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Evaluated Strategies for Embedding Building Information Modeling (BIM) In Architecture Pedagogy in Alexandria Universities

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Abstract

Managing the complexity of building-related information has shown drastic changes as a result of utilizing computational-based approaches. The Architecture, Engineering, and Construction (AEC) industry has seen a remarkable change using new platforms such as Building Information Modeling (BIM). Consequently, embedding these platforms in architecture pedagogy is seen as a direct reflection of this increasing need.

This paper aims to effectively determine the guideline strategies that are needed by the whole BIM educational process stakeholders; colleges, instructors, students, and the AEC sector to develop the BIM embedding process in Architecture pedagogy in Alexandrian Universities.

This paper discusses approaches used to embed BIM in architecture curricula. It analyses several leading experiences showing their embedding strategies, stages of implementation, and their drawbacks. It uses these worldwide experiences to benchmark the way BIM is embedded in two schools of architecture in Alexandria, Egypt. It correlates between the way BIM is embedded in Architecture pedagogy and students' and instructors' feedback concerning the working domain. However, the findings of this paper draw a framework for embedding BIM in Architectural pedagogy concerning both local conditions and expertise expected to be gained to face industry challenges.

Several implementation approaches were studied to develop a solid survey that targets students graduated from Alexandrian Universities who benefited from a previous BIM-related course in their undergraduate studies, to inquire about the BIM implementation strategies adopted at college. To examine how this process affected the respondents in their careers, their opinions and recommendations about the best implementation strategies were taken into consideration.

Keywords

BIM education, BIM teaching approaches, embedding BIM, architectural curricula/pedagogy, architectural teaching methods, AEC industry, AEC stakeholders, BIM courses.

1. Introduction

Architecture is the most remarkable art that reflects the character and the changes that happen to any society. The notable developments that happened to architecture from classical antiquity till nowadays were related to major historical, social, political, economic, and technological milestones that greatly affected the way architecture was being seen and taught.

As declared by Coates S., et al., (2011) architectural education is essential to produce professionals with the necessary thinking skills to undertake the architectural task. One of the main concerns of Academic institutions that offer a degree in Architecture is the relationship between the design education they provide and the skills required for successful practice. That's why the design and the curriculum's philosophy have to achieve harmony between architectural design education and the role of architecture in society (Salama A., 1995).

Architectural education plays an essential role in the production of well-trained and experienced young architects. The focus on how to teach young students has been obvious since classical antiquity and has been improving and changing to adapt to the major changes that affected society in many ways. So to move forward in the architectural profession in general and in Egypt in particular, we need to bear in mind how to improve education, taking into consideration the earlier experiences worldwide.

Currently, the architecture, engineering, and construction (AEC) sector is facing a tremendous technological revolution and its consequent challenges and results (Becerik, et al., 2011). In response to the emergence of new technologies such as Building Information Modeling and its significant growth worldwide, architectural schools are striving to introduce this system to their curricula. Many researchers have studied this topic and have reported many strategies for BIM implementation.

The decision of how to implement BIM in architectural education is crucial; it could have a great impact negatively or positively on students. A lot of questions arise in this issue, some of which are when is it better to introduce BIM? What type of courses should include BIM information? What type of background knowledge should students have to be introduced to this technology? How can we teach BIM? Before deciding on which approach to be approved for BIM implementation, a review of other universities' experiences with embedding BIM is essential. To present the most convenient approach for implementing BIM in the architectural pedagogy in Alexandria Universities such as Alexandria University (AU) and Arab Academy of Science and Technology (AAST). Several students and graduates who benefited from a previous BIM-related course in their undergraduate studies were asked to share their experiences through an online survey. The survey was divided into 4 parts, focusing on the student's educational and vocational background, their BIM educational experience, their experience evaluation, and its impact on their work experience. The results were studied and analyzed to find the best approaches for embedding BIM in Architecture pedagogy.

According to the survey results, recommendations and guidelines were reached to enhance the strategies for embedding BIM in architecture pedagogy at Universities in Alexandria. Although the results that were received are based on the replies of respondents who studied in Universities in Alexandria, these results could be applied in other educational institutions that share the same circumstances and characteristics.

2. Methodology

Qualitative/quantitative research was conducted to set out the guideline strategies required for executing the BIM educational process including all stakeholders; colleges, instructors, students, and the AEC sector. This research is composed of a survey that includes 36 questions divided into four parts. The survey is 2-3 minute read, and was published as a Google form on social media, universities' official groups, and LinkedIn. The survey is targeting the BIM students in universities in Alexandria Universities such as such as AU and AAST. No gender or age limitation. Only geographical segmentation and studies were taken into consideration. It targets the students to explore the impacts of BIM-related courses as they were introduced in the curriculum of educational institutions in the past few years.

Part one aims to understand the respondent's educational and practical background. Part two is about the respondent's experience in taking a BIM-oriented course during their undergraduate studies. Part three aims at evaluating the respondent's experience in learning BIM at their university. Part four analyzes the impact of BIM education on starting a new career in the AEC industry.

3. History of Architectural Education

Through the years, architecture has witnessed various changes due to historical, social, economic, political, technological, and environmental factors. Schools of Architecture had the responsibility to update their learning and teaching methods to respond to previously mentioned factors. This led consequently to a change in education to match the needs of society as well as the market, to adapt to these new technologies and meet the growing global energy challenges and requirements. A new method of education has recently become obligatory because traditional education is "not in line" with the rapid development the world is witnessing and is incompatible with market requirements (Kadhim, 2018).

Since the seventeenth century, architecture education has been affected by four essential points of view: the academic architect, the craftsman builder, the civil engineer, and recently the social scientist. Those four points of view led to four different methods of education: academic, craft, technological, and sociological. Academic education focuses on teaching theories and principles of architecture, taking into consideration historical buildings and concepts. On the contrary, craft training is aimed at educating and training the craftsmen who are responsible for building. In technical training, the function outweighs the aesthetics; in other words, the focus is to solve specific problems using scientific principles taking into consideration economic and functional aspects. Due to the sociological changes that happened in the last few decades, architectural schools motivated their students through sociological education to keep in mind the environmental needs of society due to population growth, new technologies, and urbanization (Barapatre, 2016).

Different models of teaching are discussed in the following section highlighting the causes behind each of them. The early dominant models of teaching architecture that will be discussed later, is that of Gropius' Bauhaus where the course brought together training with different materials, training in a workshop, and working in a building site. On the other hand, another alternative model is that of the Beaux-Arts which is equally blind to the practical context (Martin Symes, 1989).

3.1. Milestones in Architectural Education

Since architecture was considered one of the superior arts thousands of years ago, it has been affected by major milestones. Some of these factors affected architecture education as well. Beginning with the very primitive teaching methods of architecture at the hands of professional masters to the well-known treaties that changed the way architecture was been addressed. And the influencing factors continued to occur affecting the teaching methods of architecture.

These factors can be classified according to their nature. Significant milestones that affected architectural education are:

- Historical
- Social
- Environmental
- Political
- Technological

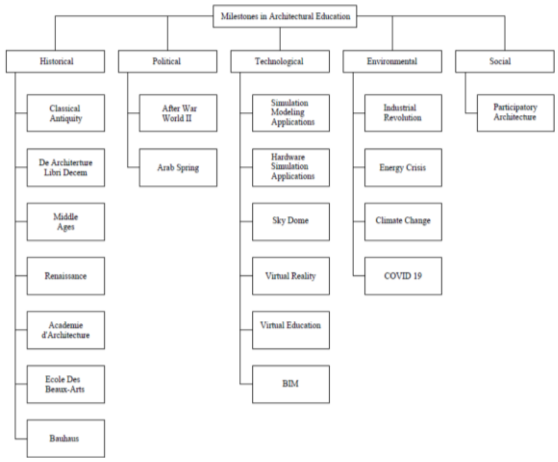

Fig. 1 – Classification of Different Milestones in Architectural Education

The following figure (**Fig.1**) shows a diagram that illustrates a brief about these factors and significant examples for each factor. These factors are discussed later in detail showing the effect of each one of them on education.

3.1.1. Historical Aspects

One of the factors affecting architecture that consequently had some effects on architectural education is the historical aspect. It includes the main masters of architecture and their treaties which had a significant effect on the way architecture was being taught. The following lines explain in detail the main historical changes that led to major educational practices.

3.1.1.1. Classical Antiquity

According to Aristotle, architecture was considered one of the "arts of necessity" that is different from superior arts. Because of this, architecture was taught in professional practice, away from the great philosopher's academies (Celani G., 2012).

3.1.1.2. De Architectura Libri Decem

The credit for changing the previous situation about architecture goes to Vitruvius and his treaty, "De architectura libri decem" (between 30 and 20 BCE). Vitruvius's treaty combined his personal experiences and the history of ancient architecture. It helped in the formation of the "modern concept of a broad liberal arts education" of architects (Celani G., 2012).

3.1.1.3. Middle Ages

In the early days of architectural education, there were no formal schools for teaching architecture craft, however, the liberal arts were taught in the Trivium and the Quadrivium in the first universities. The "arts of necessity" including architecture and other trades, were taught at the guilds and professional associations with technical instruction without any links to philosophy or any higher arts. They were taught through the age-old process under the system of apprenticeships in workshops or even in the master craftsmen's homes. Apprentices would study the profession of architecture under the guidance of master architects through hands-on experience and observation. This resulted in the production of skilled craftsmen, though it might be limited due to the confined experience and knowledge of the master architect (Cret P., 1941; Celani G., 2012).

3.1.1.4. Renaissance

One of the results of the Renaissance was the separation of the fine arts from the crafts (Cret P., 1941). Between the sixteenth and the seventeenth Centuries, Architecture gained a higher status becoming closer to science as literature and liberal arts became more distant from crafts. This shift happened with the aid of architects such as Alberti, Leonardo, and Brunelleschi (Celani G., 2012).

The Renaissance was an ideology that was easily implemented into a new architecture education system; which was to abandon the idea of a single master of the apprenticeship and educate a large group of students in studios and lecture courses (Wheeler K., 2007). During the Renaissance, architects were not following guilds' masters anymore, and architecture became a well-known science with its theories. This was achieved by treaties for architects who were inspired by Vitruvius, such as De Re Aedificatoria (1452) by Alberti and Quattro Libri Dell'architecttura (1570) by Palladio. These treaties helped architects gain more control over the production of buildings with the help of tools like perspectives and scale models. The academy was created to introduce a theoretical discussion about art and architecture, as well as to define the building through the drawing. However, the practical issues were still provided by professional associations and private workshops for many centuries (Celani G., 2012).

3.1.1.5. Academie d'Architecture

In the seventeenth century, the national government of France decided to adopt architecture as one of the fine arts by supporting schools to educate artists (Cret P., 1941). The Academie d'Architecture (later known as the Beaux-Arts) was the first attempt at teaching architecture founded by King Louis XIV (Armstrong C., 2017; Barapatre, 2016).

The academy was opened on December 3rd, 1671, and lasted for over 100 years. It was the first school that started training architectural students rather than depending on the apprenticeship model in teaching, where architectural masters had the chance to discuss and study the principles of Classicism. The school's purpose has developed from providing help in connection with the royal building to providing special training in design to its students (Armstrong C., 2017; Barapatre, 2016).

3.1.1.6. École des Beaux-Arts

The École des Beaux-Arts was the extension of the Academie d'Architecture in France after it was moved to the Louvre until closed during the French Revolution. The Academy was revived in 1795 then soon it became known as the École des Beaux-Arts. It modeled its curriculum on the old school, but it wasn't until the nineteenth century that the École des Beaux-Arts showed remarkable growth (Cret P., 1941).

The École des Beaux-Arts educational method depends on the exchange of advice and critical thinking among students through design problem learning. The school depends on practical exercises for a certain type of building as a method of education through the use of esquisse (sketches). Students gained the ability to incorporate architectural elements into a simple project, resulting in an understanding of order, proportion, and scale. However, graduates were not fully prepared to practice as designers because of a lack of practical knowledge (Cret P., 1941; Ramzy, 2010; Simon, 2002).

3.1.1.7. Bauhaus

After Germany's defeat in World War I, a German art school was founded by architect Walter Gropius in 1919 in response to the technological changes caused by the Industrial Revolution. He wanted to create a new architectural style that reflects this new era; being functional, cheap, and consistent with mass production (Ramzy, 2010).

Education in the Bauhaus school depended on the integration of the professional workshop with the academic education of architects (Ramzy, 2010). Such philosophy dates to medieval craft guilds. The school intended to remove the barrier between craftsmen and artists and to be a combined architecture school, crafts school, and academy of arts. Workshops had two masters; an artist and a craftsman. The first is responsible for the design and aesthetics and the other is responsible for the technical skills (Ramzy, 2010; Celani G., 2012; Daichendt G., 2010).

3.1.2. Political Aspects

The compulsory factors that affect education as well as other aspects are the political factors. The following are some of the political factors that helped in changing how architecture was being taught.

3.1.2.1. Pre-World War II

After World War II architectural education became officially a part of professional programs in universities, art schools, and technical institutions. Many professional schools had to introduce more scientific content to their curriculum to be more technical. This caused many professional schools to incorporate into larger universities and transform their architectural programs (Celani G., 2012; Simon, 2002).

Another addition to architecture schools was the creation of the Architectural laboratory in 1950 by Jean Labutut – a design professor in the faculty of Princeton University and an AIA award recipient – which was a workshop with indoor and outdoor observation areas. This laboratory helped develop and examine projects under realistic light and weather conditions both indoors and outdoors (Labutut, 1979).

3.1.2.2. Arab Spring

Movements and revolutions that started in 2011 in some Arab countries known as the "Arab Spring" caused many challenges in Arab society. These challenges had a direct effect on Architecture and consequently, the way Architecture was being studied in these countries. The Arab society at this point needed a type of architecture that recognizes its country's challenges and works to solve its problems; an approach that is based on the participation of society members and local communities who are the most aware of their needs. They can help in planning and decision-making processes according to their living and working conditions.

The Participatory Design approach –explained later in the next section– one of the trends in contemporary architecture, is considered the most appropriate approach for teaching architecture in these circumstances. Arab universities must take into consideration developing courses that include such an approach in the architectural design studios. This would lead to teaching young architects through "Hands-on training" the construction techniques and strategies (Hoteit, 2016).

3.1.3. Social Aspects

Architecture is a socially driven science that is affected by social aspects. Accordingly taking social problems into account is an integral part of educating young architects.

3.1.3.1. Participatory Architecture (1968)

When many non-profit organizations started to shed more light on poverty and social problems of the marginalized community, prestigious universities worldwide started implementing new programs that depended on a multidisciplinary fieldwork approach to teach university students how to meet the needs of the marginalized community. The Design/Build studio approach provides experiential learning and community-based research opportunities for students and helps develop the community. Students start in the "academic classroom" and then move to the "social classroom". They begin with learning the manual work, and then sometimes communicate with construction workers in or outside the country. This helps them explore new materials and techniques (Hoteit, 2016).

3.1.4. Environmental Aspects

Environmental aspects have always had a great influence on architecture as an industry since the Industrial Revolution. In response to that, most schools of architecture have updated their curriculum to include courses that discuss environmental issues and help educate young architects on how to deal with them in their designs.

3.1.4.1. Industrial Revolution

The Industrial Revolution was considered one of the pivoting points in human history. The impact of the industrial revolution that started around 1760 was substantial at different levels throughout the whole world. It helped develop architecture practically and theoretically. The use of steel, reinforced concrete, and glass was considered a revolution in architecture (Ramzy, 2010).

3.1.4.2. Energy Crisis (1970s)

By the early 1970s, the lack of oil around the world was the reason for the eruption of the energy crisis. Since then, architectural design has witnessed significant developments and new competing building technologies have appeared. Investors have had increased expectations concerning the quality of architectural projects which consequently led architecture schools to consider new ways of teaching design; from the traditional approach in architectural design to the sustainable approach. However, the sustainable approach was effectively introduced much later than 1970s into the curricula of specialized and postgraduate courses at first. It considers more use of renewable energy sources and materials, reducing energy demand in buildings, and respecting the environment. This approach promotes more cooperation between multidisciplinary professionals involved in the construction team.

3.1.4.3. Climate Change

Threats to the Earth's environment have increased since the beginning of the 21st Century as a result of rapid civilization developments (Gil-Mastalercyzk, 2020). Since then, the world has become more concerned with topics related to the environment. Global warming, climate change, sustainability, and energy efficiency are at the top of the list. Architecture practice has been affected by the production of more efficient construction materials. Subsequently, architectural education was expected to develop to adapt to the new practices in architecture and produce energy-efficient designs to overcome the climate crisis (Celadyn, 2018).

Architecture School of Universidad Austral de Chile (UACh) has developed a new methodology for teaching Architecture and sustainability in the academic curriculum. They designed a new urbanism module to include teaching technical courses such as sustainability, construction, and energy efficiency to complement design studios. (Sepúlveda M., Gajardo H., 2016). As knowledge about sustainable architecture and its best practices is added to architectural education, this aids in educating young architects in finding the most convenient solutions facing urgent challenges, through combining scientific and research experience. Interdisciplinary education and extended design workshops that encompassed disciplines such as social sciences, economy, ecology, and health were found to be the best bases for teaching that take sustainable features into account. This conclusion was reached from a study conducted at Kielce University of Technology, Kielce, Poland (Gil-Mastalercyzk, 2020).

3.1.4.4. COVID 19

The critical challenge that affected the whole world in different aspects such as economically, socially, politically, and at the education level as well was the appearance of COVID-19 at the end of 2019. Many Universities worldwide have adopted the distance education approach to address the challenges of the pandemic situation. With the help of technology, computers, and mobile phones along with the internet, e-learning became a possible solution to such challenges. However, students' communication with faculty members was one of the common disadvantages (Ibrahim et al., 2020).

3.1.5. Technological Aspects

Computer applications have been used in the profession over the past three decades. The use of computer applications aided in the production of a huge number of drawings with high accuracy consuming less time. They have also been used by schools of architecture to enhance architectural practice and imagination (Soliman et al., 2019).

3.1.5.1. Simulation Modeling Applications

The technology of CGI (Computer Generated Images) first kicked off when Ivan Sutherland, a computer scientist from the USA invented the first 3D modeling program called Sketchpad in 1963. This invention is considered the father of CAD programs invented later on (Basu, 2019).

The invention of these types of programs led to the introduction of another type of laboratory used in architecture schools. The Computer-Aided Design (CAD) lab was first introduced in the 1970s offering CAD-specific courses. The 3D modeling programs started spreading in schools in the 1980s till they became very common in the 1990s programs (Celani G., 2012). At the beginning of the 1990s, 3D simulation technology was introduced into architecture education in parallel to its introduction in professional practice. The design studio in architecture schools around the world has witnessed a radical change since the 1990s after importing this technology (Omar et al., 2016). Physical scale models began to disappear in many schools after the spread of 3D modeling techniques (Celani G., 2012).

3.1.5.2. Digital Fabrication Technologies

Physical models have changed since the 1990s after the digital revolution. The appearance of some new equipment such as computer numerical control (CNC) machines, 3D printers, plotters, 3D scanners, robots, and virtual digital pens among others made a huge change in the modeling industry including architecture. In addition to modeling equipment, engineers invented simulation modeling hardware such as thermal cameras, digital glasses, digital helmets, virtual simulators, and environmental simulation equipment (Omar et al., 2016).

One of the first digital fabrication laboratories in an architectural school was introduced by Professor William Mitchell at MIT's School of Architecture and Planning in the late 1990s. Machines like fusion deposition modeling (FDM) machines, laser cutters, CNC router machines, and water jet cutters were gradually available at the lab to help Ph.D. students produce their scale models. The developments made by fabrication labs in professional schools like MIT made it easier for other schools to adopt such applications and implement their labs. This was beneficial for both students and teachers to study architecture in a more creative way that enables deeper participation in design issues (Celani G., 2012).

3.1.5.3. Sky Dome

One of the most important environmental simulation hardware that has been used in architecture education is the sky dome. It's a dome covered by fluorescent lamps simulating daylight. Students place their study model in the middle of the dome to study environmental issues such as sunlight and temperature experiments (Omar et al., 2016).

3.1.5.4. Virtual Reality (VR)

The first attempt at a VR system was 2 years after Ivan Sutherland created Sketchpad. In 1965, he explained the concept of his "ultimate display" in which the user can interact with objects in a hypothetical world, where everything around seems real. The first HMD (Head-mounted Three-Dimensional Display) for interactive computer graphics was created by Sutherland and his student Bob Sproull in 1968. This was the first time in the history of computer graphics that helped people see into a computer-generated virtual world (Basu, 2019).

Virtual tours are considered a supplement to traditional classroom learning. The application of digital virtual reality in the process of architectural design by creating a virtual world is considered an interactive experience. It allows architects to explore sites and buildings from their homes, providing them with valuable perceptions about the design and construction of such spaces. It also assists students in experiencing the pros and cons of the internal layout and external design of a building, which helps them rectify their designs according to their experience (Celani G., 2012).

3.1.5.5. Distance Learning (Virtual Education)

The invention of computers in the early 90s and the mass access to the Internet in the same decade led in a way to the appearance of a new learning method known as distance learning (e-learning concept) (Fonseca et al., 2013).

3.1.5.6. Building Information Modeling (BIM)

The history of Building Information Modeling dates back to when Professor Charles Eastman at the Georgia Tech

School of Architecture, published a paper in 1975 discussing ideas of parametric design and 3D presentations. Then Eastman created GLIDE (Graphical Language of Interactive Design) in 1977, which was the first platform characterized by modern BIM characteristics. Later in 1987, ArchiCAD was marketed as a BIM architectural design tool that lasted till today (Khochare S., Waghmare A., 2018).

BIM is defined in many ways; some definitions were summarized by Coates S., et al., (2011) as follows: it could be considered as a language that allows interoperability, a method that codifies knowledge, a method of human-machine interaction, a method of applying parametric behaviors or the process of creating and using digital object orientated models for design, construction, and operations for projects, also defined by Suermann (2009) as "BIM is the virtual representation of the physical and functional characteristics of a facility from inception onward. As such, it serves as a shared information repository for collaboration throughout a facility's lifecycle" and by Eastman, et al (2008) as "a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, planning, construction and later its operation" and finally by (Penttilä, 2006) as "a set of interacting processes and technologies developing a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle".

Using BIM in design is not just a software change but it requires a change in the whole approach to the design process and accordingly to architectural education (Bonenberg et al., 2018).

3.2. Different Types of Spaces and Courses in Architectural Education

Architecture education has evolved over time. It started by teaching design, construction, and materials through an age-old process under the guidance of master architects in small offices and guilds. Education then became more formal after the establishment of architectural schools during the Renaissance period. When the role of the academy became more dominant, schools started to develop their curricula and spaces. They began to focus on more architectural aspects such as spatial organization and aesthetics. According to this, types of spaces have developed including lecture halls, workshops, and design studios. In traditional architectural education, students learn to work in a design studio under the observation of an instructor or a professor. The design studio had a great impact on the architectural process which helped students work individually and in teams; it also encouraged collaboration and peer critique where students learn from each other's ideas. With the appearance of computer technology, another type of laboratory started to be included in architectural schools (Celani G., 2012).

Building types of Architecture schools have evolved from private ateliers to public institutions. After the war years, schools began to prioritize function in choosing buildings' components. However, some schools still preferred monumentality over function. The 20th-century schools of Architecture were swinging back and forth between monumentality and function in designing their buildings (Daichendt G., 2010). The following table (**Table 1**) illustrates the evolution of spaces and classes used for architectural education over time. It also summarizes how architecture was being taught starting from the guilds to the famous schools of architecture.

4. Literature Review

4.1. Deficiencies Facing Architectural Education

It's noticed that some of the systems used in architectural education don't reflect the real professional practice. Architectural Education around the world faces a lot of difficulties that affect students as well as tutors. These challenges range from difficulties in learning to hardness in coping with the market needs once students have graduated to face practical life.

The following issues point out the remarkable difficulties in architectural education that will be explained later and how they could be treated with BIM being implemented in different years and courses.

4.1.1. Market Needs

One of the main difficulties that face architectural education worldwide is the impossibility of relating education systems and techniques to the needs of the increasingly complex world of practice. The market gets affected and changed easily with the fast-changing world and developing technologies, easier than education gets affected.

Most architectural schools teach their curricula detached from the market needs for qualified architects who manage to work in interdisciplinary firms, this leads to graduating unskilled architects despite their scientific background. This might be due to the rapid changes in market needs and the inability of academia to keep up with these changes in updating their pedagogy.
There's a rising dilemma that states there's evidence that there is a gap between students' educational experiences and how much these experiences are effective in the professional and physical environment, the gap between what is taught and what the market needs this dilemma suggests that we must put more efforts in reshaping architectural education (Salama A., 1995).

4.1.2. Lack of Coordination (Incomprehensive content)

Young architects are not used to collaborating with other disciplines for a broader picture of a project moreover there's no interaction whatsoever with the users of a building (Shih R., 2015). They are taught how to design but they aren't taught how to interact with the structure or MEP departments to produce a more comprehensive design, which causes a gap between what architects learn at school and what they get to face in real life after graduation.

Also Salama A., (1995) believes that design studio doesn't simulate the interaction between clients and users which is the main characteristic of real-life practice this is why there's a gap between what student learns and how he/she will practice after graduation.

4.1.3. Impractical Education

Young Architects learn during their study at the Architectural department at their schools how to fulfill the three qualities that Vitruvius mentioned in his book "Firmitas, utilitas, and venustas", in other words, a building must be well built and useful also taking into consideration its beauty. Graduates of architecture schools might know how to design a useful, beautiful building but rarely know how to put a building together.
And because educators focus mainly on creativity in design without taking into consideration other factors that affect a building rather than its form as construction techniques, financial issues that affect certain decisions, this also creates a gap between education and real-life profession (Shih R., 2015).

One of the main generic problems affecting architecture is the lack of knowledge among architects and how they fail to expect and fulfill users' needs causing their dissatisfaction (Salama A., 1995). According to Barrada (1986), "there are very few buildings in Egypt that could be classified as architecture." Architects try to reach the maximum size of building envelope that is legal at the cheapest cost. They ignore the function and aesthetic needs of people. Their buildings lack any concept or language, and very few have architectural values (Salama A., 1995).

4.1.4. Requirements for Accreditation

There is a formal and strict process for the accreditation of architectural schools; this is mainly to ensure the quality and qualified performance of students. There are also plenty of regional, national, and international conferences where educators meet to discuss the future of architecture education (Salama A., 1995). Some of the Architectural schools help their students with the accreditation criteria so it allows the graduates to sit for the ARE licensing exam (Livingston C., 2008)

Table 1 – Illustration of different spaces and courses in architectural education (Source: elaborated upon literature review sources)

School of Architecture / Association	Period of Time	Type of Class	Type of Education
"Guild" Apprentices	Early days of Architectural Education	Offices of self-taught architects	Learning through the Age-old process of apprenticeships
Academia di San Luca in Rome	Renaissance Period (1577)	In the first architectural schools	Architecture education adopted a more "academic" form
The Académie Royale d'Architecture	1671	The atelier was developed in royal school of Architecture	Based on the ex-cathedra teaching with more hands-on education
Ecole De Beaux-Arts	1795	The traditional design studios became the core for architectural design education	The primary method for teaching architecture was "learning by doing" in addition to design teaching by practicing professionals
Establishment of *Association of Architectural Draughtsmen*	1842	No classes or formal instructions (members of association were dissatisfied with trainings in architects' offices)	Improving members' skills through criticism and discussion of drawings contributed by members
	After the Industrial Revolution	"Architectural workshops" conducted in the private offices of leading architects	
Bauhaus	1919	Workshops	Educational system that separated the practical workshop training from design aesthetics education. Also linking the educational program with professional practice
Computer Technology (Digital Era)	1970s	A new type of labs (CAD labs)	Disappearing of the physical model using 3D models instead
Digital Fabrication Technology	1990s	Digital Fabrication labs	A new type of physical models made by students with a better hands-on experience
Virtual Reality	Late 2000s	Virtual Tour as a supplement to traditional classroom learning	

The RIBA assumes that there's an important role that architects play in ensuring the correspondence between the AEC industry and the opportunities BIM offers. It has developed a new Plan of Work (launched in May 2013) as an important piece of new guidance for architects and co- professionals yet there's no clear roadmap for institutions on how to adapt BIM in education (Kocaturk T., Kiviniemi A., 2013).

4.1.5. Environmental Context

Architecture is not a department that depends on physics, mechanics, or mathematics, though, young architects should have more knowledge about environmental and physical topics that affect the durability of buildings and the comfort of inhabitants. Also, the impact of the geographical location on our designs should be included in the architectural pedagogy.

4.1.6. Traditional Design Studio

Working in a traditional design studio has many disadvantages, one of which is that it's still operating on the traditional concept of dealing with the teacher as a master and the student in an apprentice position (Shih R., 2015).

4.2. Benefits of BIM in education

To BIM or not to BIM isn't the issue anymore for most architectural schools because the benefits of BIM have outweighed its concerns, and because Ibrahim M., (2006) believes that architectural education is supposed to reflect the needs of the work market. According to Wu and Issa, 2014, Russell et al., 2014, Ganah and John, 2014 embedding BIM in education is highly valued by the industry because it reduces the high costs of adopting BIM in the industry and also improves career opportunities for graduates of architectural schools (Hamid et al., 2016). One of the main obstacles that come in the way of integrating BIM into the industry is lack of the proper training (Ibrahim M., 2006). However, academia is leading the way in the inclusion of BIM in their architectural curricula (Hamma-Adama M., et al., 2018).

Some faculties as Colorado State University desire to enhance the learning environments for their students through effective communication and visualization techniques, also the desire that the academia and industry share to expose the students to emerging BIM-enabled workflows and industry best practices are some of the reasons that prompted Colorado State University to include BIM in their teaching curricula (Clevenger et al., 2010).

Teaching BIM in an interdisciplinary way where students get to understand a complete whole rather than several 2D drawings and be able to perform daylight and energy calculations studies, will eventually impact the practice of architecture as students with such abilities and advanced computer technologies merge (Livingston C., 2008). It's significant to teach BIM in design studios as a design tool however BIM could be a remarkable tool if BIM models were used to estimate cost, for quantity take-offs, schedule simulations, and last but not least for design coordination (Leite F., 2016). Students of Texas State University used BIM to avoid conflict and enhance coordination ahead of actual construction; also they made changes to building assemblies and components with an understanding of overall cost and schedule impact (Weber D., Hedges, 2008)

Before considering the adoption of BIM into architectural education, we must first get a closer look at how BIM would be useful to the AEC industry through education. Listed below are some benefits of including BIM in the architectural curriculum, some of which could be considered the solution to the above problems facing architectural education.

4.2.1. Market Needs

The main purpose of architecture as a business is to provide the services needed to specific markets and so has to be responsive to changing requirements for those markets. Naturally, architecture education is supposed to support this business by providing highly educated architects who can adapt to these changes. Many design firms that are highly responsive to market demands are providing plenty of services that weren't available a few years ago, these include, among others, consulting projects in up-front site analysis, building and floor plate analysis, strategic planning, environmental reports, code review, and analysis (Lawrence A., 2000).

Educational systems are supposed to maintain some similarities between real-world practices and the curriculum that has to be in line reflecting whatever the market demands (Burcin B., et al., 2011; Ibrahim M., 2006). Also, Ibrahim M., (2007) believes that it's essential to understand the needs of architectural education, and as BIM-based CAD is gaining more reputation in the professional practice of architecture we expect more graduates to be aware of the new technology as they were aware of conventional CAD platforms.

As found in the survey by Dean 2007 the two main reasons to teach BIM in education were firstly that 70% of the industry participants indicated that they were either using or considering using BIM in their companies. Secondly was that about 75% of survey participants considered employing candidates with BIM knowledge over those who lack BIM skills (Gulbin, 2018).

4.2.2. Collaboration

As mentioned above, one of the weaknesses of architectural education is the gap between academia and the industry, where architects graduate with the least experience in how to interact with other disciplines. BIM manages to narrow the gap between academia and the market through the collaborative approach as a method among others to indulge the architect more into the construction industry as a whole. When BIM is implemented into the architectural curricula it is used to teach how students could interface with other disciplines within a multidisciplinary project-learning environment.

Multidisciplinary or interdisciplinary teaching focuses on the knowledge of one or more than one traditional discipline. In a study applied to more than 100 AEC programs in the US by Burcin B. et al., 78% stated that multidisciplinary collaboration is very important to the future of the AEC sector while 22% thought it was important. That's why education should be more focused on the collaborative nature of multidisciplinary courses (Burcin et al., 2011). This is mainly to face the current increase in design complexity (Poerschke et al., 2010).

Burcin et al., (2011) and Kim et al., (2009) believe that disciplines could work together to inspire AEC professionals to improve their performance and this is through learning new methods for solving problems.

An experiment was conducted by Poerschke et al., (2010) at Pennsylvania University, USA to prepare future building professionals for interdisciplinary collaboration by using a "Collaborative BIM studio" where students of six different disciplines (architecture- landscape architecture- construction- structural- mechanical and lighting/ electrical engineering) were given the task to revise the prototype design of an elementary school using BIM technology for data collection, analysis, design development, data coordination, and project presentation. This experiment helped the students get engaged in team organization and BIM workflow. This led to a collaborative educational experience for students of the participating disciplines and the opportunity to gain insight into the work processes of other disciplines. It also helped to design the building in a more holistic method. So it's clear that clash detection is one of the BIM benefits that can assist in interdisciplinary coordination issues (Coates S., et al., 2011).

Students before BIM had difficulty understanding the effect of some structural decisions on Architecture as they used to design their plans first and then overlay another structural plan; that of course never helped them to understand the relationship between systems. A study by Azhar et al.,, (2010) showed that students gained a better understanding of the construction department especially MEP mechanical, electrical, and plumbing because of BIM's ability to detect clashes and provide visual details (Clevenger et al., 2010).

4.2.3. As a Design Tool

BIM can be used in designing to replace the traditional design method that usually starts with site analysis and bubble diagram passing by schematic design and design development. BIM software assists in the interaction with models so the student can see the model and begin the editing process faster. The advantage of using BIM in the design process is that the students can start anywhere they want and still get the outcome eventually (Nakapan, 2015). When BIM is taught in cooperation with the design studio, students learn how to comprehend the procedural nature of the building design process and how BIM is meant to help in the process and not only learn how to draw lines, arcs, circles, etc. (Techel F., Nassar, 2007). Also, BIM allows for more exploration of design alternatives "in process", this helps students to check the effect of design alternatives to make more intelligent decisions (Denzer, Hedges, 2008).

As for modeling buildings using old techniques such as CAD, comparisons were made on students using CAD and BIM to show that students model buildings faster with BIM for most of their designed buildings except free-form buildings that required combining both CAD and BIM techniques (Yan, Wei. 2010), also students using BIM choose to develop designs more complex than those depending only on CAD as 3D representation is needed to develop their idea (Denzer, Hedges, 2008).

Because BIM could be used for quantity surveys, site studies of shadow and sunlight as well as visual timelines for the construction process; this helps to discover more information earlier in the design process including errors and omissions. Also, the ability to show structural, mechanical, and electrical systems allows students to understand the complexity of design and integration which in turn expands the limits of design (Livingston C., 2006).

One of the major goals of BIM is that all the information of a project is contained in the model itself; which can then be used in the design process to generate all the required documentation and drawings that are updated as soon as the model is (Marcos C., 2017).

4.2.4. Requirements for Accreditation

BIM is being taught in universities such as Montana State University as a tool to demonstrate two of the NAAB criteria which are building systems integration and comprehensive design; where students learn how to integrate various building systems within their design work through an interdisciplinary approach of learning BIM. Accreditation of the university program allows the graduates to sit for the ARE licensing exam that's why it's important to the licensing of architects (Livingston C., 2008). However, Denzer and Hedges (2008) suggest developing curricula independent of the accreditation criteria to avoid the stifling of creative education.

National Architectural Accrediting Board (NAAB), The American Collegiate Schools of Architecture (ACSA), and The National Council of Architectural Registration Boards (NCARB) all believe that architectural design is about collaboration and students of architecture schools should have collaborative skills. That's why NAAB criterion 7 identifies the current requirement for collaborative skills as the "Ability to recognize the varied talent found in interdisciplinary design project teams in professional practice and work in collaboration with other students as members of a design team". As BIM helps in collaborative design, if NAAB follows suit and formulates a collaborative design requirement, most probably architectural programs would be interested in implementing BIM (Denzer, Hedges, 2008).

4.2.5. Sustainability

BIM can be used to enhance student's understanding of the environmental consequences of design decisions, and because BIM applications support the exporting of model data to an energy application such as Green Building Studio which is used by students at the University of Wyoming to simulate the performance on designs produced in BIM after they got the results they compared it to case studies of high-performance buildings. Students then modified their design ran the application then studied the consequences; this was only possible because of BIM (Denzer, Hedges, 2008).

4.2.6. Schedules and Cost Estimation

Auburn University in Alabama requires students to complete their capstone project schedules and estimates using the BIM software of their choice. Students were able to communicate with team members of other disciplines as well as complete the entire project more easily. Another example is the assignments given to students at California State University in cost estimating; the use of BIM helped in overall speed and accuracy in completing the quantity take-off exercise (Clevenger et al., 2010).

4.3. When to Introduce BIM into Education

Researchers disagreed on when is the appropriate year to introduce BIM into education. Some claim that students should be perfectly aware of all design theories and architectural knowledge before being exposed to such new technology. Others believe that BIM should be introduced gradually starting by learning fundamental skills and then integrating BIM into more complex courses.

It was found by Ibrahim M. (2006) that students should be trained on the application after they get to understand what design is. On the contrary, it was assumed by Kymmell W. (2008) that the first two years should focus on the individual skills of modeling and analysis of the model by integrating a BIM course with a Digital Graphic Representation Course, the subsequent years could focus more on teamwork and complexity through collaboration in Design Studio and Building Technology courses, the final year should be more interactive with companies through actual collaboration in real life projects with construction companies as a method of BIM practices (Barison M., Santos E., 2010).

From the experience in UK schools studied by Kocaturk T., and Kiviniemi A., (2013) it was recommended that BIM technology should be introduced gradually in undergraduate education starting from year 1 and progressing in content and complexity as the students get more experience in studying architecture. Similarly, it was recommended by Ahmed A., et al., (2013) that teaching BIM in the first year gives students a taste of the collaboration skills needed for group work in the coming years without direct reference to BIM, this will ease the learning curve of BIM. The second-year technical support will be added through BIM software workshops. The third year will witness a multidisciplinary collaborative integrated project. The final year project will require students to work in groups from multidisciplinary backgrounds, students are asked to analyze and apply the knowledge gained from previous years to develop a major construction scenario-based project so BIM could be used as a tool for the energy improvement of these buildings.

It was suggested by Yan, Wei. (2010) to adopt an incremental BIM skill development that starts with modeling in the first year of college, passing through simulation and analysis for building systems in the second and third years to customization in the fourth year as well as graduate level. (Livingston C., 2008) reported that the lack of an introductory course at Montana State University was one of the shortcomings in teaching BIM as this places pressure on the Comprehensive Architectural Project course to not only teach some principles of construction documents and detailing but also provide resources for students to accelerate their knowledge of construction and BIM applications.

MSOE offers a freshman CAD and BIM course, whereas Florida International University has its first BIM course in the sophomore year, Oklahoma State University offers a CAD and BIM combined class in the junior year (Gulbin, 2018).

Some Universities include graduate-level BIM courses in addition to the undergraduate courses; Penn State University and University of Southern California are some examples while other universities only include BIM at the graduate levels such as Polytechnic Institute of NYC, University of Washington, and Texas A&M University (Livingston C., 2008).

According to the case study studied by Sah V., and Cory C., (2008) at Purdue University, it appears that the time to integrate BIM into education is something to be considered; because BIM needs a more in-depth understanding of the subject matter and the building's systems which makes it a real challenge for the students to get involved with BIM in the early years of their study. However, it was argued by Sacks R., and Barak R., (2010) that BIM should be taught at the beginning of the basic civil engineering degree because BIM is viewed as an essential skill.

It was believed by Weber D. and Hedges, (2008) that introducing BIM the earlier the better because students would take time to adapt to the program before getting used to it and exploring the power of the program; consequently enhancing their designs. So they believe that introducing BIM in the introductory studio leaves the students with the same experience and outputs as introducing it in the terminal studio, just at an earlier stage.

Lee et al. (2003) recommend that general knowledge and general operations are covered early in a curriculum, while specialty BIM uses, collaboration, and integration are topics for senior-level courses (Hamid et al., 2016).

The results of the analysis of 101 programs in the US that responded to the survey conducted by (Burcin, et al., 2011) showed that BIM courses are mostly offered at the senior and master levels.

The expected level of BIM competency for undergraduate students is recommended to be at basic and intermediate levels (understanding and applying), while for graduate-level courses it was recommended by Sacks, Pikas, (2013); Joannides et al., (2012) that BIM competencies be more demanding (analysis, synthesizing, and evaluation).

4.4. BIM Implementation Strategies

As recommended by Kocaturk T., and Kiviniemi A., (2013) BIM concepts need to be introduced to the architectural curricula gradually and in a progressive manner and not in the method of “add and stir”; it has to be connected with the rest of the courses.

Having analyzed literature that examined different architectural institutions on how they teach BIM, when they introduce BIM into the curriculum, different approaches for implementing BIM, and different course types, along with different strategies in teaching BIM, the following pages summarize the findings.

It was suggested by Ibrahim M., (2007) that proper teaching of BIM should focus on the concept of data modeling and the content creation process and then move to the details of using a specific application exactly as the Beaux Arts school method that depends on learning skills of drafting while working on project design generally with no particular courses on skill development. He also suggests that learning should follow three steps: Drafting, programming; that’s to empower the students with the ability to change and create new tools that they need, and finally data modeling which is about clarifying the fundamentals behind the data modeling concept.

Teaching BIM is different than the conventional CAD platforms that were just a replacement for the drafting table and pen; as it should focus on thinking about the building more than thinking about drafting. This needs a change in the teaching process that should focus on the change in the workflow in addition to teaching the application and its functionalities (Ibrahim M., 2006).

The results of the analysis of 101 programs in the US that responded to the survey conducted by (Burcin, et al., 2011) showed that 56% of all programs offered BIM courses mostly from 2006 to 2009. Of the programs that don’t yet offer BIM courses, 57% were planning to integrate BIM courses within a year (43%) or two (44%); that’s approximately 25% of all programs. However, 19% of all programs don’t have any plans to integrate BIM courses in their programs. Of the architectural programs surveyed 72% said BIM was very important, and 28% said it was important to the future of AEC.

4.4.1. Types of Courses

Through the literature review, it was possible to analyze the types of courses used to introduce BIM in several architecture schools around the world. Later on, it will be discussed how schools approached these courses and how they were implemented into the existing architectural curriculum.

These courses are classified as follows: single course, intra-disciplinary, inter-disciplinary, multi-disciplinary, and distance collaboration (Barison M., Santos E., 2010).

These courses are discussed later and arranged from the least collaboration between disciplines to the most collaboration and engagement.

4.4.1.1. Single Discipline Course

The most common type of courses that schools depend on to introduce BIM is the single courses, where BIM is taught in one discipline away from other disciplines. Those courses could include the use of BIM software, teaching BIM concepts, or creating, developing, and analyzing BIM models (Barison M., Santos E., 2010). The single course can be approached through a various number of techniques which will be discussed later.

4.4.1.2. Intra-disciplinary

This type of course means working in a team within a single discipline. Rangsit University has experience in teaching BIM through an intra-disciplinary approach. They started introducing BIM in the second semester as a design method in a course Computer-Aided Design II. The course runs in parallel with other related courses. One of which is the intra-disciplinary Basic Design Course where students collaborate with the 4th year students (Nakapan, 2015)

4.4.1.3. Multi-disciplinary

Another module proposed by Kocaturk T., and Kiviniemi A., (2013) is mainly used after students gain a certain degree of maturity in their specialization, where they get to be introduced to a set of tools, methods, and techniques that help to compare and appreciate the differences between individual and collaborative working. Multidisciplinary, as explained in Marilyn Stember's paper 1991, is that people from different disciplines are present and working on the same project; however, each one is operating on their disciplinary knowledge where they stay within their boundaries although using knowledge from other disciplines (Kocaturk T., Kiviniemi A., (2013).

As an incentive to encourage collaborative learning, many accrediting boards such as ABET and NAAB require collaboration as a learning content without dictating in which setting (studio, seminar, or lecture) this collaboration should be achieved. This is because the architectural design and construction process is highly interdisciplinary by nature (Poerschke, Holland, Messner, Pihlak, 2010)

The concept of integrated practice in real-world practice could be mirrored in academia, as Architecture, Engineering, and Construction Management students would all benefit from working as a team in an educational environment. Thanks to BIM which has paved the way to more Integrated Practice into the classroom (Berwald S., 2008)

As recommended by Kocaturk T., and Kiviniemi A., (2013) this approach is better used when the learners have the necessary maturity to recognize their discipline's values, procedures, and protocols at the postgraduate level.

The University of Southern California has CE 570: Building Information Modeling for Collaborative Construction Management course to create multidisciplinary and virtual project teams that work together for projects selected in collaboration with industry partners (Gulbin, 2018).

Another case study at Thomas Jefferson University (upper level) taught in 3rd year so students have enough time to take basic building design, materials, and technical specialty courses; students from different disciplines work on their projects then all students work on collaborative final projects in teams composed of one student from each discipline.

The results of the analysis of 101 programs in the US that responded to the survey conducted by (Burcin et al., 2011) showed that 50% of the architectural programs used BIM to teach their students how to interface with other disciplines in a multidisciplinary/ collaborative project-learning environment.

From the observations of a case study applied at Pennsylvania State University by Poerschke, et al., (2010) it was found that successful design collaboration depends on the planning of model content and workflow at the beginning of the project. The advantage of the Collaborative BIM Studio mainly lies in the intensive collaboration educational experience for both undergraduate and graduate students of the participating disciplines and in mutual understanding of technical and social

4.4.1.4. Inter-disciplinary

Referring to Marilyn Stember's paper in 1991 the word interdisciplinary means a design team who are responsible for integrating knowledge and methods from different disciplines using a synthesis of approaches (Kocaturk T., Kiviniemi A., 2013).

As recommended by Kocaturk T., and Kiviniemi A., (2013) this approach is better used in the later years of undergraduate education so students can gain some experience in their field first. This course depends on the collaboration of more than one discipline where students from different disciplines work together to develop projects in collaboration using BIM software (Barison M., Santos E., 2010).

An example of such an approach is the course taught at Montana State University under the name of Advanced Building Systems where students were split into groups to form four BIM models from these primary systems: structure, envelope, mechanical, and the interior for a particular popular building they choose. All four models are then to be integrated to form a master 3D building information model; which makes it similar to any master building information model with all systems to be coordinated in an office environment. Students then had to analyze each of the primary systems with six performance mandates: building integrity, air quality, visual, thermal, acoustic, and spatial performance. The purpose of the course was to help students understand the interactions that influence the whole architectural product by applying the General Systems Theory which is a more holistic view instead of breaking down the whole into its smallest pieces; it's looking at the dynamics of the whole to understand the properties of its parts (Livingston C., 2006).

Using this approach of modeling buildings with systems such as structure, mechanical ductwork, and piping helps students to study the impact of the interior and exterior spatial configuration of the project as well as understanding the building as a whole and not as a group of 2D drawings. Also after completing the model students would be able to perform studies as daylight and energy calculations (Livingston C., 2006).

Project Implementation Plan (PIP) is a BIM execution plan offered to a second-year interdisciplinary group project involving 230 students working in groups at Coventry University. This idea concentrates on the "Information" aspect of BIM, a clear focus on the PIP document to effectively plan the projects, emphasizing collaborative and integrated working practices (Ahmed A., et al., 2013).

4.4.1.5. Distance Collaboration

This is the most uncommon type of course where students from one school work remotely with others from different schools. (Barison M., Santos E., 2010).

4.4.2. Teaching Methods

As discussed earlier in this chapter, BIM is being integrated into different types of courses, one of which is the single discipline course. When a single discipline adapts a BIM course into its curriculum, this single discipline course can be approached through many techniques according to the school's vision. Five approaches in which the course is integrated into the architectural curriculum are discussed below.

BIM technology could be taught as a tool; in this case, a BIM platform is discussed and students get to know commands to create basic structures. This could be done through the standalone single course. Another way is to teach BIM as a method; by learning design fundamentals, methods, and procedures through BIM courses (Nakapan, 2015)

Also, it's stated by Clevenger, et al., (2010) that the three strategies: in a specific course, integrated with other courses, and a combination of both strategies are used for implementing BIM in the Construction Management Department at Colorado State University. To address the dissatisfaction among students and educators caused by the advancement of technology-based curriculum development, especially BIM, 133 students were asked about their opinion of the best strategy for implementing BIM.

- In a specific course (elective or compulsory)
- Integrated with other courses
- Combination of both strategies
- As workshops
- Case studies or presentations and Collaborative learning

4.4.2.1. In a Specific Course

Previous studies such as Berwald, 2008; Denzer and Hedges, 2008; Livingston, 2008 suggested teaching BIM tools and concepts in a specific course (standalone courses). It was suggested by Yan, Wei. (2010) that students in graduate education should study the core of BIM technology instead of using the existing functionalities of BIM. Texas A&M University had an experience at the graduate level where a BIM-focused facility Information Technology course was taught in 2008 followed by a Building Information Modeling course taught in 2009 and 2010. These courses introduce BIM principles, methods, and applications in the design process and the building lifecycle. Advanced topics such as parametric modeling, databases, computer programming, web technologies, design performance simulation, and visualization are included, so students gain knowledge of basic and advanced BIM technologies that can be used to model and retrieve building information in the building lifecycle from design to facility management. BIM's wide applications help each graduate student interested in a specific application to find BIM useful. These courses are good for exploring the potential of BIM because the students are introduced to basic BIM API (Programming and scripting) (Barison M., Santos E., 2010).

It was also suggested by Clevenger et al., (2010), and Bur, (2009) to replace the existing CAD classes with introductory BIM classes at the freshman level that discuss all different uses of BIM focusing on the use of software; this is to introduce students to BIM and reinforce them with basic BIM modeling skills using a specific modeling program.
This option was also suggested by 29% of the students surveyed in the Construction Management Department at Colorado State University, these students believed that existing courses are already overloaded (Clevenger et al., 2010).

The Technion-Israel Institute of Technology has adopted this approach in teaching BIM, a freshman-year course entitled "Communicating Engineering Information" has been developed to replace the traditional engineering graphics course as they believed that BIM should be taught in its own right not as an extension to computer-aided drawing because students do not need CAD to learn BIM and once they do they wouldn't need CAD (Sacks R., Barak R., 2010).

According to a survey done by Sabongi F., (2009) who surveyed 119 institutions, members of the Associated Schools of Construction (ASC), responses from 45 institutions were received that showed that BIM was taught as a standalone course in less than 1% (only one institution), while 9% said that BIM was integrated within existing courses.

It was claimed by Hamid et al., (2016), claim that previous studies find offering BIM courses with no follow-ups in other courses doesn't assist in the long-term learning process for students. They have no chance to apply BIM skills in other courses, which destroys the concept of learning BIM. Also according to Kalay Y., (2009), this approach is referred to as a "square peg in a round hole", which means adopting new technology into the current paradigm. This approach raises a problem where a dysfunctional relationship is developed between the new tools and the task when introducing a new technology into practice. This happens because the task is not fully understood or because new tools substitute old ones. An example of this happened in the early adoption of CAD tools in the design process. This dysfunction is mainly solved by making tools that fit the needs of practice.

4.4.2.2. Integrated with other Courses

Other resources such as Azhar et al., (2010); Clevenger et al., (2010); Sacks R., Barak R., (2010); Sharag-Eldin and Nawari, (2010), studied the impact of integrating BIM into core courses. The standalone, non-integrated courses don't meet the needs of students who plan to be employed in the construction industry and don't help in their learning process progress (Sabongi F., 2009; Hamid et al., 2016) that's why this type of long-established courses are more preferred by students even without integrating new developments in technology.

This includes the development of existing modules to integrate BIM into upper-level courses such as estimation, safety, scheduling, and construction methods. The aim is to show the powers of BIM as a new working process and discuss the relevancy of BIM to those subjects. Only 9% of the students surveyed selected this option (Clevenger et al., 2010).

It was stated by Burcin et al., (2011) that integrating BIM with other courses could be as a part of existing information technology courses (Taylor et al., 2008) or as a part of other construction courses (Woo, 2006)

It was recommended by Livingston C., (2008) that one of the best techniques is to sprinkle small doses of BIM through the curriculum. Schools are introducing BIM integrated with different courses of the curriculum. The study made by Barison M., and Santos E., (2010) grouped them into six categories: Digital Graphic Representation (DGR), Design Studio, Building Technology, Construction Management, Thesis Project, and Internship. However the most predominant of these is integrating BIM in the Design Studio.

Texas A&M University has experience teaching Computer Technology for Visualizations and Design Communication Foundations Courses 5 times from 2008 to 2010 linked to the Design Studio. As stated by Yan, Wei. (2010) BIM was one of the major components of the course and it was focused on the following topics: 3D geometry modeling; modeling building objects; modeling information; domain-specific knowledge; and representation. Basic theories were introduced with a group of software functions that met the modeling requirement for each design studio project. The main objectives of the course were: (1) Mastering basic BIM methods including modeling techniques; (2) Acquiring a basic understanding of BIM that can be used to study buildings interactively. For example, studying the relation between buildings and the site, wall layering and joints, window components, etc.. (3) Acquiring visualization skills. Modifications were made to the course to include special instructions to facilitate free-form modeling by combining CAD and BIM.

Another experience found in the literature is that of the University of Sharjah using the segregated-integrative approach of teaching BIM within a sustainable design framework, where students were taught a simplified set of rules and guidelines related to sustainability which permitted BIM to be introduced in a comprehensive way (Techel F., Nassar, 2007) were students were able to understand the meaning of some terms as solar simulations and solar geometry and deal with them through the given exercise where they were asked to apply BIM which helped in visualizing the building that in return helped to analyze the impact of their design.

Although teaching BIM integrated with other courses might be more useful than teaching BIM concepts as a standalone course. Still, it's assumed by Clevenger et al., (2010); Sharag-Eldin and Nawari (2010) that existing courses are already fully loaded with a significant amount of knowledge which gives no time to cover full tools and concepts of BIM. Meanwhile, having been exposed to many computer commands makes the learning curve of software more prominent than core subjects. Still, Livingston (2008) believes that this strategy is more useful than harmful if there are no other convenient strategies (Hamid et al., 2016). Also according to Kalay Y., (2009) this approach which is referred to as "horseless carriage", is characterized by the transformation in perception of current practice to include the new technology. The opportunities provided by the new technology and their effect on the design process should be taken into consideration.

4.4.2.3. Combination of both Strategies

To overcome the insufficiency of the results from both previous strategies, a combination of both approaches is recommended; creating a standalone course and then adding BIM teaching modules across existing coursework. This provides students the sufficient knowledge about BIM concepts and skills, before getting in-depth with the advanced BIM concepts and skills in updated modules of current courses (Hamid et al., 2016).

This option was chosen by 62% of the respondents who suggested offering standalone BIM courses at lower level classes to introduce BIM and learn how to use the software at a simple level –this could be by replacing existing CAD courses- then after taking this course students suggest exposing to a higher and more complex level of BIM courses to expand their knowledge about BIM and its applications through the BIM curse modules, this way they could be updated with the software as they will still be exposed to BIM software. Respondents also suggested adding a BIM capstone course at the end to fully use BIM in a course that brings everything together (Clevenger et al., 2010).

Although this might seem the most convenient BIM teaching technique, it still has some drawbacks. The inflexibility to adjust school curricula due to accreditation criteria set by entities like the Accreditation Board for Engineering and Technology (ABET) and the National Architectural Accrediting Board (NAAB) is one of the main challenges facing this strategy. Another challenge is the requirements for upgrading classroom equipment and software/ hardware infrastructure and the need for continuous maintenance and technical support (Hamid et al., 2016).

4.4.2.4. Workshops

Workshops used to teach BIM can be isolated or integrated with another course, also some workshops are offered online for students or AEC professionals (Barison M., Santos E., 2010).

4.4.2.5. Case Studies/ Presentations and Collaborative Learning

Russel et al. (2014) suggested that case study presentations and discussions are an effective way to help students think and learn about real-world challenges and solutions as well as standards and conventions in BIM implementation. Collaborative learning through working in teams, knowledge-sharing platforms, and web-based media as creating a blog for group discussions and peer learning opportunities is also a new approach gaining momentum in BIM education. This method of sharing knowledge can raise topics to be lectured in class (Hamid et al., 2016). It was suggested by Livingston C., (2006) that seminar readings help to provoke discussions; where questions about specific topics were raised at the beginning of each class and discussed in a seminar format.

4.4.3. Teaching Techniques

Different types of teaching methods have been observed in similar papers discussing implementing new technologies in the current curriculum. These are the instructor-led method, the Self-paced method, and project-based learning (PBL). Educators have to find a suitable method according to the expected outcome of each course and the availability of resources (Hamid et al., 2016).

4.4.3.1. Instructor-Led Method

Giving step-by-step instruction to students in a virtual or physical class has been the most common tutoring method (Instructor-led method) is the most common way for BIM tutoring methods (Hamid at al., 2016).

However, the instructor-led method might be a little frustrating because students pick up steps at a varied pace. So it was suggested by Lewis et al. (2014) that instructors should demonstrate all steps at once, and then students follow step-by-step instructions (Hamid et al., 2016). However, the practical face-to-face course with guidance from an instructor has other advantages such as direct feedback, direct interaction, and the ability to satisfy students' curiosity to learn more (Hamma-Adama M., et al., 2018).

4.4.3.2. Self-Paced Method

Using handouts and reading materials, audio-video tutorials, coaching and interactive simulations (Self-paced method) is another way used as software tutoring methods. On the other hand, the self-learning method is essential if students have the flexibility to choose among BIM software platforms (Hamid et al., 2016).

4.4.3.3. Project Based Learning (PBL)

Project-based learning is a strategy where students gain their knowledge about BIM concepts through the lifecycle of a certain project, it's considered adequate for engineering education because it resembles the professional behavior of the engineering discipline (Fernanda, 2016).

It's an innovative method for teaching BIM that's been used to give students the chance to work in groups and practice aspects of collaborative working practices expected later in the construction industry (Ahmed A., et al., 2013).

PBL works as a desired pedagogical approach, where a real-world project is included in delivering the course content (Gulbin, 2018). Pennsylvania State University used the PBL experience that focused on the integration of the disciplines (Poerschke et al., 2010).

From the table below (**Table 2**) we conclude that integrating BIM was applied in many schools of architecture around the world through many approaches. These approaches were analyzed based on the time when BIM was introduced to education and how was it introduced each year.

- **Approach A:**

Introducing BIM in the first two years in architectural schools was found to be taught through courses in the same discipline, where students start gaining information about theories of architecture and basic knowledge. This approach is mainly taught as a specific course where tools of software are explained to students as well as being introduced to BIM is sometimes introduced in an intra-disciplinary way; where students of first year work collaboratively with students of the final year for better results.

- **Approach B:**

Introducing BIM in the middle year is expected to be through the multi-disciplinary approach when students have gained a certain degree of maturity in their discipline. Students of more than one discipline work together on the same project, and each team gets to improve their understanding of architectural-related topics and concepts, taking into consideration other disciplines' knowledge. This is done when BIM is integrated into other courses after students have gained information about BIM in specific related courses.

- **Approach C:**

The advanced adoption of BIM into the final year can be done through different types of courses. Some schools use the same multi-disciplinary approach explained earlier in approach B, while others adopt the interdisciplinary approach where students of different disciplines work together to develop a project collaboratively using BIM software. These approaches are accepted in the final years of education because students have already gained experience in their field. Distance collaboration between different colleges is another advanced level of BIM adoption that is more suitable to students of the last year. Methods of teaching differ from the basic specific course to be more integrative like workshops and presentations that discuss BIM concepts and principles.

- **Approaches A+B+C:**

The three approaches can be adopted together in education in a gradual manner. Education starts with a standalone course in the first years, then gradually adding new modules into existing courses with more advanced content. The BIM concepts are integrated with other courses that help in training students who plan to be a part of the construction industry later on, by developing existing modules in upper levels to include BIM in specific courses such as estimation, safety, and construction methods.

- **Approach D:**

Some studies were made on graduates; it was found that BIM can be taught in post-graduate studies through both multi-discipline and inter-discipline approaches.

4.5. Steps for Planning a BIM Curriculum

The architecture program has to be planned to hold a sequence of BIM contents. The following steps are required for planning a BIM-enabled curriculum (Barison M., Santos E., 2010).

4.5.1. Prerequisites

Whether students need to learn manual or CAD drawing is a controversial subject for most researchers (Hamid et al., 2016). Most universities that teach BIM in design studio require that students have attended courses in engineering graphics and CAD because learning manual drawings enhances creativity for students (quality of design) and help produce more qualified drawings (Western Illinois University 2007; McLaren 2008; Ibrahim M., 2007). Similarly, it was reported by Wetzel (2012) that basic knowledge about buildings and manual training as well as 2D CAD drawings are essential prerequisites for learning BIM because when students create digital models early in their freshman year, they produce weak models due to the limitation of architectural knowledge (Hamid et al., 2016). Later when BIM became more prevailing, other studies argued that students don't need to know CAD to learn BIM because it's of little use for courses that require BIM for their projects (Sacks and Barack, 2010; Weber D., and Hedges KE., 2008; Russell et al., 2014), though it was beneficial as some of the basic drafting tools are the same in Revit (Weber D., Hedges, 2008; Hamid et al., 2016). Moreover, Sacks and Barak (2010) found that students with CAD backgrounds would have more difficulties in catching up with BIM tools because of the continuous comparison between both concepts (Hamid et al., 2016).

However, considering what prerequisite courses should precede BIM introduction is essential. Denzer and Hedges (2008) suggest that Design Fundamentals, Building Technology, and Professional Practice should be studied before getting introduced to comprehensive building design with BIM. An additional privilege for students is to learn programming for the extra advantage of customizing, however, this is not the rule, and it's just an exception (Ibrahim M., 2007)

Table 2 – Illustration of different approcahes based on the previous study (Source: elaborated upon the literature review sources)

Approach	Types of Courses					Method of Teaching				
	Single Discipline Course	*Intra-disciplinary*	*Multi-disciplinary*	*Inter-disciplinary*	*Distance Collaboration*	*Specific Course*	*Integrated with other courses*	*Combination of both strategies*	*Workshops*	*Presentations/ collaborative learning*
Approach A (First two years)	*	A+C together				*		A+B+C gradual		
Approach B (Middle year)			*				*	A+B+C gradual		
Approach C (Final year)		A+C together	*	*	*		*	A+B+C gradual	*	*
Approach D (Post graduate)			*	*						

4.5.2. Goals and Objectives

Universities such as George Mason University, University of North Carolina, Texas Tech University, and University of Southern California have set some objectives for their BIM courses. They are to understand the history, principles, and strategies underlying BIM;

understand the functions, capabilities, and limitations of BIM tools; be able to develop, handle, manage, and coordinate a BIM model; be able to carry out an interdisciplinary design and design review; understand the linking of virtual information; being able to locate the details and amounts required to undertake the estimates bidding and scheduling with the model; conduct an on-site "constructability" analysis in BIM; develop and use the model as if the student were also the contractor; understand contracts and administrative procedures of design and construction and; show a commitment to an attitude of life-long-learning through technology. Other goals include: promoting the interaction of the students with stakeholders from the real world; developing skills for working in teams; and producing drawings from a model (Barison M., Santos E., 2010).

4.5.3. Contents

According to Kymmell 2006, A BIM curriculum should start with BIM technical content that helps the students learn the (what, why, and how) (Barison M., Santos E., 2010).

4.5.4. Teaching Methodologies

There are several methodologies adopted in many universities around the world; workshops, discussions, and hands-on exercises are common examples.

As an example applied at the University of Texas; the course content is to be organized into modules covering all the topics agreed to be taught. Each module is composed of a certain number of sessions starting with a background introduction followed by lab sessions accompanied by workshops and hands-on exercises and finally a reflection and discussion session for group discussions and presentations (Leite F., 2016).

4.5.5. Activities

According to Kymmell 2008, each BIM exercise should contain elements from three different categories of skills:

software tools (technical skills), management process (conceptual skills), and project team roles (psychological and social skills). Exercises differ according to the level of difficulty of the BIM course (Barison M., Santos E., 2010). Activities vary from constructing 3D models to working on existing models or other activities such as clash detection, schedules, estimates …

4.5.6. BIM Models

It's recommended to use a small, single-story BIM model; it should be neither complex nor boring. This makes it easier to determine the nature of an exercise in a BIM course (BIM Manager 2009). An example of this is the small simple building used by students at Auburn University. Another example made by students of Purdue University is to form models of the existing university buildings (Barison M., Santos E., 2010).

Students received a basic BIM model with only room layout and volumes to help speed up the initial design process giving more time for other advanced tasks such as lighting design, construction scheduling, cost estimating, clash detection, etc. (Poerschke et al., 2010).

4.5.7. Teaching Resources

The essential requirement for BIM courses is computer tools. Tools that are used for visualization and simulation, BIM environments, 4D planning, automated estimating packages, automated bill of quantities, code checking, and clash detection. The lecturer would have to identify the relevant software for each task (Barison M., Santos E., 2010). Besides computer tools, another tool that is effective for discussions and presentations is a simple smart board (Kymmell, 2008).

4.5.8. Evaluation and Assessment

Sacks and Barak, (2010) found that it's difficult to test modeling skills for a large number of students in an exam, to overcome this issue they asked students to do a model before the test and answer written questions based on the exam day (Barison M., Santos E., 2010).

Students' performance is based on the following: building modeling exercises, the production of a range of outputs from the model, carrying out projects, BIM presentations, readings, analysis of BIM cases, class participation, and reports about visits. Assessments include either projects and exams or the conclusion of the course in the form of presentations (Barison M., Santos E., 2010).

5. Study Cases

In the process of presenting the most efficient approach for implementing BIM in the architectural pedagogy at the Universities of Alexandria. A survey was conducted that targeted students and graduates who benefited from a previous BIM-related course in their undergraduate studies at the Universities of Alexandria. Respondents were asked to share their experience and evaluate it, giving recommendations for the best practice. It's a 2-3 minute read survey, published as a Google form in many groups on social media, universities' official groups, and LinkedIn. The survey was divided into 4 parts, focusing on the student's educational and vocational background, their BIM educational experience, their experience evaluation, and its impact on their work experience. The results were studied and analyzed to benefit from the respondents' experience in taking a BIM undergraduate course to help find the best approaches for embedding BIM in Architecture pedagogy. Some recommendations are given to colleges, students, and AEC employers.

Discussion about each university has been made separately according to the results extracted from the respondents' answers which have been thoroughly examined. Some recommendations were reached to be applied to different universities in Alexandria.

5.1. Results

5.1.1. Part One: Background

The survey targeted the graduates of Alexandria Universities: Alexandria University (AU) and Arab Academy for Science and Technology (AAST) as follows: 66.5% and 33.5% respectively. Some other respondents graduated from 7 other universities in Egypt but their answers were neglected due to geographical segmentation.

37.4% of the respondents have over 5 years of working experience in the AEC industry, while 25% have no experience in AEC, 15.6% of the respondents have 0-1 years of experience. 12.5% of the respondents have 3-5 years of experience and 9% have 1-3 years of experience in working in the AEC industry.

43.75 % of them had BIM knowledge before taking any undergraduate courses, while 56.25% didn't have any BIM knowledge before the course.

5.1.2. Part Two: Educational Experience

It was found that 77% of AU respondents have taken BIM in their final year, while only 9% have taken it in their first year and 5% in their third year. As for the AAST, 60% of AAST respondents have taken BIM in their third year, while only 20% have taken it in their final year 12.5% of the respondents have 3-5 years of experience and 9% have 1-3 years of experience in working in the AEC industry.

It was found that 82.9% believe that previous BIM knowledge was beneficial for their undergraduate course, while 17.1% found that it was useless. Similarly, 82.2% found that previous CAD knowledge was beneficial for studying BIM, while 17.8% found that it was useless. According to what's mentioned in section 4.4.2 Teaching Methods, respondents were asked how BIM was integrated into the curriculum. Responses were somehow similar, where 40.9% were taught BIM through standalone courses that discuss the uses of BIM focusing on the use of the software replacing CAD. 10% of the respondents were taught BIM by integrating BIM into already existing courses. 30.9% of the respondents were taught through a combined method of both previous teaching ways. While 6.5% were taught in workshops and 13.32 were taught using presentations and teamwork collaboration. **Table 3** shows an illustration of different approaches based on the respondents' answers.
Respondents were asked about ways of evaluation at their college and their responses were as shown in (**fig. 2**). 23.3% were satisfied with their assessment method and only 76.7% weren't.

Respondents were asked about the main advantages of using BIM. The following figure (**fig. 3**) shows their answer, knowing that more than one answer was accepted in this question.
Around 56% of the respondents believed that computer labs were adequate for BIM training. About 43% considered the software used at their training was adequate. And around 17% believed that tutors' knowledge and number of computers weren't enough.

5.1.3. Part Three: Educational Assessment

It was also found that the year when BIM is integrated into the curriculum and the way it is implemented affects respondents in so many ways. The following table (**Table 4**) shows the impact of which year BIM was implemented and how it was taught in the following:

1- Undergraduate studies
2- Their BIM skills development
3- Understanding architectural and specialty systems
4- Their work experience

The following figure (**Fig. 4**) shows the respondents' reservations about the deficiencies of BIM education and implementation.

Table 3 – Illustration of different approaches based on the respondents' answers (Source: by Author)

Approach	**Types of Courses**					**Method of Teaching**				
	Single Discipline Course	***Intra-disciplinary***	***Multi-disciplinary***	***Inter-disciplinary***	***Distance Collaboration***	***Specific Course***	***Integrated with other courses***	***Combination of both strategies***	***Workshops***	***Presentations/ collaborative learning***
Approach A (First two years)	*					*		*		
Approach B (Middle year)	* *					*	*	*	*	
Approach C (Final year)	* *		*	*		**		*		*

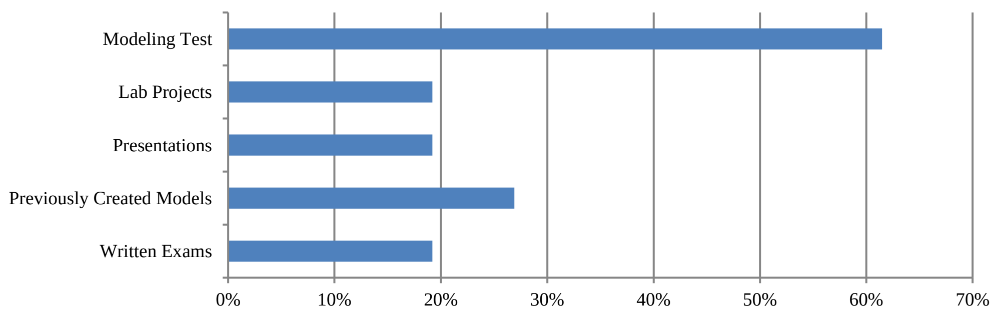

Fig. 2 – Types of assessment and evaluation used at the respondents' college

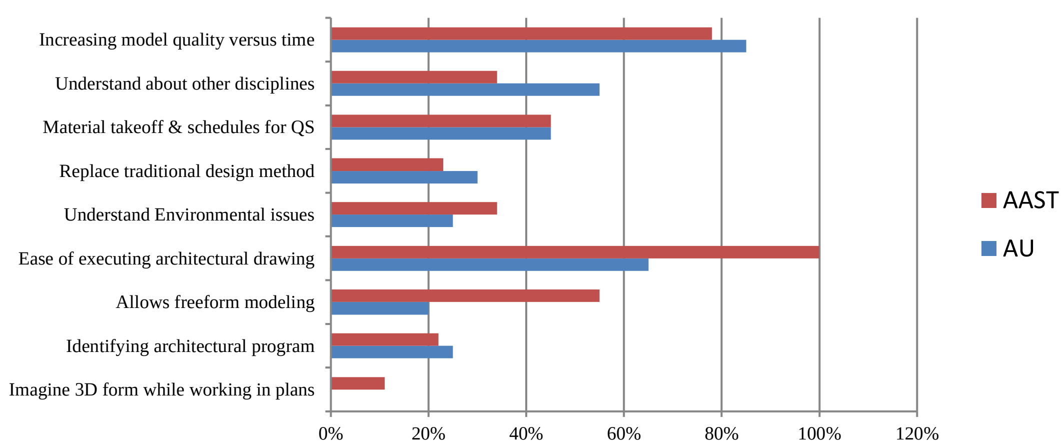

Fig. 3 – Advantages of using BIM in the respondents' point of view

5.1.4. Part Four: Practical Impact and Learning Outcomes

The following figure (**Fig. 5**) shows the opinions of the respondents towards the preferred BIM teaching method upon their experience in working in the AEC sector. They were asked which type of course they thought was beneficial for their career.

Table 4 – Impact of BIM implementation year and implementation method (Source: by Author)

Implementation year	School	Undergraduate Studies Assessment					Self-Development		Understanding architectural & Specialty systems		Experience in work		
		Basic	*Limited*	*Intermediate*	*Advance*	*Expert*	*Yes*	*No*	*Yes*	*No*	*Useful*	*Not needed*	*Irrelevant*
Approach A (First two years)	AU	0%	25%	75%	0%	0%	100%	0%	100%	0%	50%	50%	0%
	AAST	0%	100%	0%	0%	0%	100%	0%	100%	0%	0%	100%	0%
Approach B (Middle year)	AU	0%	50%	50%	0%	0%	100%	0%	100%	100%	50%	0%	50%
	AAST	16.5%	16.5%	67%	0%	0%	83%	17%	83.5%	16.5%	60%	0%	40%
Approach C (Final year)	AU	7%	28.5%	57.5%	7%	0%	95%	5%	95%	5%	54.5%	27%	8.5%
	AAST	0%	50%	50%	0%	0%	100%	0%	50%	50%	100%	0%	0%

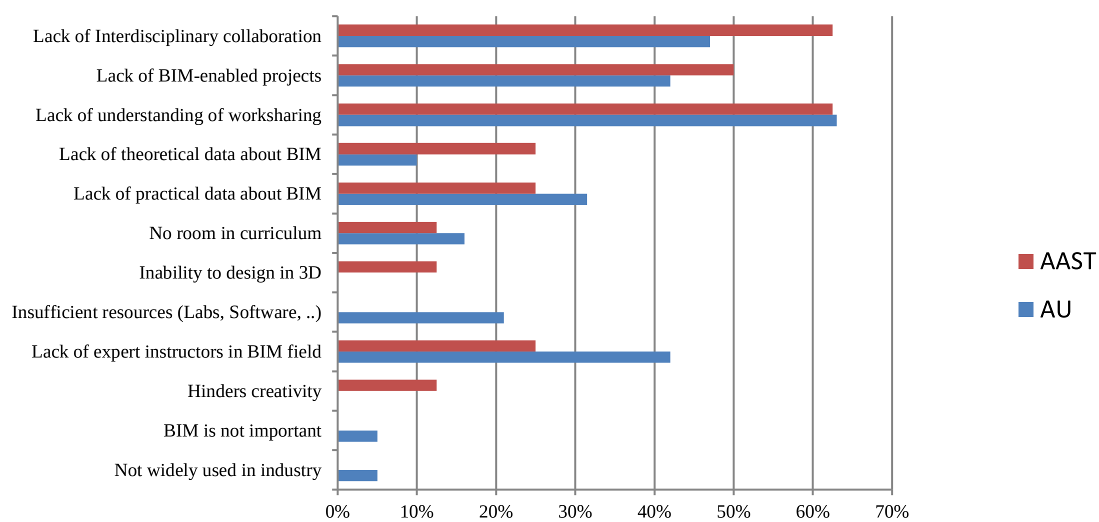

Fig. 4 – Deficiencies of BIM education

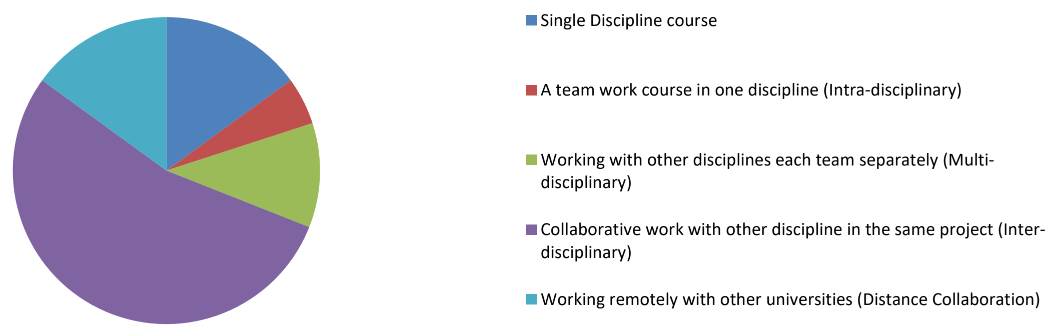

Fig. 5 – Beneficial courses for the respondents' career

The following figure (**Fig.6**) shows the respondents' opinions about the benefits of having taken an undergraduate BIM course before getting started with their career in the AEC industry.

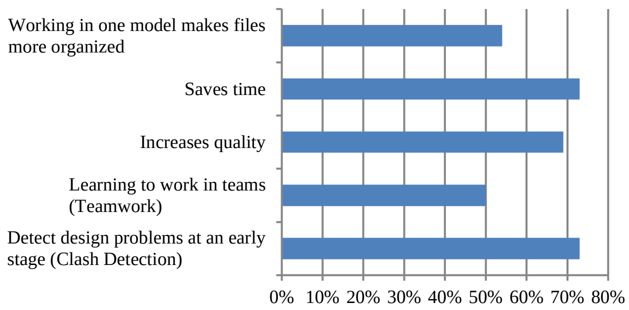

Fig. 6 – Benefits of having a BIM background in industry

The following figure (**Fig.7**) shows the respondents' reservations about BIM education and implementation systems after being involved in the AEC industry about the following: The unachieved expected outcomes.

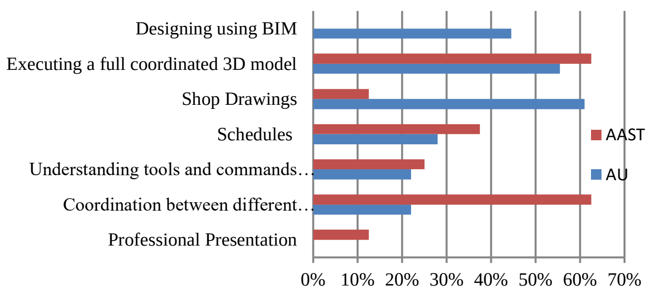

Fig. 7 – Unachieved expected outcomes

Knowing that 90.3 % found that undergraduate BIM course was a good start if they plan on making advanced studies in BIM, while only 9.7% found that it wasn't that good.

5.2. Discussion

5.2.1. Alexandria University (AU)

As per the respondents' answers about the beginning of BIM education in the Architecture Department and its methods of teaching, it was found that the course being implemented in 4th year had more efficient outcomes than teaching BIM in the 1st year, this is due to the increase of architectural design and specialty systems understanding, especially those who studied BIM through standalone courses that discusses all uses of BIM focusing on the use of software replacing CAD courses. This is also reflected in increasing model quality versus time, getting to understand more about other disciplines, and the ease of extracting architectural drawings. On the contrary, students of advanced years who studied BIM on their own and applied their knowledge in existing undergraduate courses found several challenges such as a lack of understanding of interdisciplinary collaboration in BIM (other disciplines), lack of experience in BIM-enabled projects and a lack of understanding of work-sharing and BIM-based communication. The respondents who had taken the BIM courses in their 1st year taught as a single course, suffered from the following: lack of understanding of interdisciplinary collaboration in BIM (other disciplines), lack of experience in BIM-enabled projects, and shortage of time (no room in the curriculum).

Based on their experience after finishing the BIM course at the undergraduate level regardless of the way BIM was integrated, almost half of the respondents believe that BIM should be integrated into the curriculum as a combination of both standalone courses and adding BIM modules to existing courses for the best results. The second preferable approach was using case studies and presentations.

As for the best BIM teaching methods, respondents equally answered that teaching BIM through specific software courses and specific projects is the optimum teaching method. It is notable to hint that other given choices such as self-study and teaching BIM concepts in classes as a tool weren't chosen by any of the respondents.

Regarding resources required for BIM education at Alexandria University, the respondents claimed that only computer labs and software were adequate. A very few percentage of them were satisfied with the tutor's knowledge and the number of computers.

Regardless of how BIM was being taught at their university, most respondents agreed that the main deficiencies in BIM education are the lack of understanding of interdisciplinary collaboration in BIM and lack of experience with BIM-enabled projects, accordingly they believe that interdisciplinary courses are the most beneficial for their career.

It was a certain fact that respondents who found their experience from the BIM course at the undergraduate level beneficial for their job requirement were all designers of technical office engineers.

5.2.2. Arab Academy for Science and Technology (AAST)

As per the respondents' answers about the beginning of BIM education in the Architecture Department and its methods of teaching, it was found that all respondents have studied BIM in the 3rd and 4th years. Regardless of the way BIM was integrated into the curriculum whether in workshops or standalone courses, respondents believed they acquired skills in increasing model quality versus time and the ease of extracting architectural drawings. This was due to that BIM has been taught as a single specific course as software. Teaching BIM a single course led to some challenges such as a lack of understanding of interdisciplinary collaboration in BIM (other disciplines), a lack of experience in BIM-enabled projects, and a lack of understanding of work-sharing and BIM-based communication.

Based on their experience after finishing the BIM course at the undergraduate level regardless of the way BIM was integrated, almost half of the respondents believe that BIM should be integrated into the curriculum as a combination of both standalone courses and adding BIM modules to existing courses for the best results. The second preferable approach was adding a BIM module to the existing courses.

As for the best BIM teaching methods, most respondents believed that teaching BIM as a software course is the best teaching method. Both teaching BIM as a tool and through specific projects were chosen equally as a second preferred option.

Regarding resources required for BIM education at the Arab Academy for Science and Technology, most of the respondents were satisfied with computer labs and software but weren't pleased with their tutor's knowledge and the number of computers.

Although all respondents have been taught through a single specific software course, they equally agreed that the most beneficial type of course for their career is to be taught BIM either through an interdisciplinary, multidisciplinary, or intradisciplinary approach; this is due to the challenges that faced them in their vocational work after graduation.

All engineers who found their BIM experience in their undergraduate courses beneficial for their careers were designers or technical office engineers.

5.3. Recommendations

Institutions need to carefully consider their unique circumstances, resources, and objectives when taking into consideration the following recommendations for implementing BIM into their architectural pedagogy.

As per the findings that have been reached from the survey. The following recommendations should be taken into consideration when planning to implement and develop BIM in architectural education:

- BIM courses are preferred to be in the 3rd and

4th years of architectural education. In other words, the later the better to ensure that students have gained basic knowledge in architecture.

- BIM is better integrated into the curriculum through a combination of both standalone courses and adding BIM modules to existing courses.
- The best advisable methods of teaching BIM are through specific software courses and projects.
- The most suitable type of undergraduate BIM courses that have a great positive impact on vocational work is the interdisciplinary courses engaging all disciplines together through BIM-enabled projects for technical office engineers and designers.
- The management and the heads of architecture should take into consideration putting more financial support in equipping labs with a suitable number of computers and focus on hiring more experienced tutors as well as training existing tutors.

6. Conclusion

After reviewing a notable number of papers discussing the changes that happen to architectural education in response to major changes that affect society and architecture in particular. Also by studying the research that gets in depth with BIM education and how it should be implemented into architectural pedagogy. Several approaches have been reached according to the literature review. These approaches helped build a survey that targeted architects who graduated from Alexandria Universities (AU, AAST) to inquire about the BIM implementation strategies and type of courses they were taught at college, and how it affected the respondents in their careers in the AEC sector. Also, their opinions about the best implementation and teaching methods were taken into consideration. Accordingly, recommendations and guidelines were reached to enhance the strategies for embedding BIM in architecture pedagogy at the Universities of Alexandria. It is worth noting that even though the received answers were from respondents in Alexandria universities, these results could be applied in other educational institutions that share the same circumstances and characteristics.

It was found that BIM being taught as a single discipline course would reflect the level of proficiency of respondents. Also number of computers and experienced tutors are important factors that help in the educational process. The expected outcomes of the given course that weren't achieved after completing the course were all related to the type, of course, the students have been involved in, and they match with the deficiencies of BIM education from the respondents' point of view. It was agreed that BIM technology is indeed required to be implemented in education due to the increasing demand in the AEC industry. It was quite obvious that most of the respondents, after being involved in the AEC sector, preferred to be taught BIM in an interdisciplinary way to be more involved with other disciplines for better collaboration purposes.

Recommendations have been made for the whole BIM educational process stakeholders; colleges, instructors, students, and the AEC sector. Colleges have to consider improving their resources such as the number of computers as well as enhancing the level of proficiency of assigned tutors. Also, the method of teaching and the type of courses have to be adjusted to include different disciplines for the best collaborative results. Instructors have to develop to be more qualified to help students with their courses. As for the students, they have to consider putting BIM as a priority in self-study to enhance their skills and improve their level of proficiency. Finally for the employers in the AEC sector, encouraging the implementation of BIM in their scope of work reflects on those who are still studying in their undergraduate courses and comprehending the benefits of BIM.

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