both should be developed in parallel and the content should be synchronized and compatible. This strategy should be approached collaboratively, by industry, academia and governmental body.

2) **Practice-education partnership**

The results of the case study demonstrate that seeing architectural practice and education as partners in introdcuting BIM into architectural education is beneficial in multiple ways. Involvement of practice not only influenced positively on student learning processes during the course, but also motivated them to explore BIM further. One of the main reasons for involvement of practice is to bring the real-life dimension of BIM into educational setting by providing examples of BIM application in real-life projects. The use of real projects makes educational exercises much more meaningful. The reality factor and the real-life dimensions of an exercise showed positive effects in understanding BIM concepts and their application. The involvement of professional practice and real-life projects in learning BIM improves students' understanding and general interest and motivation to learn BIM.

The results also reveal that the model of practice present in schools is far behind the emerging models currently present in practice. There is a need for focusing more on familiarizing students with the developments and emerging requirements of current practice. The involvement of practice did not only improve the knowledge about real-life aspects of BIM, but also of architectural practice that generally lacks in education.

As practice and education have essentially different approaches, practice involvement should be planned and coordinated carefully in order to make their contribution useful for educational purposes. Two scenarios for involvement of practice were observed: partial and full involvement. Partial involvement means occasionally inviting practitioners to give lecture on specific topic, while full involvement means having practice involved from planning, teaching and evaluating the course as equal partner. Both scenarios can be beneficial if planned and coordinated properly. In partial involvement, practitioners should be given specific and focused topics, as well as detailed instruction of what is required for the course. In full involvement, the instructor should provide the framework, structure and learning objectives and help practitioners to adjust their lectures to the level of beginner learner.

By bringing the real-life dimension into education, involvement of practice promises to make current education more recent and informed about the new forms of practice.

3) **Hybrid approach – new strucutre of university class**

BIM is complex and multidimensional concept. Its introduction into architectural education requires new structure of university class based on learner-centered approach. Our results demonstrate that hybrid model that combines different components creates environment that enhances BIM learning and is in line with contemporary context. The hybrid approach involves four main components (Figure 5.1):

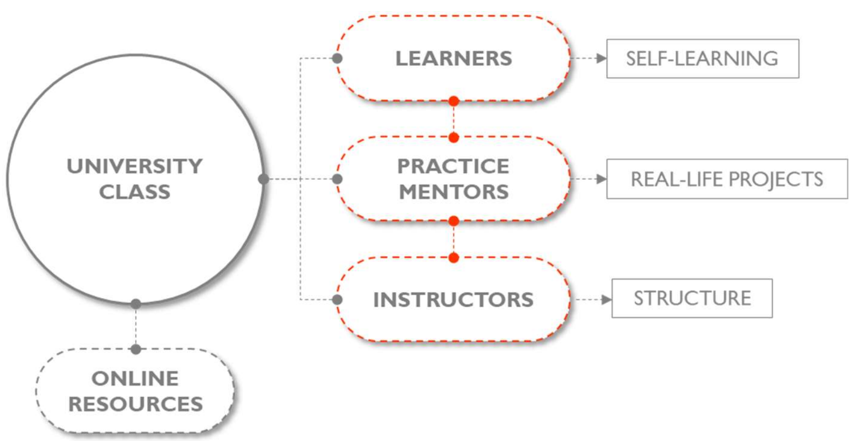

Figure 5.1 : Components of hybrid approach.

a. Instructors are moderators of learning activities, they create the structure of the course, determine the learning objectives, main contents and milestones. The university class provides guidelines on ‘learning how to learn’ - showing only main chunks of knowledge and teaching students to learn on their own.

b. Practice-mentors are contributing with their practical knowledge and experience.

c. Learners – the model is based on active involvement of students. The core idea of hybrid approach is to distribute learning activities between in-class and out-of the class which places the responsibility of students to self-learn. The in-class time should be used for discussing the advanced issues and real-life aspects that students cannot learn on their own.

d. Online resources - almost all BIM resources are online and they have specific importance for learning BIM. For the purpose of course, two types of resources can be used: the global/open resources and in-house resources created and used for the purpose of the course.

The hybrid approach proposed in this study creates a new culture that merges professional expertise and experience with pedagogical methods and theoretical concepts 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. In this hybrid approach, the boundary between teaching and learning gets blurred. The traditional role of teacher who holds the knowledge and transmits it to students gets replaced by the role of coordinator of learning activities. Furthermore, involvement of practice transforms this task into collaborative activity between course instructors and practice mentors. Students become responsible for determining the dynamics of their self-learning process which extends beyond the boundaries of classroom unit.

Carefully selected and prepared learning resources is another important factor that supports learning process. The study showed that using clear, understandable, high quality and up to date resources are valuable supplements to in-class learning. 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. Learning how to use the right resources is important for student’s development of BIM knowledge and skills in the future.

4) Theory and Hands-on

Architecture students learn by doing, therefore learning BIM should be balanced between hands-on and theory classes. 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. The theory is necessary for understanding BIM, but should not dominate over the practical application.

Hands-on exercises should start from simple procedural tasks progressing in complexity. The case method used in this study, which utilizes the reeal-life projects in learning BIM should be apllied when students have acquired basic skills and knowledge to be able to understand components of finished building. In addition, to make BIM learning more meaningful for architectural student, the clear relationships with architectural knowledge should continuously be made.

5) **Gradual development of BIM knoweldge and skills**

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. New content should be gradually introduced to avoid congestions with too much new information and complex tools. In this sense, we propose three levels in learning BIM (Figure 5.2):

a. Technical level – acquiring basic software skills. Our results show that learning BIM tools is effectively achieved by self-learning.

b. Knowledge level – consider what information do we put in BIM model. This requires knowing the type of information and their utilization in real-life projects. For this level, involvement of practice is essential.

c. Interaction level – is using BIM for communication and sharing. For this level, collaborative learning environment should be created in the class.

Figure 5.2 : Three levels of learning BIM.

Another importan characteristic of architectural education is strong indluence of drawing tradition which makes students to think primarily in representational terms and the ways buidings are visually presented not how they are built or maintained. Therefore, the transition form drawing to intelligent dynamic model-based logic, from dissection into plan-section-elevation to integrated thinking and building as a system should be carefully planned.

In addition, drawing is essentially individual tool based on direct relation between mind and hand which is cherishing the skills of a single designer. However, BIM involves social dimension and requires collaboration skills. Thus in understanding the logic of BIM tools, the hand-mind-enviroenment relstionship should be emphasized (Figure 5.3).

Figure 5.3 : Transition from individual to social tool.

Furthermore, 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 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.

As Foque reminded:"…the introduction of BIM technology fundamentally shifts the architect's knowledge base and the way the architect should be educated and trained. Even profound and detailed disciplinary knowledge, such as architectural history, architectural theory, building technology, etc., will become irrelevant if they stay fragmented and not integrated into a greater whole. Building information modeling requires extraordinary insight into the relationships between different kinds of disciplinary knowledge, the interaction between them, and the way this knowledge can be integrated on the design-build level." (Foqué, 2010).

However, this study showed that before interacting with others, students should be aware of their own disciplinary roles and responsibilities (intradisciplinarity). The *condicio sine qua non* for collaboration with other disciplines is learning to collaborate within one discipline.

6) **Development of BIM knoweldge and skills**

In times of rapid changes learning passes the boundaries of classroom. It poses the requirement of continuous learning. When it comes to development of BIM knoweldge and skills after the introductory level, our results show that the division into smaller chunks and more focused topics which a student can grasp can be more effective way of learning then having all students learn everything together. While some architecture students have more interest in design, others have interest in technology or in organization of design projects. In this sense, we propose the division of BIM content into learner-defined modules in advanced levels of BIM learning.

5.1 Practical Implications

In line with the aforementioned conclusions, we can propose an introduction of BIM in architectural curricula in three stages: 1 – planning and preparation; 2 – integration in graduate level curricula; 3 – integration in undergraduate curricula starting from the final years to the beginning of education.

Before BIM becomes part of curricula, a substantial amount of preparation which involves analysis of existing curricula and contents that can be added, changed or omitted, educating the faculty and creation of a plan for BIM introduction. This should be followed by introduction of BIM in graduate level. We propose introduction in two courses run in paralele, mandatory for all students. These courses should provide an overview of BIM concepts and technology and their application in real-life projects. This should also give students good foundation for development of BIM knoweldge which can be done in the second levels, through elective courses – BIM modules such as design, technology or organization module. In each module, students can learn in more depth about the BIM area they are interested in (Figure 5.4).

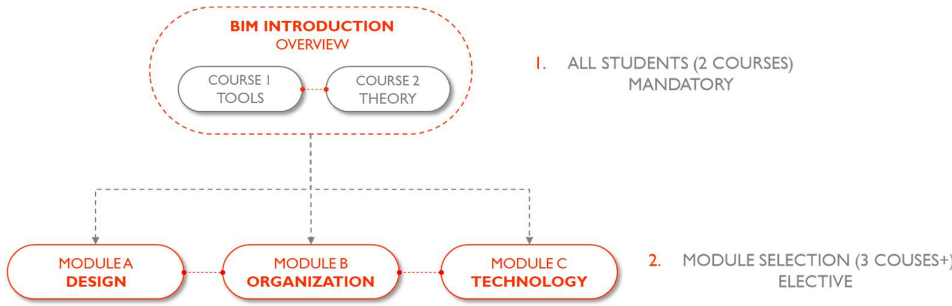

Figure 5.4 : Introdcution of BIM in graduate curricula.

As the context of undergraduate education is significantly different from the graduate level and is specifically sensate and difficult to change, this should be part of a separate future research and is not addressed in this study.

5.2 Contribution

The study provides valuable insights into the local perspectives on BIM which is generally lacking in the research literature. Data collected from observations, surveys and interviews with local practitioners and educators can inform future initiatives for planning BIM in architectural education. Based on how students responded to different BIM learning scenarios in multi-level case study, this study extracted important suggestions for BIM introduction into architectural education. A practical implication of the mentioned findings is the development of a strategy for BIM integration into architectural curricula of the ITU Faculty of Architecture in graduate as well as undergraduate program which is planned for the future.

We hope that this will establish the basis for formation and development of new educational model for architectural education in which BIM will have the central role.

The learning scenarios developed in this study are not completed propositions, rather they are open-ended, leaving space for future development and upgrade. A strategy for introducing BIM in architectural education proposed in this study was defined by the means of an exchange of experience between the academic world and practice with the aim of simulating professional practice in the university. This made the basis for creating a new culture in education. This strategy promises that the divergence between what is taught in architecture schools and what is practiced in real life can begin to transform into convergence through collaboration between education and practice. Students should not only learn the theory and functionality of BIM and understand the current implications of BIM, continuously learn, constantly adapt to the requirements of the practice and update their practical skills and knowledge. BIM will continue to evolve and change our profession thrillingly.

5.3 Future Development

Findings from the research study suggest strong assertions for further development. This study considered the introduction of BIM in architectural curricula. The contested question for further research is: "How to advance BIM in architectural curricula in Turkey"? We recommend considering some of the following aspects:

- The research represents the insertion of BIM in the top-down direction, meaning that BIM is introduced at the end of education when students already have certain skills and knowledge about architecture. However, the bottom-up approaches, introducing students with BIM concepts and technology early in their education, should also be explored.
- Another opportunity for development should be explored through establishing relationship with other courses in architectural curriculum and in curricula of related disciplines. To make BIM more meaningful part of curricula, BIM contents should be combined with contents of other courses. Design studio, building construction, building physics and building materials courses should seriously reconsider their contents and tools and combine them with BIM-related ones. Re-questioning of what to add, change or omit?
- In addition, this study addressed the intradisciplinary collaboration. However, architectural education should address interdisciplinary collaboration through collaboration with faculties and departments from related disciplines.
- BIM puts learning task in front of teachers as well. It is clear that one instructor is not enough to teach BIM. One of the essential requirements for further development of BIM in architectural curricula is educating the faculty in BIM theory and technology.

- 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. Well-defined models for collaboration with practice need to be developed.
- The potential of *case method* has been partly explored in learning BIM concepts and skills. Its different uses in teaching skills and knowledge required in BIM-supported practice should be further explored.
- Implementation of different methodological approaches, especially quantitative ones in research on BIM in architectural education.
- Finally, rapid technological development puts an infinite task for researchers to explore and evaluate emerging opportunities they provide. 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.

Future development of BIM in architectural education will require the formation of interdisciplinary curricula which will require collaboration of AEC disciplines. Furthermore, this is not only the task for educators from architecture and related fields, but also practitioners, researchers, institutes and governmental bodies to collaboratively approach the development of a new educational paradigm. The initiative should start from the public sector to develop the national BIM educational standards and regulations.

5.4 Final Words

No single approach to BIM integration in education will suffice. Each academic program is different, with unique and often innovative ways in accomplishing its goals of BIM integration. In this study, rather than concentrating on a single strategy, we proposed that for successful BIM introduction in education, the professions and academia must be better integrated, and that BIM is one step, albeit with flaws, towards developing better, more efficient, more sustainable design solutions. For future, an important task still remains; for educators and practitioners from architecture and related fields, researchers, institutes and governmental bodies to collaboratively approach the development of a new educational paradigm. Positive experience from this research shows that with the raise of BIM, the common misbelief in architecture education that practice and education are separate worlds, can be changed to the belief that architecture education can work with practice as an equal partner. Hopefully, schools are conscious that the skills and other knowledge that we share with our students should be the skills of today, not the skills of yesterday.

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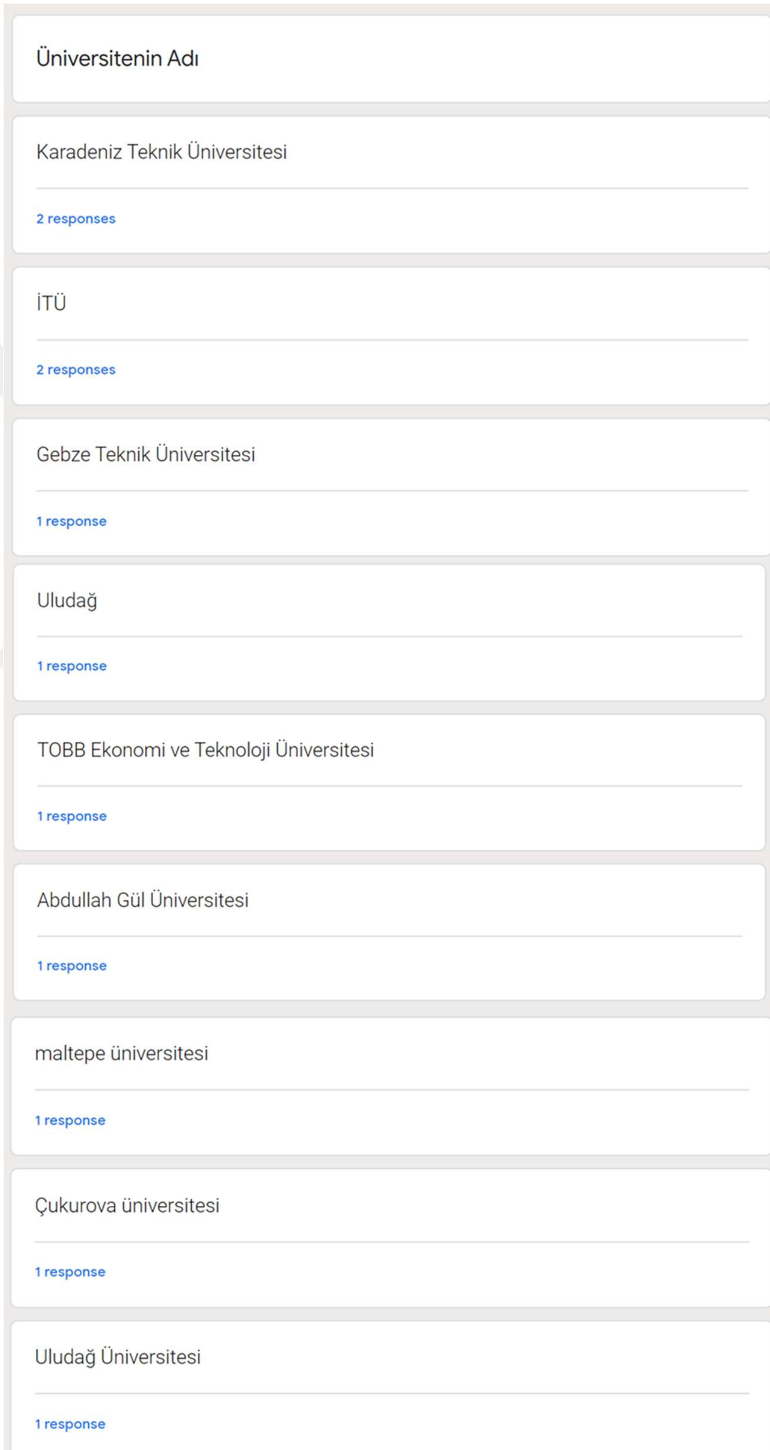
APPENDICES

APPENDIX A: Survey respondents by university

APPENDIX A



Üniversitenin Adı

Karadeniz Teknik Üniversitesi

2 responses

İTÜ

2 responses

Gebze Teknik Üniversitesi

1 response

Uludağ

1 response

TOBB Ekonomi ve Teknoloji Üniversitesi

1 response

Abdullah Gül Üniversitesi

1 response

maltepe üniversitesi

1 response

Çukurova üniversitesi

1 response

Uludağ Üniversitesi

1 response

Figure A.1 : Survey respndents by university.

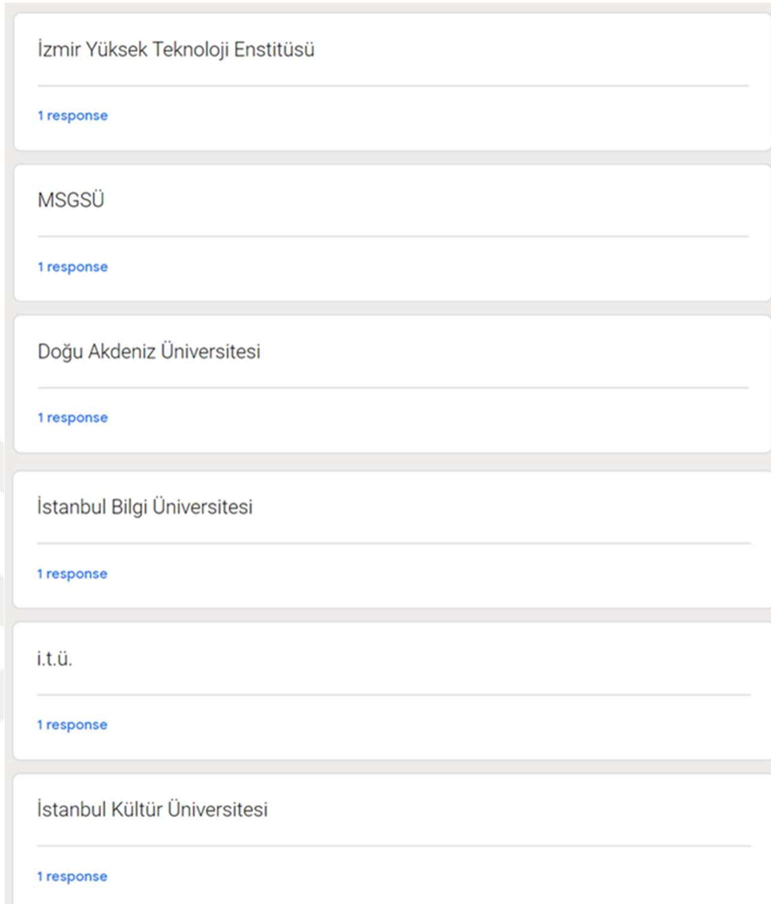


Figure A.2 (continued) : Survey respndents by university.

CURRICULUM VITAE

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PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Isanovic, H.** and Colakoglu, B. (in press). Students' Perceptions of BIM Learning Scenario in Architectural Education. *A|Z ITU Journal of the Faculty of Architecture.*
- **Isanovic, H.** and Colakoglu, B. (2018). Developing a Methodology for Learning BIM through Education-Practice Collaboration. eCAADe 36, Lotz, Poland: Lotz University of Technology.
- **Isanovic, H**. and Colakoglu, B. (2018). Turkiye'deki Mimarlik Programlarinda YBM (BIM) Adaptasyonu. Presented at: *12th Computational Design in Architecture National Symposium*, Isparta, Suleyman Demirel University.
- ECAADE PhD Grant, Thesis Proposal Presentation. Presented at 35th eCAADe, Rome, 2017.
- **Isanovic, H.** and Colakoglu B. (2017). 21 yy. 'ın MMI sektörel profesyonellerini şekillendirme. Presented at: *11th Computational Design in Architecture National Symposium*, Ankara, Middle East Technical University.

OTHER PUBLICATIONS, PRESENTATIONS AND PATENTS:

- **Isanovic, H.** (2014). Should the Informal become Formal: The Case of Karanfilkoy in Istanbul, Turkey. *International Journal of Arts & Sciences*, *7*(5), 629.