UNIVERSITAT POLITECNICA DE CATALUNYA

BIM* IMPLEMENTATION IN THE AEC* CURRICULUM

A quasi-experimental case study of the Architectural Engineering (AE) Bachelor's degree at the United Arab Emirates University (UAEU)

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"*Twenty years ago, AutoCAD pushed designers into a new era; BIM represents a new generation of virtual model already widely accepted by the industry*" [1]

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Resumen de la tesis

La implantación del "*Building Information Modelling (BIM)*" en la industria de la construcción, es una realidad que esta cambiando el sistema de trabajo. En muchos países, los proyectos se han de documentar y legalizar obligatoriamente usando esta metodología y sus herramientas. Este es el caso de todos los proyectos financiados con fondos públicos UE, o Inglaterra, Dubái y California, y una seria recomendación en muchos otros. Es por tanto necesario que los alumnos de las Escuelas de Arquitectura o Facultades de Ingeniería de la Construcción, o grados equivalentes dispongan de las competencias y habilidades que esta metodología comporta para conseguir una fácil incorporación al mercado laboral.

Nos encontramos en un momento en que cada centro, introduce BIM a su modo, con diferentes metodologías, intensidades y con muy poca literatura científica, dado que estamos hablando en primer lugar de una herramienta, pero en el fondo es una nueva manera de gestionar toda la información que gira alrededor de los procesos de diseño, construcción y mantenimiento de los edificios y ello depende mucho de cada caso particular y las personas que lo gestionan.

En todo caso podemos encontrar referencias a experimentos docentes equivalentes a la hora de introducir nuevos procesos de gestión de la información aplicada en otros campos de las ciencias, pero muy pocos al del BIM.

Este trabajo de investigación educativa pretende ser un primer paso para la creación de una estrategia de implantación de BIM, aportando datos científicos sobre los problemas que nos encontramos al introducirlas. Para ello hemos estudiado la introducción del BIM mediante la aplicación Revit de Autodesk, una de las más extendidas en el mundo de la construcción. Nuestro estudio se ha centrado en los cursos de construcción de la Universidad de Emiratos Árabes Unidos. Unos estudios que a diferencia de los españoles, son de ciclo corto y en un contexto profesional en el que los arquitectos han de colaborar obligatoriamente con ingenieros para poder diseñar y construir sus edificios. Aspecto que se repite en la mayoría de países y donde su currículum académico no insiste en la adquisición de competencias técnicas de cálculo.

El interés radica en este caso en evaluar si en plazos de tiempo más cortos y con contenidos teóricos más acotados, sigue siendo válida esta estrategia BIM, que parte de la base de que el procesos de diseño y construcción de un edifico es un trabajo multidisciplinar y coordinado de muchos profesionales distintos y para eso el BIM es la herramienta adecuada.

Para ellos hemos estudiado el rendimiento académico, la motivación y la satisfacción de los estudiantes a través del uso de encuestas, comparativa de ejercicios, notas y entrevistas a los estudiantes; así como las experiencias de los profesores que imparten los cursos.

Los datos analizados nos han servido para determinar problemas de implantación, conductas a evitar y elementos a tener en cuenta a la hora de introducir BIM-Revit en los cursos de construcción. Esta tesis termina con la evaluación de dos diferentes metodologías para introducir BIM en los cursos de construcción y una serie de directrices para la correcta implantación de esta nueva herramienta.

En cuanto al futuro de esta investigación, se pretende expandir esta investigación a mas universidades, empezando por la universidad americana de Ras Al Khaimah y tratando de extenderlo por los miembros de la "*Academic for interoperatibility Coalition (AIC)*" a la cual pertenezco y hay afiliadas 48 universidades de todo el mundo y combinarla con otra investigación sobre BIM en academia en la cual estoy participando y en la cual el foco es sobre todo los "*Students Learning Outcomes*" (SLO)s; por ultimo se va a empezar otro projecto de investigación para el desarrollo de una guía para la implantación de BIM en el curriculum de los programas de Arquitectura, ingeniería y construcción.

Keywords: BIM, Construccion, currículo, Revit, Autodesk.

Abstract

The introduction of Building Information Modeling (BIM) is changing the work environment in the AEC industry. Many countries require the AEC industry to submit building documentation using BIM. For example BIM is a requirement to obtain funds the from European Union (EU); England, Dubai and California also require BIM for some typologies of building projects, and most countries are moving towards BIM as a must. It is therefore necessary to introduce BIM into the Architecture, Construction and Engineering curricula. These skills, abilities and methodology will increase student opportunities.

Nowadays each institution and faculty introduces BIM in its own way as there is very little scientific literature about how to go about it. There are many proceedings about offering introductory BIM courses and documentation of those experiences, but few scientific publications are available, as there are for the introduction of new information management processes applied in other fields of science.

This educational research aims to be a first step to create a BIM introduction framework providing scientific data. For this thesis we focused on the introduction of BIM based on Autodesk products in the construction courses of the United Arab Emirates University. Whereas in Spain architectural curricula is broad spectrum, in the UAE, US and many other countries the architect is not overseeing the structure, MEP and HVAC, and must rely on engineers; this study of BIM is based on the fact that the design and construction processes of a building are multidisciplinary work and coordinated by many different professionals, therefore BIM is the right tool.

In the course of our research we have studied student academic performance, motivation and satisfaction using surveys, comparison of exercises, grades and student interviews, as well as the feedback of the professors. The analyzed data helped us to determine introduction problems, behaviors to avoid, and elements to take into account when introducing BIM-Revit in construction courses. This thesis ends with the evaluation of two different methodologies to introduce BIM in construction courses and a first step towards a BIM introduction guide.

In future studies from this research we will expand the study to other universities, starting with the American University of Ras Al-Khaimah (RAK) and working further to extend it further through the members of the Academic for Interoperability Coalition (AIC). We will also participate in other BIM introduction studies from the AIC research group, and based on our initial work here will develop a research project to create a guide for BIM implementation in the Architecture, Engineering and Construction curriculum.

Keywords: BIM, Construction, curriculum, Revit, Autodesk.

Resum de la Tesi

La implantació del "*Building Information Modelling (BIM)*" a la indústria de la construcció, és una realitat que està canviant el sistema de treball. En molts països, els projectes s'han de documentar i legalitzar obligatòriament usant aquesta metodologia i les seves eines. Aquest és el cas de tots els projectes finançats amb fons públics UE, o Anglaterra, Dubai i Califòrnia, i una seriosa recomanació en molts altres. És per tant necessari que els alumnes de les Escoles d'Arquitectura o Facultats d'Enginyeria de la Construcció, o graus equivalents disposin de les competències i habilitats que aquesta metodologia comporta per aconseguir una fàcil incorporació al mercat laboral.

Ens trobem en un moment en què cada centre, introdueix BIM a la seva manera, amb diferents metodologies, intensitats i amb molt poca literatura científica, atès que estem parlant en primer lloc d'una eina, però en el fons és una nova manera de gestionar tota la informació que gira al voltant dels processos de disseny, construcció i manteniment dels edificis i això depèn molt de cada cas particular i les persones que el gestionen. En tot cas podem trobar referències a experiments docents equivalents a l'hora d'introduir nous processos de gestió de la informació aplicada en altres camps de les ciències, però molt pocs al de l'BIM.

Aquest treball de recerca educativa pretén ser un primer pas per a la creació d'una estratègia d'implantació de BIM, aportant dades científiques sobre els problemes que ens trobem a l'introduir-les. Per a això hem estudiat la introducció del BIM mitjançant l'aplicació Revit d'Autodesk, una de les més esteses en el món de la construcció. El nostre estudi s'ha centrat en els cursos de construcció de la Universitat de Emirats Àrabs Units. Uns estudis que a diferència dels espanyols, són de cicle curt i en un context professional en el qual els arquitectes han de col·laborar obligatòriament amb enginyers per poder dissenyar i construir els seus edificis. Aspecte que es repeteix en la majoria de països i on el seu currículum acadèmic no insisteix en l'adquisició de competències tècniques de càlcul.

L'interès rau en aquest cas a avaluar si en terminis de temps més curts i amb continguts teòrics més acotats, segueix sent vàlida aquesta estratègia BIM, que parteix de la base que el processos de disseny i construcció d'un edifici és un treball multidisciplinari i coordinat de molts professionals diferents i per això el BIM és l'eina adequada.

Per a ells hem estudiat el rendiment acadèmic, la motivació i la satisfacció dels estudiants a través de l'ús d'enquestes, comparativa d'exercicis, notes i entrevistes als estudiants; així com les experiències dels professors que imparteixen els cursos.

Les dades analitzades ens han servit per determinar problemes d'implantació, conductes a evitar i elements a tenir en compte a l'hora d'introduir BIM-Revit en els cursos de construcció. Aquesta tesi acaba amb l'avaluació de dos diferents metodologies per introduir BIM en els cursos de construcció i una sèrie de directrius per a la correcta implantació d'aquesta nova eina.

Pel que fa al futur d'aquesta investigació, es pretén expandir aquesta investigació a mes universitats, començant per la universitat americana de Ras Al Khaimah i tractant d'estendre-pels membres de la "*Academic for interoperatibility Coalition (AIC)*" a la qual pertanyo i hi ha afiliades 48 universitats de tot el món i combinar-la amb una altra investigació sobre BIM a acadèmia en la qual estic participant i en la qual el focus és sobretot els "*Students Learning Outcomes*" (SLO) s; per últim es va a començar un altre projecte d'investigació per al desenvolupament d'una guia per a la implantació de BIM en el currículum dels programes d'Arquitectura, enginyeria i construcció.

Keywords: BIM, construcció, currículo, Revit, Autodesk.

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List of Abbreviations

ABET	Accreditation Board for Engineering and Technology
ABET (A–K)	ABET Criterion 3, Student Outcomes (a-k)
ABS	Advanced Building Systems Course
AE	Architectural Engineering
AEC	Architecture, Engineering and Construction
AIC	Academic Interoperability Coalition
AIA	American Institute of Architects
AURAK	American University of Ras Al-Khaimah
BC	Building Components Course
BIM	Building Information Model/Modeling/Management
BIM^3	Building Information Model/Modeling/Management
BOK	BIM Body of Knowledge
BS	Building Systems Course
CIII	Construction III Course (AURAK)
IT	Information Technology
ICT	Information and Communication Technology
TAP	Technology and Architectural Practice
PBL	Project Based Learning
R&D	Research and Development (Spanish I+D)
UAE	United Arab Emirates
UAEU	United Arab Emirates University
US	United States of America
NAAB	National Architectural Accrediting Board

1. Introduction

The Architectural, Engineering and Construction (AEC) industry and contemporary governments show great interest in implementing Building Information Model/Modeling/Management (BIM) for the many benefits it can provide. Academia must be an active part of this implementation process, which should be carefully studied. The implementation of a new information technology (IT) tool has considerable potential benefits, but also a great risk of failure without proper planning and ongoing adjustments. BIM is not just a new IT technology, but a new working concept or methodology where all the various project stakeholders will have access to information in real time to cooperate, develop, produce, and manage a project through each different stage of its production.

Academia and industry have different timings, but for the proper introduction of a new working environment these new skills should be established during the basic, or foundational, courses at the university. This research examines the introduction of BIM skills at the intermediate course of construction of the AEC curriculum. We will use the Building Components Course (BCC) at the Architectural Engineering Department (AE) of the United Arab Emirates University (UAEU) as our data provider case study. In order to have a comprehensive picture of this implementation, we will study all the construction courses at the UAEU.

As we examine implementation at the AE department, we should understand that the architectural learning process is in continual evolution parallel to the different disciplines that create the architectural base of knowledge. This learning process has been adjusted to incorporate new knowledge since ancient times. In Egypt, Rome, and Greece the master taught his pupils while they were working for him; in medieval culture architects became artisans more than thinkers; and finally at Ecole des Beaux-Arts in Paris, the Bauhaus in Weimar, and the Architectural Association of London we can recognize the base of our current programs.

The AEC industry is directly correlated to Information and Communication Technology (ICT), changing its working environment as ICT evolves. First, AEC simplified construction drawing production. Architects used to spend most of their time at the construction site, because buildings were developed with minimum plans and so most decisions were made on site. With this first change the AEC team developed a complete set of working drawings which specified almost everything needed at construction, minimizing on-site decisions. After this advancement some architects, like Zaha Hadid, used 3D modeling to produce very complex buildings that formerly required the architect to be on site the entire time, like Antoni Gaudi. Today BIM is defining a new era of AEC processes, where all the different contributors are able to participate in every stage of the project, improving decision-making charts and timings, without necessarily requiring on-site presence. However this won't be successfully introduced without the proper skills and knowledge of all participants, and the only way to guarantee these skills is by introducing them in the AEC educational curriculum.

BIM became an academic reality during the 2006 BIM symposium at the University of Minnesota, where it was widely accepted that while BIM would change the AEC profession, many issues would be raised and answered when the Academy would actually begin to implement BIM in its curriculum. [2,3] In

2007 during the III BIM Workshop sponsored by the American Institute of Architects-Technology and Architectural Practice (AIA-TAP), the attendants discussed the obstacles to establishing a teaching methodology which would create the perfect connection between BIM tools and curricular content. The consensus was that a new level of abstraction will be needed to achieve this goal. [3,4] The rapid advance of some ICT tools and the obsolescence of others is a major disadvantage, but this will not impact BIM because while tools evolve and change quickly, and people will need to continually update their skills, the concept of BIM will remain with little change until the next paradigm shift.

Kymmell in 2007 [5] identified the possible obstacles to the introduction of BIM in the curriculum. These obstacles were categorized into three groups: difficulties in learning and using the software, misunderstanding the BIM process, and issues related to academic environment circumstances. The problems related to misunderstanding BIM concepts are the most important hurdle to overcome [5] because understanding the idea is more important than mastering the use of the tool. [6] The fundamental BIM concept to be taught and learned is collaboration, as stated by Kymmell in 2007 [5] and Barison in 2010. [3]

Nowadays BIM is a reality. Governments are legislating towards BIM in the AEC industry, with most projects delivered by BIM all over the world. Some examples of the different approaches:

- UK -- every public project must be delivered by BIM with a maturity level 2 in the Bew Richards [7] scale since March 2016.
- Dubai, UAE -- a developing country with a mandate to use BIM for major projects.
- Canada – not required, but they have a national BIM mandate that sets out the framework (technological, organizational and procedural) for the deployment of collaborative BIM-based project delivery environments for the AEC community.
- Australia -- it will be a requirement in the future.

When talking about introducing IT at the academic level, we begin with Kymmell's [5] statements that IT technologies can be implemented at three different stages in academia:

- Skills stage, which can be embedded during the first two years when students will learn how to use the program, model, and the introduction of data.
- Second stage, where the BIM concepts can be applied in design studios or building technology courses to provide both analysis and data collection, in order to improve design and production.
- Final stage, the collaborative one where BIM practices can be applied in management courses or in collaboration with real companies; this can be used to introduce students into the industry.

It is very important to understand that there is no agreement inside academia about when BIM should be included in the curriculum. BIM is being implemented all over the world by different institutions [8-13] at different stages, without a standard methodology or assessment process.

This thesis aims to provide the first steps towards a BIM introduction framework in the AEC curriculum through construction courses, including good and bad practices, in order to enable students to succeed in BIM introduction.

1.1. Author Motivation for Research

I have always loved ICTs. I had my first personal computer in 1987 when I was seven years old, which I used to program my own small video games. In 1999 I was introduced to architectural IT tools. I have been constantly updating my skills, learning how to use Autocad, 3d max, V'ray, Project, Primavera, Arquimides, Cype, 3D printers, Vr, Revit, Navisworks and any other software which could help me to improve the tasks where I was determined to succeed. These tools were not mainly to design, but to represent, facilitate and improve a project. Obsolescence is a reality -- most of these programs will soon be forgotten and new ones will provide us more and better possibilities. However the concepts behind ICT tools to help us develop, analyze and complete our projects will remain. This means that as the tools evolve, our skills should do so as well.

I have worked as a faculty member at the university level since 2007, teaching construction, design, computer tools and BIM. In 2013 I decided to look for new adventures and moved to the United Arab Emirates to continue my academic career. At the beginning of this research, I was working in the faculty of the architectural engineering (AE) department in the United Arab Emirates University (UAEU), presenting courses in design studios, construction and computer tools. In 2015 the AE department decided to incorporate BIM into the AE curriculum based on ABET recommendations, beginning by including BIM in the design and construction courses; the task of introducing BIM based on Revit was delegated to two instructors, Rahma Hagi and Jose Ferrandiz (myself). In order to introduce these new skills and new working environment, we were assigned to teach and help other faculty in different courses of design and construction, providing specific lectures and exercises about BIM and Revit to achieve the skills needed in each of the courses. I began this research in order to evaluate and improve the courses and the students' experience where we implemented BIM.

1.2. Research Problem

We are now in the middle of a technological paradigm shift in the AEC industry. As Farid stated in 2009, "*Twenty years ago, AutoCAD pushed designers into a new era; BIM represents a new generation of virtual model already widely accepted by the industry*."[14]

BIM is a worldwide reality that each country, company, and university is developing individually without a common framework, scope, or procedure. As can be observed in Barison's research,[3,15] every university studied introduced BIM at a different level and course, and with very different approaches. There is no cross communication or coordination on course or curriculum design to develop a comprehensive strategy, or to evaluate the pros and cons of a strategy. A quick view of the world will provide a picture of the current realities:

- Countries where BIM is required by law for some projects, such as Europe and the UAE.
- Countries where it will be required soon, such as Chile and Germany.
- Countries where it is not regulated but is in high demand and with several third-party standards, so that technicians do not really know which certificate they should get, such as the US and Canada.
- Countries where it is beginning to be introduced, such as India.
- Developing countries where it is not yet a reality.

BIM skills are required by the industry and the introduction of these new ICTs should be at the academic level. There are few studies on the introduction of Revit and BIM in the architectural curriculum, even though these tools are necessary in the AEC Industry.

1.3. Hypothesis and Objectives

This research aims to be the first stage towards the creation of an implementation framework for the incorporation of BIM into the intermediate construction course in the AEC curriculum. The results presented in this thesis are from the Building Components (BC) Course in the Architectural Engineering (AE) department at the United Arab Emirates University (UAEU).

Introducing changes into the curriculum, teaching methodology, learning environment and new ICTs is not a simple task. Introducing BIM requires all these changes at once and despite the potential benefits there will be a lot of problems, tensions and obstacles to overcome in order to succeed. We have three mains strands of work in this research:

- Understand the process of BIM introduction into the academic curriculum, and the obstacles to success;
- Evaluate the impact of BIM introduction on student development;
- Create alliances and new research collaborations connected to this research.

These main strands guide us to define clear research hypotheses:

Hypothesis 1 (H1): Understanding the main obstacles to the introduction of BIM will lead to concrete solutions.

Hypothesis 2 (H2): Introducing BIM in an Architectural Engineering course will improve student motivation, satisfaction and performance.

Hypothesis 3 (H3): Based on the conferences and papers submitted from this research, it will be possible to join a research group and collaborate on international research about BIM.

In order to evaluate our hypotheses, we developed several objectives related to each one individually:

Hypothesis 1 objectives:

A. Research the problems in introducing BIM into the curriculum;
B. Document and categorize the different problems found in this research;

C. Propose a new hypothesis of how to solve these problems which will be part of future studies.

Hypothesis 2 objectives:

D. Evaluate student motivation, satisfaction and performance with the different approaches tested in this study;
E. Identify good and bad practices for BIM introduction;
F. Identify the best way to introduce BIM at the construction courses of the AEC curriculum.

Hypothesis 3 objectives:

G. Publish indexed papers at international conferences and journals to pursue a future accreditation.
H. Join an international research group which conducts and supports the research;
I. Join an international research program related to this study.

As part of future works, we will use the conclusions of this study to begin a new research project about a framework guide to introduce BIM into AEC curriculum, which will be explained in chapter 11.3.

1.4. Scientific Relevance

1.4.1. Academic Improvement Contribution

ICTs are rapidly changing participation, interaction and collaboration in higher education. There is a great need of new ICT strategies and innovations in the teaching of construction.[16] It is important for academia to not only be connected to the industry, but lead this evolution [17] and not slowly follow industry developments. As stated in the research problem, this thesis aims to create a body of knowledge about the introduction of BIM in the AEC curriculum in construction courses by four means:

- Provide data to understand the process of introduction of BIM in the AEC curriculum;
- Provide evidence of the effects on the students of the different approaches to introducing BIM;
- Provide high-relevance publications which details the importance of the data provided;
- Provide a first sketch of the BIM introduction guidelines framework, based on this study.

1.4.2. Research Contribution

Interest in and recognition of the benefits of Building Information Model/Modeling/Management (BIM) are growing globally, as its potential as an innovative and evolving technology is being realized.[18-21] Published research in the BIM field has likewise seen a marked increase.[22] Notably, in a review of 445 published journal articles conducted by Olawumi *et al*, it was determined that 75% of the research papers on BIM had been published within the last four years.[23] However research to date, while covering a broad range of topics and issues within BIM, both technical and non-technical,[24] has focused more on topics such as construction and project management, building design and energy conformance, and BIM software and data schema. There have been comparatively fewer publications on education and incorporation of BIM learning and training within university curricula.

Olawumi *et al* began their study by examining prior efforts to evaluate research in the BIM field. What they discovered was that earlier studies focused on individual, specific areas of BIM -- for example environmental sustainability,[25] waste management,[26,27] and BIM-GIS integration.[28-30] More recently there have been projects focusing on determining and defining a set of research areas in the BIM field based on the number of citations of authors and articles. Santos *et al* conducted a study of published articles to determine which areas of BIM were most cited and specifically which authors had the most citations. Using this data he was able to identify trends in BIM research and further determine specific fields of interest.[22] Zhao completed a similar study by using a computer software to identify authors and topics with the most citations.[24]

Using bibliometric analysis Olawumi *et al* were able to complete a deeper and broader study – not just individual, specific areas of BIM, and not identifying popular trends in BIM through citations, but finding key research categories and sub-areas and thereby isolating those areas where further research is needed.

Bibliometric analysis is the "*mathematical and statistical analysis of patterns that appear in the publication and use of documents*"[31] and is a means of "*providing quantitative analysis of written publications*."[32] Olawumi *et al* analyzed 445 published articles. Of these, 70 were categorized as concerning BIM learning, adoption and practice – approximately 15%. This broader category was further divided in the study into 11 subcategories, only two of which – BIM curriculum development and BIM teaching and support – could be directly related to the adoption of BIM teaching and training into university courses. Analysis of the publications by project sector revealed that only 22 of the 445 articles – approximately 5% -- covered "*Education,*" which included: BIM curriculum development; BIM implementation; BIM in Quantity Surveying practice; BIM teaching; Developing Students' Collaborative Skills; and Course Development.[23]

Given BIM's importance as an innovative approach to design, construction and facilities management,[33] education and training in BIM within the university framework becomes increasingly critical.

> There [has] been a steady increase in the number of BIM articles published under the category "*BIM learning, adoption and practice*" between 2013 and 2016; however, prior to this period, less than four BIM articles in this research area were disseminated… [there is an] increasing spotlight on the development of BIM module and training for undergraduate university students and professionals who would be the fulcrum in the adoption and implementation of BIM.[23]

In addition, fluency in BIM skills acquired at the university level increases career opportunities for graduates, who are in greater demand from the architecture, engineering, and construction (AEC) sector.[34-36] Research has been done that correlates the BIM curriculum to the needs of the AEC industry,[37,38] and it is expected that research and analysis of the inclusion of BIM in university courses and curricula will continue to increase.

Instead of following a bibliometric approach, Abdirad and Dossick conducted a systematic review as outlined by Denyer and Tranfield.[39] They formulated a research topic – BIM in AEC curricula – then evaluated 375 published papers. After filtering out book reviews, editorial notes, and papers that did not address the set topics, they were left with 59 papers which were then analyzed to determine research trends in BIM curriculum design.

The increase in published articles in BIM research was confirmed, as two (2) publications were noted in 2007 and fourteen (14) in 2014.[40] This echoes the overall trend of research publication about BIM-related subjects generally – with few published studies in prior years but a dramatic jump in number since 2011.

There was a marked drop in the number of publications in 2009, which Abdirad and Dossick attributed to a fewer number of conferences. "*As conferences are major publication venues for papers on this topic, a possible explanation for the dip in 2009 is that the number of conferences (especially ASCE conferences) in 2009 was fewer than other years.*"[40] Their studies show a steady increase in publications since 2012 (doubling from 7 papers to 14, 2012 to 2014 respectively); a trend which will likely continue in the future. For example, we have participated in two conferences in 2016 alone, presenting "*Mixed Method Assessment for BIM Implementation in the AEC Curriculum*"[41] at the Human Computer Interaction conference in Toronto, Canada, and "*BIM Implementation at the Building Systems Course at the United Arab Emirates University,*"[11] at the BIM Academic Symposium in Orlando, Florida, USA.

What about the incorporation of BIM specifically into architecture programs and courses? The review by Abdirad, H. and Dossick, C. discovered that the majority of studies focused on the integration of BIM adoption into civil engineering and management courses over architecture, architectural engineering and building science courses, at 65% and 35% respectively.[40]

This shows that there is still a need for more research on the implications of educational strategies and their outcomes in BIM courses in architectural design and architectural engineering majors. Although research on design computing methods in architectural design has been growin`g, the number of studies on pedagogical issues of BIM-based collaboration and object-based platforms in architectural education is relatively small.[40]

There is a decided need for further research and publication regarding the adoption and implementation of BIM training and practice within the educational framework in general, and in university curricula that target architectural programs and students in particular. To this end we have published "*Evaluating the Benefits of Introducing* "BIM" *Based on Revit in Construction Courses, without Changing the Course Schedule,*"[42] which addresses the issues surrounding the introduction of BIM without re-designing the course as a whole.

2. Background

2.1. BIM – Definition, Importance, and Reason for Studying Its Introduction into Academia

BIM has many definitions because it is not something easily described. BIM is not a fixed terminology -- many different professionals use it and understand it from their own point of view, and their descriptions evolve alongside the technology. Many professionals regard BIM only as a tool to develop a digital model,[43] however this is just one part. It must be emphasized in every discussion of BIM that it is not only a three dimensional digital model, but an information database for the entire life cycle of a project from design to demolition.

Miettinen and Paavola[44] found four common elements in BIM definitions: first the database, which must be included in the model or accessible from it; second the interoperability of the information between the different tools used; third the primary concept of BIM as a whole life information model that begins in the design phase and is used until a project's demolition; and fourth the advantages of BIM, that it should improve the efficiency and productivity of the construction industry.

After utilization and research the following definition is reached: BIM is mainly a concept, the idea of creating a unique model which houses all the necessary information to fulfil a project; which means that all the stakeholders of one project will upload to and take information from the same model. This idea has been described in many ways depending on the stakeholder defining it, according to his use and needs. There are also definitions from ICT companies, researchers, committees, and many other people.

Autodesk, one of the biggest ICT companies for the AEC industry, defines BIM as "*an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure.*"[45]

We can also define BIM as a centralized database, where each stakeholder can download, use and upload information into the same model by using different tools. Bill Gates stated in 1999, "*The most meaningful way to differentiate your company from your competition, it's to do an outstanding job with information. How you gather, manage, and use information will determine whether you win or lose*." From Bill Gates' words we can understand how important BIM could be to the AEC industry.

Beyond these definitions, the most complete, scientific definition of BIM and the one we use for this research is from the National BIM Standard – United States® Version 3 (NBSUS-v3), which states that BIM (Building Information Modeling, Model or Management [3 (cubed)]) is a term which represents three separate but linked functions:

- Building Information Modeling: a BUSINESS PROCESS for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.

- Building Information Model: the DIGITAL REPRESENTATION of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards.
- Building Information Management: the ORGANIZATION & CONTROL of the business process by utilizing the information in the digital prototype to effect the sharing of information over the entire lifecycle of an asset. The benefits include centralized and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as-built documentation, etc. effectively developing an asset lifecycle process and model from conception to final retirement.

2.1.1. BIM in the World

BIM has sparked a paradigm shift in the AEC industry, and a large segment of the industry and international governments have already recognized the benefits of gathering the entire data of a given project in just one single file. To make this a reality, different approaches at different levels all over the world have been initiated. After all the research has been done, it is clear that BIM is the future of the AEC industry and already has a strong presence in some countries.

Every time an innovation occurs, there are a lot of difficulties to introduce it properly due to the lack of data, references and precedent cases to use as a framework for this introduction.[46] Governments are promoting BIM by requiring its use in projects developed with public funds.[47] The private sector improves BIM processes, but without government mandates the level of implementation will neither be equal [48] nor efficient.[47] By the use of mandates governments are trying to propel the AEC industry into the BIM era.[49]

Figure 2.01 BIM adoption around the globe[50]

The adoption of BIM for use in the AEC industry is growing globally. Governments are increasingly recognizing the cost and workflow benefits that the BIM methodology can provide.[51] The precursors of BIM – early solid modeling programs – were first seen in the 1970s; further developments resulted in ArchiCAD in 1982 and Revit in 2000,[52] and since then the adoption of BIM has increased dramatically, particularly in recent years.[53]

Change is sweeping the globe. Project teams are benefitting from faster communications, smaller more power and mobile computers, robust digital modeling tools and a transformative shift toward integrated delivery processes, all of which are generating positive outcomes, efficiencies and benefits unimaginable just a few years ago.[54]

North America

North America has been at the forefront of BIM implementation globally. In the United States the US General Services Administration (GSA) established the 'National 3D-4D-BIM Program' that requires the use of BIM for all federal public building projects. They have also worked towards fostering the development of a BIM community, including open standard organizations and professional associations – including the internationally recognized National BIM Standard[55] -- so that now the majority of construction firms in the US are using BIM. Various individual states have begun issuing their own mandates, and BIM is increasing among private organizations as well.[56]

South America

Brazil is witnessing a growing trend of BIM adoption,[57] and has worked with the UK to develop a national BIM implementation plan. The expansion of the Panama Canal project, adding a new set of locks at either end,[58] has utilized BIM from the beginning to coordinate design work on one 3D model between five offices worldwide.[59]

Europe

In Europe, the EU has formally recommended the use of digital methodologies such as BIM, issuing the 'European Union Public Procurement Directive' in 2014 that permitted member states to mandate or otherwise encourage the use of BIM in government projects.[60] The UK government mandated the use of BIM on its projects as part of the 'Government's Construction Strategy,' which included BIM in its efforts to reduce procurement costs by 20%. Adoption of BIM outside of government projects has likewise increased and the majority of those firms are now using BIM. The UK has also initiated efforts to establish national standards through the British Standards Institute,[56] part of an effort to present the UK as a global BIM Leader.[61]

In 2015 the Ministry of Development in Spain created a commission, 'es.BIM', to oversee the implementation of BIM methodology, with a target of mandated use in public buildings in 2018. Andrés *et al* conducted a survey to assess to what extent BIM has been adopted in Spain. Out of nearly 550 participants, a little more than half stated they used BIM in their projects, with architects more likely to be utilizing BIM than other professionals such as building and civil engineers. It is being used mainly at this stage for design and modelling, with fewer using BIM in the construction stage or after.[62]

Spain is part of the European Union (EU) and all projects underwritten with EU public funds are already mandated to establish and maintain a BIM working environment. Beyond the national level as per this policy, several regional governments in Spain have decided to implement the same type of mandate and require BIM methodology for their publicly funded projects. Catalonia has been at the forefront of regional BIM adoption in Spain. As Cerdán stated in a 2017 interview, "*Probably the biggest influence [on the Spanish Government to adopt BIM] has been the Regional Catalonian Government, which one year ago started to require BIM on many projects.*"[63] The application for BIM usage in smaller projects is increasing, although not always as part of the main specifications but as part of the improvements.[63]

Areas of France have adopted BIM regionally, but a national program has not yet been implemented. The French government has set forth a 'Digital Transition Plan' for the construction and building industry with the goal of reducing costs and focusing on sustainability.[56] The government of Germany formed a task group, the 'Digital Building Platform,' to investigate and devise a national strategy to adopt BIM but this has not yet been achieved. Developments have centered more in the commercial and residential sectors, where the majority of project owners require BIM.[56]

Scandinavian countries were among the earliest to adopt BIM, with Finland investing significantly in research and development in IT tools in the AEC industry since the 1970s.[64] Other countries in the area are conducting research and development projects, and some government agencies – like the Swedish Transport Administration and Danish government clients – have mandated its use.[56,65]

Asia

In Asia BIM adoption in China is slower than in other areas, as of 2012 less than a quarter of the companies surveyed were using BIM in their projects. Conventional wisdom is that the government is encouraging the use of BIM but is not mandating it or providing the leadership necessary to instigate more widespread adoption. There are also legal hurdles that would make using a fully-collaborative method difficult – for example by law the design and construction stages of a project must be separate.[57] An exception is Hong Kong, where the Housing Authority has devised plans for adopting BIM and the 'Institute of Building information Modelling' was established.[56] BIM has been successfully used in several high-profile projects, such as the Shanghai Disney Resort.[51]

Singapore has made strides towards establishing a BIM electronic submission platform. The Building and Construction Authority created a 'Construction and Real Estate Network' to serve as a repository for codes and regulations to achieve standards, and has created a BIM fund to offer grants to facilitate the adoption of BIM.[56] BIM is mandatory for all larger government projects in South Korea, and the government has funded a project to set BIM-based building design standards.[56] BIM adoption in India is still in beginning stages, with larger construction companies using it on bigger projects, but there is still a need for further education, training and development to expand the implementation of BIM. (Smith)

The Dubai government in the UAE issued a mandate in 2013 requiring BIM be used in a limited number of construction projects, and it expanded that mandate in 2015 to include all government buildings, in addition to projects that are over a certain number of storeys or a given square footage.

BIM is being encouraged "*because of how much it lowers the cost of construction projects and the time* taken *to finish them; and increases the level of coordination between the engineers working on designing and implementing the project, and their counterparts in the management and funding and manufacturing the project*."[66]

While the majority of AEC professionals in the UAE use BIM to greater or lesser extents, there are no government-established standards to regulate its implementation across the industry. In particular, with no contractual or regulatory language, the legalities of who has access to or owns what information are cloudy.[67]

Mehran conducted a study in 2016 of AEC firms in Dubai and the status BIM technology. Through an online survey of 60 AEC professionals, it was found that the majority (87%) have used BIM in their projects, mainly in 3D visualization and 2D drawing extraction. Although Dubai is currently the only emirate requiring use of BIM, most professionals felt that BIM implementation will spread across the country.[68]

Africa

BIM is being used to a limited degree in South Africa, mainly by architects in the design phase of projects and therefore not utilizing the method to its fullest collaborative effect. In a study conducted by Froise and Shakantu, more than half of architects surveyed had used some form of BIM, as compared to contractors only 12% of whom had used some form of BIM.[69] In Kenya BIM adoption is more likely to be encouraged by private developers and companies over the government, particularly when working on projects with international companies from areas where BIM is becoming the status quo.[70]

Australia

By 2014 a little more than half of AEC design professionals in Australia were using BIM and this was projected to increase by a quarter within two years. Interest in implementing BIM has grown since buildingSMART published the National BIM Initiative report, as it gave concrete and detailed plans for the implementation and management of BIM across the industry, including in the education sector. They established the "*Open BIM Alliance of Australia*", which was a collaboration between software vendors to encourage the idea of an "*open BIM*".[51]

The spread of BIM globally is increasing, more quickly in some areas than others. Research by Smith[57] suggests that successful BIM adoption is contingent upon government leadership in order to guarantee long-term success and avoid the many conflicts and problems that could occur if BIM is introduced in a piecemeal or disjointed fashion. Government mandates, such as those in the US and UK, have been shown to be the most successful in instigating an industry shift towards BIM adoption. Support from leading industry businesses and professional associations is also critical. If the use of BIM is required by the project owner, this drives architectural and construction professionals to align their companies with BIM protocols. This is furthered by the continued globalization of the AEC industry, with international companies competing with local companies for projects.[57] Therefore the global spread of the BIM methodology is expected to continue to increase exponentially.

2.1.2. BIM importance

AEC companies use and manage a lot of information from many stakeholders, thus the proper management of the information during the design and live cycle of a project plays a critical role in the success of the business.[71] The information and number of documents needed for each AEC industry project grows parallel to the size of the project [72] at each of the phase. Information management is a key weak point of the AEC industry due to three different factors:

- The interdependency of the different stakeholders and technicians of the project. Each one of them produces 2D information, which usually is handled manually by the design and site teams.[73] What it translates into is poor communication and information sharing between stakeholders.[74]
- Lack of communication between the different disciplines in the design and construction process.[75]
- Low level of ICT knowledge in the AEC industry, where everyone uses an ICT tool even if they do not have a sufficient level of knowledge.[76]

As Dr. Giner stated in her study [75], the communication and information problems create real difficulties mainly at the construction phase and increase the cost and the timeline of the project, due to uncertainty of the information, lack of coherence between documents, and changes in the project during the construction phase.

All this together with the large number of technicians and companies involved in each project has pushed the industry to develop an information management system, [77] in order to change the way that information is transformed from 2D plans and PDFs into a 3D model which contains all the information. This model is used as a common database where all the participants in the project can download and upload their data (BIM).[75]

This realignment into a new working environment based on BIM compels the industry to look for graduates with BIM understanding and skills as stated by Ku, Taiebat [78] and Mcuen [79]. There is a discrepancy between the skills sought by the industry and job seekers, as the European commission indicated.[80]

The AEC industry believes that BIM is very important for clash detection, quantity surveying, 4D simulation, and many other factors. For these reasons the AEC industry is looking to hire graduates and professionals with BIM skills and experience, but most of the Architectural and Civil Engineering curricula are developing other skills.[81,82]

This study and others in this area are of vital importance for a proper understanding of the problem of introducing BIM into the curriculum, to bridge this gap between student skills and industry expectations.

2.1.3. BIM tools, and Reason for Using Revit in This Study

BIM as a concept has existed for many years, but as a concrete method with actual tools it is a newer development in the AEC field. Consequently the tools are developing at a rapid pace, with new ideas and updates coming out each year.

In 1986 at the 5th CIB International Symposium, Aish discussed the importance of developing an integrated computer-aided design (CAD) program. He recognized that current methods had professionals creating orthographic drawings and 3D views independently, which could negatively impact "*coordination and consistency*" of the design data.[83]

An alternative approach is to develop an integrated CAD system which is capable of handling multiple representations. Here all representations are related to a single 3D model of the building, and, therefore, encourage consistency and coordination of design information across the whole multi-disciplinary team.[83]

At the time Aish was with GMW Computers, Ltd., who produced RUCAPS, regarded as a forerunner of BIM software.[33] This and other early programs served as springboards for further developments. In 2005 the first industry-academic conference on BIM was held at the Georgia Institute of Technology, which included an array of design-software and analysis vendors.[84] There were several different available platforms, each with its own capabilities and weaknesses, and the prevailing thought was that companies could use multiple platforms, switching between them as suited the individual project. There was also the recognition that these programs were in a state of constant development, so that "*a purchaser is buying into both the current product and its future evolutions, as projected by the company*."[33] At that time the main programs were [33]:

Revit 9.1, from Autodesk	introduced in 2002	user-friendly interface, but slower on larger projects and some design limitations
Bentley Architecture 8.9.2.42	introduced in 2004	comprehensive and detailed design capabilities, interface difficult to learn and navigate, weak integration between applications.
ArchiCAD 11.0 from Graphisoft	marketed early 1980's	oldest continuously marketed tool, simple and intuitive interface, broader applications in construction and facility management, and some modeling limitations.
Digital Project from Gehry	developed in 2005	powerful and complete modeling capabilities, steep learning curve, high cost, and complex interface
ADT from Autodesk	AutoCAD based	built on 2D platform therefore easy to adapt to, inherent limitations in several areas like interfaces and project management.
Tekla Structures	expanded in 2004	variety of possible structural materials and detailing, can accommodate large projects, complex to learn and use to fullest potential.

DProfiler from Beck Technologies	able to generate quick economic evaluations of a project; limited to economics, limited in ability to interface with other tools needed to complete design and production.

In the space of only five years, by 2010 the list of vendors and programs had grown exponentially. Some programs developed out of earlier attempts, while others were total newcomers.[85]

Architecture	**Structures**	**Construction** (Simulation, Estimating and Const. Analysis)
• Autodesk Revit Architecture	• Autodesk Revit Structure	• Autodesk Navisworks
• Graphisoft ArchiCAD	• Bentley Structural Modeler	• Solibri Model Checker
• Nemetschek Allplan Architecture	• Bentley RAM, STAAD and ProSteel	• Vico Office Suite
• Gehry Technologies - Digital Project Designer	• Tekla Structures	• Vela Field BIM
• Nemetschek Vectorworks Architect	• CypeCAD	• Bentley ConstrucSim
• Bentley Architecture	• Graytec Advance Design	• Tekla BIMSight
• 4MSA IDEA Architectural Design (IntelliCAD)	• StructureSoft Metal Wood Framer	• Glue (by Horizontal Systems)
• CADSoft Envisioneer	• Nemetschek Scia	• Synchro Professional
• Softtech Spirit	• 4MSA Strad and Steel	• Innovaya
• RhinoBIM (BETA)	• Autodesk Robot Structural Analysis	

Table 2.01 BIM tools list 2014[85]

As the industry has progressed further and BIM reached greater developments, even more vendors have appeared on the scene, with some acquiring older companies and others bringing their own products to the field. In 2017 these reached a much broader scope.

MANIFACTURES	3D Modeling	4D Scheduling	5D Costi	6D Sustainability	7D Maintenance & Operation	Architecture	Structure	MEP	Viewer	Rendering	Management
AUTODESK AUTODESK AUTODESK AUTODESK	Revit Infrawork 360 AutoCAD Civil 3D AutoCAD Architecture	Naviswork Manage	Naviswork Manage	Vasari Green Building Studio Ecotect Analysis	Builng OPS	Revit	Revit Robot Structural Analysis Advanced Concrete Advanced Steel	Revit	A360	3D Studio	BIM 360 DOC BIM 360 Field
BENTLEY SYSTEMS BENTLEY SYSTEMS BENTLEY SYSTEMS BENTLEY SYSTEMS BENTLEY SYSTEMS	AECOsim Building Designer MicroStation OpenRoads ProStructures Generative Components	Navigator	ConstructSim	Hevacomp AECOsim Energy Simulator	AssetWise Bentley Facilities		RAM STAAD ProSteel	Hevacomp Hevacomp	Bentley View Navigator	Luxology	ProjectWise
NEMETSCHEK NEMETSCHEK NEMETSCHEK	Allplan Graphisoft ArchiCAD Vectorworks		Nevaris	EcoDesigner STAR	Crem Solution ArchiFM		Scia PreCast Frilo Software	Data Design System MEP Modeler	Solibri Model Cheker Solibri Model Viewer BIMx	Maxon	
TRIMBLE TRIMBLE	SketchUp Pro	Vico Office	Vico Office	Sefaira	Tekla BIM Sight		Tekla Structures	DuctDesigner 3D PipeDesigner 3D	Tekla BIM Sight SketUp Viewer		Project Management Trimble Connect
DASSAULT SYSTÈMES DASSAULT SYSTÈMES	Solidworks Catia						Solidworks				Enovia
Midas Information Technology	Midas Design						Midas Gen				
CSI CSI CSI							SAFE SAP2000 ETABS				
ARKTEC		Gest Mideplan	Gest Mideplan				Tricalc				
DIAL								DIALux			
DesignBuilder				Design Builder							
IES				VE Pro							
RIB SOFTWARE RIB SOFTWARE		iTWO	iTWO Presto Cost-it								iTWO
Beck Technology			DESTIN IEstimator								
Micad Global Group		Gestproject			GestProject						
MICROSOFT		MS Project	Excel								Excel
ORACLE		Primavera P6									
SYNCRHO Ltd.		Synchro Professional									
LEMSYS LEMSYS LEMSYS					NEXT-FM				Building in Cloud		Building in Cloud Building in Cloud

Figure 2.02 BIM tools list 2017 – part1[86]

ACCA Software ACCA Software	Edificius	PriMus-K	PriMus PriMus IFC							Edificius RTBIM	
VISUALARQ	VisualARQ										
BIM Vision									BIM Vision		
RDF									IFC Viewer		
REVIZTO									Revizto Viewer	Revizto	
OpenStudio				OpenStudio							
Zimfly											BIManywhere
Archibus					Archibus						
CADSoft	CADSoft Envisioneer										
STI	Softtech Spirit										
STRUCTSOFT							Metal Wood Framer				
EcoDomus					EcDomus						
ONUMA					Onuma						
FMSystems					FMSystems Interact						
ARC-TECHNO	ARC+ x9										
Handle Software Company					BIM Consultant				BIM Consultant		BIM Consultant

Figure 2.03 BIM tools list 2017 – part2[86]

Where is the next generation of BIM tools headed? Historically designers would choose a single BIM program and then use it to their best ability but perhaps sacrificing the flexibility and artistry available in other non-BIM-specific programs. Rather than further developing established BIM tools to incorporate more and more complexity in each area of a project's design and construction, focus could shift to improving "*computational BIM workflows*" by developing third-party plug-ins that would allow different conceptual modeling tools to be integrated into a BIM system project – not simply pasted in, but integrated to the point of being fully compatible.[87] So individual tools can continue to grow and develop individually, but still maintain connectedness with the overall project through plug-ins.

Another avenue for further exploration and development is BIM information exchange via a "*cloud-based BIM*" with programs such as BIMcloud from Graphisoft, BIM 360 from Autodesk, and Onuma system. This would allow a greater "*possibility of many disciplines within the Architect, Engineering and Construction industry's environment collaborating on the same platform by sharing and exchanging data*,"[88] and would facilitate international projects with geographically diverse AED professionals.

Every year sees further development and improvement of current BIM tools, and concurrently the innovation of new possibilities to increase the effectiveness of these tools in the AEC industry. These developments create an alive market in constant evolution, where the architects and engineers should be continuously updating their skills. The challenge is to fit a constantly developing market into an industry, in which each product takes years to be finalized, and into the AEC academia, which also has a very slow pace in dealing with changes.

2.1.4. ITC Evolution in the AEC Industry -- from Paper to BIM

Using and assessing ICTs (Information Communication Technologies) as part of the educational methodology is a common practice in many undergraduate and master's program curricula, including architectural engineering which is the focus of our study and many others.[89-92] The architectural teaching methodology must be approached as a combination of tradition and technology, where one cannot be understood without the other. There is a lot of controversy over whether the project design should be started only by traditional methods or it can also be done using IT tools -- the application of IT technologies in the AEC process and industry is already accepted as a must, the debate is over where in the process. The introduction of these technologies in academia is also the subject of heated debate with two clear sides: those who consider IT as a tool to enhance the AEC industry and those who consider it an integral part of the AEC process itself.

ITC development in the Architectural, Engineering and Construction (AEC) industry evolved during the 20th century completely changing how project information is represented, created and delivered. The process of the AEC industry is constantly under development from the paper-based working environment, through the CAAD, until the current BIM interdisciplinary and collaborative team working environment.

As Oxman stated in 2006,[93] the main difference between paper-based design and a digital-based one is the cognitive process during the evaluation of the designs. While the original paper design process was clearly defined and took place mainly in the designer's mind, digital design offers alternatives to development and collaboration with the other stakeholders.

The evolution and change in representation tools has affected the nature of the very information these tools represent. During the period of paper-based design, and the initial stages of digital-based representation, the information embedded was geometrical. As Ibrahim [94] stated earlier generations of CAAD software like AutoCAD only represented the geometrical properties of the architectural elements. The introduction of building integration management/modeling added the value of integrating the information and graphics within the building model. New models add specifications and properties for the design evaluation, collaboration, analysis and production processes; embedded information can describe materials specifications, code requirements, and any other data associated with the building model.[95]

In their journal [96] Yi-Feng and Shen-Guan achieved a deep study of the evolution of ITC as it relates to the AEC industry; they determined five main phases:

- Mainframe age, 1960 to 1970. First research design experiments, with very primitive computers on a text interface, used mainly to record and calculate.
- Workstations age, 1970-1980. First drafting applications, still with very primitive computers and a text interface, used as drafting tools and auxiliary tools to manufacture products.
- Personal Computers age, 1980-1990. The first personal computers and AutoCAD, which provided a quick and accurate 2D drafting tool, and the beginning of 3D modeling.
- Internet age, 1990-2000. Improvement of personal computers and the creation and improvement of tools to create, draft, model, calculate and manage projects like 3Dmax, sketch up, Cype, Microsoft office or Primavera; it marked the beginning of a collaborative environment in the design, production and management processes; information began to be shared but it was spread among different tools, formats and files; each stakeholder used their own tools and models, which were usually not compatible.
- Cloud computing age, 2000-2010. Beginning of Building Information Modeling, where all the stakeholders were able to share information on the same model to design, develop, produce and manage the whole life cycle of the project.

As we can see from this timeline, the AEC industry is developing tools and processes for completing their projects based on ITC technologies. It is critical for the next generation of technicians to be introduced to new trends as soon as possible, as this evolution is quite rapid and they should be able to keep on track in order to achieve career success in the AEC industry.

2.2. Research Location, Environment, Culture and Situation

The United Arab Emirates (UAE) was founded on 2 December 1971 by his highness Sheikh Zayed bin Sultan Al Nahyan, whose family has been ruling this area since the 18th century. The UAE developed remarkably fast during its first 46 years of existence in many fields including economic, commercial, tourism, research, and also in architecture. Dubai has grown quickly to the point that it is known all over the world as an iconic city similar to New York, Paris and Barcelona. To understand this research it is important to go through the milestones of the UAE’s history, and broaden understanding of its development, present situation, and their ambitious future.

The UAE is a federation of seven emirates located on the southeastern side of the Arabian Peninsula, including Abu Dhabi, Dubai, Sharjah, Ajman, Umm al-Quwain, Ras al-Khaimah and Fujairah. While Dubai is perhaps more widely known as the larger and more international city, Abu Dhabi is the country's capital. The unification of the country in 1972 paved the way for rapid development in all sectors, and the country welcomed expatriates to assist in their efforts. As of 2016 population estimates indicate that nearly 85% of the population of the UAE are expatriates;[97] so while the official language of the country is Arabic, English is the language of business and increasingly education.[98]

2.2.1. **Location**

The location of the UAE along the Persian Gulf, a sea off the Indian Ocean, gave it historically an important role in trade. The area was controlled by individual sheikhs and tribes, although the Portuguese and then the British exerted their influence and power over the region until the emirates unified and formed their own nation. The discovery of oil in 1958 sparked an economic boom, and now oil and natural gas comprise 40% of the country's gross domestic product.[99]

2.2.2. **Climate**

The UAE is mostly arid desert, with rocky mountainous areas, oases, and coastal plains. The Hajar Mountains run along the eastern border and were formed as the Arabian and Iranian tectonic plates collided. Seismic activity in the UAE is minimal, however there have been occasional earthquakes such as in 2002 when a 5.1 magnitude quake struck the Masafi region in eastern UAE. Tremors are more common, originating in Iran which lies on a major fault line.[100]

The desert climate means that weather in the UAE is generally hot and humid in the summer, with cooler weather and occasional intense rain in the winter months. Rain level is slightly elevated in the mountainous areas in the north, and the temperature also drops somewhat. The southern part of the UAE is located in the Rub al-Khali desert and is largely uninhabited except for in oases. It is hotter and drier than in coastal locations.[101]

2.2.3. **Architecture in the UAE**

Just as the economy and society witnessed a dramatic shift after the discovery of oil and the formation of the UAE, the local architecture has also seen substantial development. Traditional architecture was dependent on the resources available – palm trees near the sea and in oases, and clay and stone in interior, desert areas. The social culture required privacy, which resulted in structures with walls separating areas for men and guests from those for women and family. A distinctive feature was the wind tower, al-barajeel, which effectively corralled cooling winds down into the home. The nomadic Bedouins used tents, which were a practical solution suiting their needs.

As the country changed over time the architecture also changed. There is a range of opinion as to how architecture in the current day relates to traditional forms -– from the thought that traditional architecture is the only authentic local architecture, so any contemporary projects are simply imitations of Western forms; to the thought that local, contemporary architecture can incorporate traditional elements into a Western framework; to the thought that contemporary local architecture is the natural development over time as traditional forms are used as inspiration for modern construction that includes and reflects different historical influences.

The increase in wealth in the UAE in the 1970's mirrored an increase in housing requirements that would meet the needs of a rapidly changing population. Western architects were brought in to help in planning and construction and they brought western ideas into the building and design processes. Even Arab professionals were influenced by western writings and experience.

People who were perhaps raised in simpler houses made of palm fronds (al-areesh) are now living in marble villas. Contemporary neighborhoods are similar to western models, with landscaped streets and modern construction materials. New designs are viewed as showcasing wealth and modernity while older architecture is associated with poverty and the past. At the same time people cherish their traditional culture – many still prefer to spend weekends in the desert enjoying traditional activities, and their homes retain certain societal norms such as private areas for women and families, separate entrances for guests, and large privacy walls around the property.

The country has also witnessed a complete transformation and expansion of its infrastructure. Several of the older surviving structures have been transformed into heritage sites or museums, and the urban landscape has changed to include high-rise apartment buildings designed for expatriates and modern malls and shopping centers. Expansion and development has increased to the level of the construction of innovative projects such as the Burj Khalifa and the Dubai Metro which began with the first icon in 1978 by British architect John Harris built the 39-storey Dubai World Trade Center.

As time has passed and architecture in the UAE continues to develop, people strive for better quality and more innovative design but there is a continual look to the past. There is increasing concern towards maintaining a cultural identity in all societal areas, including architecture, where there are calls for reviving and incorporating traditional designs in a modern context.

2.2.4. **The background of the UAE**

The UAE is a federation with a total area of 83,600 sq.km located in the Middle East region of Asia on the east coast of the Arabian Peninsula bordered by Arabian Gulf to the north, Saudi Arabia to the south and west, and Oman and the Gulf of Oman to the east over seven emirates, Abu Dhabi (the capital), Dubai, Sharjah, Ajman, Umm Al Quwain, Fujairah and Ras Al-Khaimah; it has three types of geographical areas – coastal, desert and mountainous -- which makes its climate tropical and dry in the summer, with a short winter season that runs from December to February. Rainfall in Fujairah and Ras Al-Khaimah is frequent due to their location and proximity to the mountain ranges, with low temperatures especially in the interior areas.

The geographical location of the UAE has made it an important trade center between the eastern and western world throughout history, since its origin as sheikhdoms (emirates) that were located over the north-western coast of the Gulf of Oman and the southern coast of the Arabian Gulf; each sheikhdom was managed by a different sheikh according the tribal system, until the Portuguese arrived in the region and used the lands to fight against Persia. Pirates attacked the maritime areas until 1835 when the sheikhs decided not to participate in any dispute at sea; after 20 years the sheikhs and the UK agreed to a truce, the Treaty of Perpetual Maritime Peace, which led to a formal relationship between Britain and the Trucial States that lasted until1968 when the UK decided to end the treaty. After three years the sheikhdoms became independent and entered into the current unification of seven Emirates named the UAE, which has rapidly developed after its union.

2.2.5. University Models

To properly understand the current situation of the UAEU, we need to understand the purpose of this university beginning with determining which traditional model it follows. There are three traditional University models defined by Brycal and Apaza [102,103], and a fourth mixed model called the Latin American model. Each of these models have different aims, types of funding and relations with the government.

- The German model. Universities are public institutions, the faculty are public employees, and the goal is scientific knowledge. Their main aim is to train people with a broad knowledge background which has no relation to the society and industry demands. Two main concepts are linked and are embedded in this model: the university as an image and reflection of science, and science as the unique purpose for the university. [102] The idea which supported this model was that a society of scientifically trained people will be able to improve the social, cultural and economic aspects, it existed so for more than a century.[102]
- The French model. Developed in order to fulfil the professional needs of the nation, universities were developed as part of public institutions and their autonomy was almost non-existent. The objectives and curriculum were designed for the needs of the nation. The prestige, connections and power of the full professors gave them authority to influence significantly the curriculum and the academic policies. Academic institutions existed to serve the state instead of the society.[102,103] This model is one of the oldest examples of society modernization via academia as an institutional tool, where the state controls the funding, faculty designation and legislation which ensures equitable distribution of resources throughout the nation.
- The English model. In this model the universities keep themselves as private institutions, as they were in the whole of Europe before the 19th century. Nowadays even the "*public*" universities of United Kingdom are legally considered private institutions, and their power relies on the institution itself. There is very little influence by the government, mainly in the areas of funding and general higher education policies. Each institution is autonomous, able to decide and manage their own curriculum and budget as a private company.[102,103]

- The Latin American model. During the 20th century, after the Cordoba 1918 reform of the university law, a new specific model was created based on public monopoly of autonomous universities which cooperate with the public administration. The idea is based on the French model where the universities try to feed the society and industry needs, economically supported by the state, but providing universities autonomy to rule themselves. [102]

In the UAE there are two types of universities, private and public. Private universities are based on the English model, while the public ones (like UAEU) are clearly a French-based model where the main aim is to develop the skills of the national people (citizens) towards the necessities of their society.

2.2.6. Higher Education in the UAE

Higher education in the UAE has developed as rapidly as the country itself. The seven emirates comprising the United Arab Emirates unified in 1971, and in 1976 the new government set into motion the formation of the UAE's first university, the United Arab Emirates University (UAEU), to "*meet the educational and cultural needs of the UAE society by providing programs and service of the highest quality*."[104]

The advancements and challenges facing the education sector closely mirror those of other sectors within UAE society, with a shared goal. It is linked to the desire of the UAE to position itself within global and regional arenas as a competitive player, and to meet internal development goals for modernization – with western capitalist features – in a form compatible with preserving traditional Islamic society.[105]

Originally the intention was to establish educational institutions that followed the model of traditional, older Arab ones such as in Egypt. Higher education was seen as a necessary part of forming an independent and individual country that also incorporated regional and cultural mores.[106] Earlier programs followed the traditional method of learning, with the focus on teaching rather than learning, and instruction within higher education institutions that looked little different than instruction in secondary schools. With the introduction of problem-based learning globally, it was recognized that there needed to be a shift towards student-centered learning, where the instructor is more of a facilitator.[107]

Schools in the UAE relied on instructors from abroad, who brought with them their own influences and constituted a force for change. Additionally children of the ruling families were sent abroad to complete university studies, and therefore contributed to foreign influences when they returned. They also served as a further impetus driving development and modernization of colleges and universities.[108]

Higher education institutions in the UAE are either public/government institutions (e.g. UAEU, Zayed University, the Higher Colleges of Technology) or private institutions (e.g. the American University of Sharjah, Al-Hosn University in Abu Dhabi, the Ajman University of Science and Technology). Public universities follow the societal mandate of having separate campuses for male and female students, and many of the private institutions are clustered in dedicated "*academic zones*," such as Academic City and Knowledge Village in Dubai, and University City in Sharjah. Public universities are free and available to

UAE nationals only, while private universities are not free and are open to all UAE residents including nationals and foreign students.

Government colleges and universities are overseen by the Ministry of Higher Education and follow a national curriculum that is set and developed in the UAE. They cater more to the personal development of UAE nationals taking into consideration the culture and needs of the society.[109] Non-governmental universities are either semi-government institutions that are funded by an emirate, or are private, foreign institutions that are scaled-down branches of their home campuses. They are licensed and/or accredited by the Commission for Academic Accreditation (CAA).[110]

There have been dramatic increases in the number of students at higher education institutions. For example there was a huge jump in enrollment at UAEU from the 1997-98 to the 2006-07 school year, from 502 to 14,741 students respectively.[111] This is also happening in colleges and universities across the UAE, as the society is witnessing what Baker and Wiseman termed a "*massification' linked to democratization of education systems catering to a wider spectrum of society*."[112] In meeting the needs of a larger student body, the UAE is also grappling with how to develop this growing sector – stay with the traditional, Arab format; adopt Western-style educational models; or create an amalgam of the two, importing Western elements into a more traditional Islamic framework.

Some of the specific issues faced by the UAE as they further expand and develop their higher education sector include: to meet rapid demand, should quantity take precedence over quality; are the needs of the local populace more important than national goals; how to guarantee equality and fairness between both genders and all sectors of society in education; should time and focus be spent on developing a local system above importing foreign education programs; how to lessen dependence on foreign instructors and personnel; and how to balance maintaining a traditional, cultural identity with modernization.[113]

Architecture holds a unique position in that it has both a functional purpose and is a form of artistic and cultural expression. As Kostof explained, "*Architecture itself is a language of cultural expression*."[114] In the UAE the awarding of architecture degrees began soon after universities were established. UAEU was founded in 1976 and began its Bachelor's Degree in Architectural Engineering program in 1981. As oil wealth increased and cities were developing in the region, the demand for architects grew such that it became imperative to train local architects to supplement the work of those brought in from abroad, mainly from the U.S., U.K. and the Middle East.[115]

There are currently eight accredited architecture programs in the UAE, with UAEU being the only public/government university on the list. The curricula are based on the UK and US/Bauhaus systems,[116,117] and instruction is in English.

While universities as a whole grapple with how to balance imported Western ideas into a local, Islamic culture, architecture programs in the region have been shown to have very weak cultural foundations in their curricula.[118-120] There is an over-arching drive to meet the standards of the West, sometimes to the exclusion of local cultural references.[121] Although universities are producing local architects, major building projects in the UAE are still being designed by international firms and famous architects, and the buildings they produce often do not reflect the culture in which they are being built.[115]

There is a clear opportunity to continue introducing innovative tools and techniques while exploring how they can be used to integrate architecture into the local cultural and historic context.

2.2.7. History of the United Arab Emirates University (UAEU) Architectural Engineering (AE) Program

The United Arab Emirates University (UAEU) is a French model-based university founded in 1976 as one of four federal institutions of higher education (UAEU, Zayed University, Higher Colleges of Technology, College of National Defense), each of which serves a distinct mission and student population. UAEU is a comprehensive federal university, and is widely recognized as the flagship institution of higher learning in the United Arab Emirates.[122]

UAEU admitted its first group of students in 1977, and graduated its first cohort in 1981. Initially established as a predominantly undergraduate institution, with Arabic as the language of instruction, the university shifted to English as the principal language of instruction in most degree programs in 2003. Between 2010 and 2012, the University moved from multiple campus locations around the city of Al Ain to a single, main new location over 80 hectare.

The university is currently organized into nine academic Colleges, each of which is research-active and operates at undergraduate and postgraduate levels. Total university enrollment varies slightly from year to year, but currently stands at about 14,000 students approximately 11,000 of whom are female. Students are supported by about 950 faculty members.

The College of Engineering (COE) was founded in 1980 with two academic departments: Civil Engineering (currently Civil and Environmental Engineering (CEE)); and Chemical and Petroleum Engineering (CPE). The departments of Electrical Engineering (EE), Mechanical Engineering (ME), and Architectural Engineering (AE) were added in 1981.[123]

At its founding in 1981, the Architectural Engineering (AE) program was initially planned to educate male students. Soon after the first students were enrolled, the department identified significant demand among young women to study in the discipline. By 1986 the AE program had admitted its first female students, and for the past 30 years has taught both male and female students.[124] Currently, the department serves about 140 students, the majority of whom are female. The Department includes 25 faculty and instructional staff with curricular duties (including the chair), as well as 4 staff providing technical and administration support.

The Architectural Engineering (AE) program went through many changes, it is on a developing track which began in 2012. The program is implementing changes related to new AE program criteria announced by the EAC for the 2014-2015 cycle, currently required for the 2015-16 academic year. These changes are based on discussions that took place primarily during industrial training stakeholder visits (particularly consultant offices, governmental agencies and local contractors). It was clear that an increased emphasis on building construction design and construction project management would serve both stakeholder needs and students' employment concerns, as there continues to be strong market demand for these areas in the UAE construction industry.

In 2012, the department identified building construction/construction management as its synthesis focus area, with building structures at application level and building mechanical and electrical systems both at comprehension level. In 2013 a revised Graduation Project report and supervision system was developed for implementation in spring 2014. A range of related curricular and syllabus modifications were made, with an emphasis on detailed review of building construction courses, building design studios, capstone course guidelines, and support materials to ensure compliance with the 2015-2016 Program Criteria for Architectural Engineering. Additionally the department made adjustments to elective course offerings in order to integrate these with the ongoing introduction of department/area minors across the university and college-wide joint BS/MS opportunities for undergraduate students. Program educational objectives were reviewed in AY 2014-15 as part of their regularly scheduled evaluation cycle (every three years); related to this, the overall program assessment process is currently undergoing minor modifications and further formalization of the feedback to implementation loop.

In 2014 the program addressed the implementation of BIM in the design and construction courses, and an advanced elective course of "*Modeling and Simulation*." Thanks to these changes Graduation Projects are improving their quality; the students have better expectations and will became strong assets to the AEC industry of the country, which is moving forward to adopt new technologies. To reinforce the benefits shown during this implementation by the AE department, a new BIM skills course at the early stages of the curriculum was suggested to begin in fall 2017.

3. Literature review

3.1. BIM in Academia

The basic purpose of BIM technology is to provide a way for the variety of teams involved in a building – from its design to construction and maintenance – to share and manage all information on one platform. The full extent of possibilities with BIM is still being realized, but it is already recognized as being "*one of the most promising technologies for the integration of teams working on the same project*."[125] It is currently being used within the AEC industry to a limited degree to streamline and improve design, documentation and coordination efforts between team members,[126] particularly in the architectural sector. Increasing utilization and demand in the AEC industry has led to an increased need for effective BIM integration into educational programs and curricula.

3.1.1. Demand for BIM Education

The adoption of BIM technology, recognizing it as the best option available and deciding to make full use of it,[127] is growing. Multiple studies have shown the benefits of adopting BIM holistically, using all elements and realizing its fullest potential, however currently most architectural firms select specific elements to utilize over others. Langar and Pearce conducted a research project to identify patterns and trends of adoption of BIM in architectural firms in the southeastern United States.[128] They determined from literature review that firms often began adopting BIM to take advantage of its visualization and constructability functions, with the future goal of expanding its use into estimation and cost control areas.[129] In surveys that included the AEC industry as a whole, architectural firms were found to be using BIM the most, mainly for 3D modeling.[130]

Further review confirmed that firms chose to utilize certain functions of BIM – visualization, initial presentation materials, construction documents, etc. – over others.[129-131] Langar and Pearce sought to determine specifically which functions were adopted more and which less, and whether that correlated to specific firm characteristics such as size, experience, and participation in U.S. federal projects. They constructed an online survey and from approximately 255 responses were able to determine that nearly half (42%) had adopted BIM, or elements of BIM. Additionally the survey confirmed that visualization and initial presentation remain the most commonly used functions, and that firm size and experience with federal projects were directly correlated to whether the firm had adopted BIM. (L&P article)

Experience with federal projects is an important factor in the adoption of BIM, as the U.S. General Services Administration (GSA), which oversees the construction and building of federal governmental projects, has required its use.[132] Whereas architectural firms and other AEC industry businesses have adopted certain elements of BIM that are useful in immediate terms, GSA is interested in BIM for its long-term potential uses. They have recognized not only its usefulness in project scheduling and controlling construction costs, but also building operational costs and monitoring energy efficiency and other issues connected to long term usage of the building.[132]

If there are multiple benefits to holistic use of BIM, and project/building owners are increasingly requiring the use of BIM in its projects, are there any constraints to full-scale adoption of BIM by the AEC industry?

Holistic adoption of BIM (adoption as a product and process) results in additional direct and indirect cost for adopting unit, such as training of employees, cost of software and hardware upgrade, change in work process, cost of adoption on projects, and others.[129,133]

This indicates that there are direct costs in time and money to firms looking to adopt BIM. Education then becomes key not only in the more general aspect of broadening industry knowledge and innovation, but as a means of cost savings to businesses that will be able to hire professionals already trained and proficient in BIM. There is a symbiotic relationship – building owners are looking for the long-term and short-term benefits that BIM offers, from cost savings and streamlining during the planning and construction phases through the life of the building and its maintenance; construction and architectural firms adopt BIM to satisfy customers, but also to facilitate their work and have opportunities to innovate in design and construction; and the education sector provides competent and trained professionals to meet these needs and make their own contributions to the development of the AEC industry.

3.1.2. Integration of BIM into Academic Programs

The AEC industry was quick to the see the potential of BIM and has embraced the opportunity to save time and money by adopting it to the extent possible, while still using traditional models to collate building information concurrently.[134] In contrast, academia has been slower to incorporate BIM into its courses and degree structure.[1] It is only a matter of time before the education sector fully integrates BIM in order to meet the increasing demands from the AEC industry for trained professionals who are fluent in a technology that offers such benefits to workflow and project budgets.

It is imperative for architecture and engineering programs to train and educate their students in BIM not only to meet the needs of future employers, but to stay at the forefront of innovative developments in relevant IT tools. Students themselves are highly motived to acquire new IT skills,[135] so it becomes incumbent upon course lecturers and academics to learn and recognize the ways these new digital programs can impact and benefit building design in order to be able to pass that on to their students. The traditional design-bid-build model is no longer the sole method of project management; for students to be competitive professionals post-graduation they must be able to think beyond this widespread methodology.[125]

However BIM has also been termed a "*disruptive technology*"[33] because of its transformative nature. It requires a re-orientation of thought processes around building design and construction to achieve a new level of positive results. These include:

- More knowledge about the building earlier in the lifecycle regarding cost, energy use, organizational performance, and 3-D visualization by all members of the project team.

- Ability to use construction and fabrication knowledge during design, ability for greater use of off-site fabrication, ability to use product information earlier in design and in procurement planning.
- Much better coordination of project team using the model as a source of decision making and planning, faster procurement, greater use of fabricated components from global sources, fewer owner changes because of better understanding of the building and how it will function for its users, and fewer errors, omissions and claims.[33]

The comprehensiveness of these results and the broad skills needed to harness BIM to use them, make it clear that a simple add-on course would not be sufficient to achieve complete adoption of BIM in the AEC industry.

3.1.3. Faculty Training

Academic institutions are tasked with both a quick adoption of BIM into current curricula, and looking towards the long-term goal of complete integration of BIM into their degree programs.[136] AEC instructors must recognize the broad benefits of BIM, and in order to accept this new approach institutions should offer training courses, seminars, and workshops to their faculty.[125] People can be resistant to change, and with a practice like BIM, which requires curriculum-wide changes, the acceptance of the entire faculty is critical.[137] Individual, non-integrated courses will not successfully train students in such a broad-scope tool.[1] Traditionally different disciplines of AEC have had separate and individual educational programs; however BIM by its nature necessitates a more collaborative and integrated approach.

Some of the obvious difficulties in integrating BIM are logistical – how and where to place new topics in an already complete university curriculum; how to balance class sizes with available resources and enable cross-collaboration with other departments in teamwork-focused courses; if courses are inter-departmental, how will costs and resources be allocated and shared? Other difficulties involve the teaching faculty, including those who may be reluctant to realign their teaching and break old habits; instructors who may be experts in one area who must step outside that zone into new and unfamiliar areas; and those who have been in academia so long they find the idea of trying to keep up to speed with current developments in the industry daunting.[138]

AEC industry professionals are under pressure from project owners and clients to adopt BIM in order to be competitive– some governments are already mandating its use – but university departments generally do not feel the same level of urgency.[138] Pressure on educational institutions comes from industry demand for qualified professionals, and from the students themselves who will want to be at the forefront of industry developments in order to achieve lucrative and promising careers.

One way to increase pressure on academic institutions would be to establish BIM standards requirements for accreditation, which would provide the biggest incentive for curricular changes to be made.[138] In actuality the academic sector is facing the same problem as the professional industry – "*how to recruit (or train) and then retain teaching staff skilled in the areas of collaborative working and BIM technologies?*"[138] As in other areas, industry salaries are higher than academic salaries, and often institutions invite guest lecturers from the AEC industry to conduct introductory courses in BIM technology. However it is important for these schools to find and/or train their own faculty to be proficient in teaching these courses. One idea suggested by MacDonald and Mills in their evaluation of the teaching of AEC subjects and BIM, is for institutions to pool resources to teach lower-level BIM courses – perhaps even in an online format – that would meet broad, global (or regional) standards.[138]

Suwal *et al* reviewed a program conducted at Helsinki Metropolia University to educate instructors about BIM.[136] The course, called "*OpeBIM*," targeted a group of teachers from a cross-section of the School of Civil Engineering and Building Services, and therefore also served as a means of starting a cross-collaborative course between departments. Additionally industry professionals were brought in as guest lecturers, providing a further collaborative aspect. Eleven faculty-students covered topics such as "*introduction to BIM and motivation, contractor's BIM, BIM applications, designer's BIM (architectural and structural), and building services and BIM*."[136] After these five initial lectures were completed the participants were surveyed, with eight out of nine giving positive responses. Post program, the participants were committed to integrating BIM into their courses and to developing a departmentally-integrated BIM program.

As academic departments are working towards developing a strong curriculum with trained and competent faculty, the need to collaborate with industry remains. This cross-collaboration will both raise the level of education and provide tangible benefits to students and the industry itself.[136] The establishment of professional organizations to accredit BIM programs, and measure and recognize BIM competencies, would be beneficial to all – academics, students, and industry professionals.[139]

Academic departments must accept the challenges of adopting and integrating BIM into their curricula in order to maintain a competitive level and remain current on developing technologies.[140] They must also support their faculty and teachers not only with the development of BIM-integrated courses, but also through regular teacher training to keep their faculty up to date with the latest BIM developments and innovations.[136]

3.1.4. **Undergraduate Programs**

BIM should not be regarded as something completely new, as forms of it have existed as early as 2002 when IT programs were used to achieve virtual design, construction and facilities management.[141] The vision of the architect hunched over a large drafting table is becoming more and more obsolete, as professionals have at their fingertips an array of IT programs and software. BIM is viewed as "*cutting edge*,"[142] and by its very nature – its ability to coordinate and integrate information from all myriad teams involved in a building's design, construction, and maintenance – requires a more comprehensive introduction at the undergraduate level. BIM instruction is now included in the curricula of a number of undergraduate programs.[125]

The integration of BIM into undergraduate programs has not been without difficulty. The traditional method of simply adding a stand-alone course to introduce a new concept is inappropriate, yet it is challenging to adopt BIM holistically into a long-established program that "*takes students through* *benchmarks, semester after semester, often without integrating new developments in technology or introducing new methods of delivery*."[1] Students are educated through this well-established program, with BIM (or other new systems) added on separately, and yet they are expected as graduated professionals to integrate their traditional training in the design-bid-build model with an innovative, new method that fundamentally alters this model to positive effect.

Looking at the large number of institutions that are currently using BIM in their courses in architecture and engineering, the majority have treated the introduction of BIM as one subject, while a small number have taken a more interdisciplinary approach. Sabongi completed a study of undergraduate programs to determine the status of BIM adoption or integration into undergraduate curricula in the United States. A review of university websites yielded, for example, that Auburn University held a one-week tutorial in IBM and then followed that with a semester introductory course.[137]

Barison and Santos conducted a study using Content Analysis[143] to review documents about academic experiences, namely course syllabi and papers, and then suggest strategies for the incorporation of BIM into the curriculum. These documents were divided and analyzed based on the usual criteria when planning a course – prerequisites, course goals and objectives, content, methods of evaluation, etc. in addition to criteria specific to BIM education – activities, models and resources. They were able to establish three categories of BIM courses – introductory, intermediary and advanced[144] – which in turn could be aligned with the expected skills and knowledge base of different BIM professionals.

Introductory courses should be planned to develop some of the skills of a BIM Modeler and BIM Facilitator, whereas the intermediary and advanced courses should be planned to develop the skills of a BIM Analyst and a BIM Manager, respectively.[145]

3.1.5. **Determining Curricular Standards**

What would a comprehensive integration of BIM into the departmental curriculum look like? Ideally it would first be introduced in one subject before being used in other areas, either in its own course or as part of another subject.[146] The overall structure would move from the individual to the group/team to industry collaboration – in early years a focus on building individual fluency in modeling and basic analysis; in subsequent years the focus would shift to teams and more complexity as these teams collaborate; and in the final year work on an actual construction project with a professional company.[147,148]

Prerequisites for the introduction of BIM should be aligned with the intellectual maturity of the student,[149] and while typically it is included in design studio courses which have engineering and CAD as prerequisites,[150] there is disagreement as to whether knowing CAD would put students at an advantage or disadvantage.[151,152] Students should have a basis in Design Fundamentals, Building Technology and Professional Practice.[149] Prior knowledge of a programming language would be helpful for students to learn to create content in BIM.[153]

When considering course goals, there can be a consideration of short-term and long-term objectives; in the case of BIM these may include "*knowledge of the subject-area, improved understanding,* *development of intellectual skills, and changing attitudes*."[144] Some departments, looking towards the marketability and professional competitiveness of their graduates, have started by investigating what skills are currently in demand in the AEC industry.

Barison and Santos determined, for example, the BIM competencies required by architects by analyzing a BIM workflow as used by some AEC companies.[144] In real-life instances of BIM implementation the architect creates conceptual designs which are then passed off to the BIM project manager to evaluate what information must be included and where before it is passed on to the project model manager, and so on.[154] Ideally the architect would have consulted with the contractor and others beforehand to determine the proper technology, construction process, etc. and this would require not only fluency in BIM but also basic communication skills and collaboration tools.[155] He or she would be able to analyze different aspects of the BIM model, such as the effects of solar radiation, measuring potential energy and water consumption, and the possibilities of natural air flow. These would necessitate a strong basis in current developments in construction technologies and how to analyze graphs and tables.[156]

An architect prepared to oversee and coordinate BIM processes must have a thorough knowledge of BIM basics, how to find inconsistencies or potential errors, and how to coordinate and facilitate a successful BIM workflow. These skills will achieve competency, but to be competitive an architect will need to be able to innovate using BIM, which demands an additional set of skills and know-how.

This includes… a high degree of skill in generative and 3D parametric modeling, understanding complex geometry/systems and its behavior, programming language skills, showing a particular interest in software development, scripting/routines in CAD/BIM tools and applications[157,158]… and may include a knowledge of the actual capacity of production with software, applications and equipment for digital prototyping applied to the production of models, prototypes and the manufacture of non-standard and customized elements.[159]

So as it stands architects are using BIM, but in-demand professionals of the future will need to have greater competency in BIM not only to streamline the planning and construction processes, but to utilize BIM as a tool to innovate and develop. University departments must design a curriculum comprehensive enough to prepare their students for this task. They will need to ensure that department faculty possess not only technical skills, which are more easily assessed,[160] but also the emotive, cognitive, and motivational skills that are required by such an integrated and collaborative program as BIM. Even now these skills are valued, as professional companies will sometimes see the initial employment period of a new hire as time spent learning the company's culture and adapting to its unique teamwork environment.[161] Some of these interpersonal skills are traditionally part of a post-graduate or MBA program, but given the nature of BIM successful students need to move beyond the established programs that focus on non-verbal communication and learning the traditional tools and physical trade of architects.

Students can also explore new architectural forms by using generative modeling tools. Computational courses that teach geometry and computer programming are foundational courses that are not always covered in the curriculum,[158] or are offered as electives and are not particularly popular choices for students, but these could be easily included in the early undergraduate years, even for students with little-to-no prior knowledge or experience.[162]

Basic BIM skills that should be included in the departmental curriculum include: 3D visualization, extraction of quantities and documents from BIM tools, cost-estimating tools, analysis/simulations, clash detection, scheduling, 4D simulation, logistics and safety planning, points cloud, and digital camera monitoring.[144] The critical development of teamwork skills, team coordination, etc. can be encouraged during course projects.

The architectural program has a unique nature. Students must reach competency in a range of different disciplines and tools, as they will need to have the capability to control and oversee the entire construction site and process. An architect must understand and be able to use tools for design, visual representation, quantity surveying, project management, site construction, sustainability, and urban planning. The complex nature of this discipline requires diverse ICT tools, which makes it a perfect candidate for a BIM-style working environment.

3.1.6. **Graduate Programs**

The development of BIM has heralded a period of rapid technological transformation that requires significant changes in how building projects are designed, developed, constructed and maintained. Nearly 50% of AEC companies are using BIM and that number will continue to increase.[130] The collaboration between the AEC industry and technology researchers and developers are considered of primary importance.[163] One major hindrance to these changes is the lack of personnel who are sufficiently trained in BIM. Studies have indicated which technical and professional capabilities will be necessary for graduates to be competitive:

Today's engineering graduates need to have strong collaboration and teamwork skills; they need to have a broader perspective of the issues that concern their profession such as social, environmental and economic; and finally they need to know how to ally fundamental engineering science and computer skills in practice. Today's 21st century architect, engineer and construction manager must be able to deal with a rapid pace of technological change, a highly interconnected world, and complex problems that require multidisciplinary solutions.[17]

BIM is such a comparatively recent development, there are few studies that address the status of integration of BIM in higher education, and particularly in post-graduate studies. Becerik-Gerber, Gerber and Ku conducted an online survey[17] to determine and measure the status of BIM in AEC education in the United States. They received responses from the deans, department chairs and program directors of 101 accredited programs, and the results indicated that architectural programs were quicker to adopt BIM into their curricula and had more BIM courses. However although architecture programs began including BIM sooner, they tended to introduce it later in the curriculum – senior year and at the masters level. There is an ongoing debate as to the appropriateness of including BIM in the earlier stages of design,[164] with fears that it could stifle creativity while the counter-argument is that BIM should be regarded a holistic process and not simply another technological tool.[165]

Whereas most architecture programs had required BIM courses at the undergraduate level, the study showed that these courses were mostly electives at the graduate level. Likewise PhD level research in BIM in architectural programs was low (17%) even compared to other programs (46% in construction management programs, for example). This contributes to AEC industry problems, which have been connected to less research and development within the industry[166] – perhaps a direct corollary to the low level of research at the PhD level in academia. This dichotomy between academic research and industry research – labeled the "*valley of death*"[167] – is smaller in architectural programs, which have research projects that are more in line with industry needs.

Although education and training are key to the adoption of BIM industry-wide, many organizations – particularly smaller companies – have been reluctant to make that investment in its employees because of the costs.[17,168-171] This places even more pressure on educational institutions to provide trained and competent graduates to meet this need. In the UK BIM courses have become a fundamental part of undergraduate programs, while at the graduate level BIM is covered in incorporated courses.[172] Kugbeadjor, Suresh and Renukappa conducted a survey of postgraduate (masters) students in the UK to assess their BIM readiness.[173] They constructed an online survey of 35 students from three different universities, all of whom stated they had heard of BIM; only approximately half had been introduced to BIM in their university courses, with 60% saying they heard about BIM from other sources, such as work, trade journals, etc. The survey went on to determine how knowledgeable the students were about BIM, and the result was that the majority did not have a clear or correct understanding of BIM and what it is. Only 60% of the students understood the collaborative nature of BIM, which showed a lack of awareness of its central facet. Few of the respondents felt that their university courses had prepared them to perform well in a BIM-enabled company (about 11%), although the majority were willing to add BIM to their studies as an elective.

Both studies show an opportunity for growth of BIM instruction and the adoption of BIM into the curriculum at the graduate level. BIM is increasingly in demand in the industry – for example, both the US and UK governments have mandated its use in their projects – and yet education, particularly at the graduate level, remains low in both the number of research projects and in the level of required (non-elective) coursework. It is incumbent upon educational institutions to address this critical issue and work to educate and train their students such that they can succeed and be competitive in a BIM enabled environment.[174]

3.1.7. **Continuing Education Programs and Seminars for AEC Professionals**

There have been increasing calls for comprehensive adoption of BIM into the university curricula, and AEC companies are struggling to find BIM-competent professionals. As the industry turns to the education sector to provide well-prepared graduates, current AEC professionals also recognize the importance of BIM and the need to update their own knowledge and skills.[175] There is a fundamental conceptual shift in the approach to building design and construction. The current methodology is detached, with AEC professionals compiling their data and then pushing that to the building stakeholders; BIM flips this model, focusing on collaboration and bringing stakeholders into the process. Bridging this industry shift is a considerable challenge for people who have been educated, trained, and with practical work experience in the established traditional process.

AEC professionals can take advantage of educational programs to update and develop new skills. Mathews conducted a case study[175] of just such a program that seeks to elevate collaboration over cooperation in the AEC industry through adoption of BIM.

> Cooperation can be defined within the Built Environment as, individuals and or practise firms who exchange relevant information and resources in support of each other's goals to attach their own goal, in this case getting rewarded for their professional input….Collaboration on the other hand is working together in a joint intellectual effort to create something new in support of a shared vision.[175]

The main goal and advantage of BIM is to change AEC projects to be a collaborative effort, where people and technology are realigned to streamline the building design and construction process.[176] In our individualistic culture, focus is more on building personal reputations,[177] and the educational system reinforces this emphasis on the individual, with each area concentrating on its own individual responsibilities within a design project. AEC professionals seeking to update their skills and remain competitive are tasked with setting aside their previously conceived notions of project cooperation towards more collaborative efforts.[175]

Mathews completed a case study of a collaborative module that was offered as part of a Continuing Professional Development (CPD) diploma in BIM technologies, starting with collecting data through class observations, video recordings, student writings, assessment of collaborative projects, and interviews of students after completion of the module. The overriding goal of the module was to lead students to break through established industry barriers between different areas in the design and construction industries and ultimately develop a "*pedagogy for Postgraduate BIM Reacculturation*."[175] The key result -- the education models that are required to support and underpin BIM courses and curricula are underdeveloped.

The need for current professionals to upgrade their skills is clear, but given that standards in BIM are not yet widespread it falls upon educational institutions to develop and host educational programs and modules[168] that will enable current professionals to remain competitive in the AEC industry, and support the adoption and development of BIM in a comprehensive manner.

3.2. ICT in Higher Education

The increase in ICT motivation in education is mainly because they are alluring to our current digital-native students.[80] An information and knowledge society was defined in 2003 as cited by Almenara,[178] as the stage of social development characterized by the capacity of its members to obtain, share and process any information by telematics means instantly, from any place and in any way they prefer. The ICTs are mainly tools that facilitate access to information, in addition to enabling the classification, storage and distribution of information in a simple and universal way.[71]

Before the creation of the internet and ICTs, knowledge was stored and transmitted by family, professors, books and other means within a very short range. Schools and universities hold most of the knowledge,[80] but with the development of the internet information is available almost everywhere. The proper use of ICTs achieved essentially an endless information database, which needs different skills to search, filter and organize information to weed out the excess and find what is needed.[179]

In UAEU as in universities in Spain, there is well-funded initiative to install projectors, wireless internet connectivity, and smart boards.[180] ICT introduction into the classroom is completely in the hands of the faculty; this means that a faculty member will only use the ICTs when he has the skills, confidence, support and a proper teaching methodology that suits these new technologies.[181,182]

ICTs are simply resources and a means of enhancing the learning process. The importance relies in the context, how and why we used them, and to what benefit[182].They should be used as tools that facilitate the learning environment, and improve skills development using different teaching methodologies[80].

The creation of learning methodologies which include ICTs provides the students and/or the faculty satisfaction, which translates into an improvement in skills and performance[183] due to the great interest that ICTs create in students -- they improve their visual education, spatial comprehension, performance and satisfaction. [183]

ICTs are rapidly changing participation, interaction and collaboration in higher education. There is a dire need of new ICT strategies and innovation in the teaching of construction.[80] It is important for academia to be involved with the industry, but it should lead the evolution [17](and not gradually follow industry evolutions). There should be support, planning and follow up by governmental policies [182]in order to achieve teaching innovation, reduction of ICTs introductory problems, and improvement of both access and skills of faculty and students.[182]

The training and development of faculty skills is one of the key steps to introducing ICTs in higher education properly. If the faculty attitude and motivation are not favorable towards ICT, changes will be impossible. [182]

Most of the AEC industry problems can be traced to the lack of R&D over the world,[80] although currently the AEC industry is requiring ICTs and BIM skills from graduates. Technicians should be able to update their ICT skills, collaborate, and work in interdisciplinary environments.[17] For our graduates to succeed the faculty should use the new ICTs efficiently[184].

There is a rift between the knowledge provided at the higher education level and the current skills used in the AEC industry.[185] This gap is increasing because most universities continue the old traditional processes being blind to the interdisciplinary and collaborative processes provided by BIM and their clear advantages.[186] In the US, Europe, Australia and Middle East AEC students are taught in closed departments with little or none interdisciplinary and collaboration between different disciplines[187]. This turns into the industry with as lack of an overall view of the project, and creating problems in the collaboration and interaction between the different disciplines involved in the project[80]. Few universities began teaching BIM between 2006 and 2009 [3] and the number is increasing but without a common methodology, level or framework[3].

One of the biggest changes that needs to happen is the increase of interactivity of the student in the class, which leads to an increase in student motivation. This will require a radical shift in the vision of the faculty of the class, from the storage of the knowledge to the guide for the student to learn[80] The current model is inefficient in knowledge transmission[188] and provides skills which may be obsolete when the students graduate.[189] They may lack digital skills, but they still need them. The current educational system was designed before the arrival of the internet and ICTs, providing global information and increasing collaboration between disciplines[190].

The native-digital students are willing to use ICTs, they have good skills [191]and faculty should use this as a tool for learning instead of increasing the generational gap.[192] The students' capabilities and comfort with ICTs should be used as a tool to improve their performance, and to create innovative teaching methodologies. Academia should use these digital-native skills in order to create better professionals.[80]

While most of the programs are currently developed by CAAD instead of BIM,[193] BIM increases the motivation and satisfaction of the students [194] because they view it as intuitive and easy to learn.[192,195]. 2D drawings are difficult to understand by our current students [196] and create mistakes and misinterpretation within them. This problem is directly related to the industry.[197]

As Dr. Prieto stated [80], the more extensive ICTs used in higher education are email, chat, videoconference and VOIP; in recent years' blogs, APPs, social media, Podcast and videogames are available for students and professors, to use as convenient. Muriel Prieto developed a table showing the possibilities of each of these technologies according to its characteristics and functionality:

Teaching methodology	ICTs
Theoretical class. Lecture designed to transmit knowledge, the main figure is the professor.	Podcast and video streaming
Lab class. Practical sessions designed to solve problems and exercises, the main figure is students.	Web presentations, Games and simulations.
Workshops and seminaries. Sessions designed to develop and study one specific item.	Web presentations, Games and simulations.
One to one advising, personal attention to a particular student.	Chat, Email, VOIP, video conference, APP
Studying and students work, both individual and group.	Wikis, blogs, APP, social media.

Table 3.01 ICTs organized by focus, table from Muriel, Prieto[80]

3.2.1. Psychology of Information Acquisition/ICT/Curricular Changes

Although ICT is increasingly recognized as the way of the future, particularly within education, the reality is that despite the considerable effort and money spent thus far the adoption of ICT tools into university curricula has been sporadic and with equally inconsistent results. The blame of this disconnect has traditionally been ascribed to low skills, knowledge and motivation among students, faculty, and/or school administrations, however recent studies have taken a more holistic approach to include social, political, cultural and other factors when determining both the causes and possible remedies for the gap between the promise of ICT implementation and development within universities and the achievement of those goals.[198]

Scanlon & Issroff discuss the standard means of determining whether or not a learning technology is or will be beneficial to students – through theoretical review, through examination of completed research, or through direct evidence gathered from students actually using the new technology.[199] Activity Theory, which is a framework for investigation that includes a subject's "*environment, history of the person, culture, role of the artifact, motivations, complexity of real life action, etc*."[200] is a useful tool for investigating and understanding learning situations using new technology, because this learning activity is not something conducted in a completely sterile and controlled environment; rather there are situational influences and societal contexts that play a significant role in the outcome of introducing a new technology to a classroom.

Specifically with regards to evaluating the adoption of ICT tools, there are several relevant factors to be considered: efficiency – maximum learning using minimum time/resources, a concern of both instructors and students although perhaps from different perspectives; cost, costs to the institution as well as to the student, who may have to pay additional software or other technology fees; failure, when the technology fails in some way, directly impacting the classroom experience; interactivity, how did interactions between the students and teacher, or students and themselves, change with the addition of a new technology to the classroom; and serendipity (accidental learning), who has control in the learning session, are students allowed/encouraged to be innovative in their use of the technology or must adhere to set parameters.[199] Using the framework of Activity Theory, each of these elements can be considered when evaluating student success in using a new technology, going far beyond simply analyzing course grades. This shows the complexity involved when evaluating and adopting a new program, and studies have consequentially demonstrated that "*students are inconsistent in their responses across different settings*."[199] Results can be mixed, with some students having positive reactions to certain elements such as convenience or ability to save time, but negative to other aspects such as cost or information overload; different students can have different combinations of responses, and the same holds true for instructors utilizing these resources.

Another influence on response to new learning technologies is the interplay between student expectations and understanding, instructor expectations and understanding, and the understood rules of the educational community.[199] This is further impacted when a certain educational methodology has been used for a long time before a new method or technology is introduced. For example, faculty and students may be accustomed to a strictly lecture format, or an instructor role that is quite separated from the students, whereas the successful adoption of a new ICT tool may require interaction between student and instructor that crosses these traditional lines where the instructor takes on more of a mentor role.

These considerations necessitate a change in effectiveness evaluation that before may have had a more binary focus -- success vs. non-success (pass/fail); instead a more comprehensive evaluation can be achieved through broader criteria, such as the Activity Theory, that would give an "*expanded vision of effectiveness*."[199] Similar to the quantitative/qualitative methodologies, investigating not just whether students succeed or fail with a new ICT tool, but how or why they succeed or fail, will give a more meaningful evaluation of a new learning technology and its adoption.

Siragusa and Dixon conducted a study of undergraduate students and their response to the introduction of instruction using ICT tools, and reached a similar conclusion regarding the complexity of how students react to the inclusion of ICT in the curriculum, but using the Theory of Planned Behavior (TPB) as a framework. They found that student behaviors and responses were linked to their attitudes and beliefs.[201] "*When applied to the engagement with ICT, the TPB suggests that intentions to engage and interact with a particular program or software element is influenced by attitudes towards using ICT, perceived social pressure to do so and by perceptions of control over the interaction*."[201] In their study the majority of participants were initially apprehensive about using a new ICT tool, although this feeling changed as they became more accustomed to the program (*attitude*); nearly all felt that the development of ICT skills is important (*belief/social pressure*); and at the end of the study participants were able to recognize the benefits as well as offer suggestions for improvement (*control*).[201]

For some, ICT is seen as just one tool in the classroom toolbox, that can be utilized or not, with many students and instructors reluctant to use it in a direct or sustained manner where it is a fully-integrated part of the curriculum.[202] However there are factors beyond faculty and student classroom concerns that impact the adoption of ICT. Governments concerned with economic competitiveness can stress the need for technologically-literate graduates in the workforce, stressing literacy over innovation – "*an approach to ICTs in terms of learning 'about' computer technology rather than 'through' computer technology*."[198] IT companies who supply their software products to universities also run the risk of curtailing student development and creativity as they try to balance profit and market share against education technology and the public good; similarly university administrators, faced with increased pressure from governments, competitors, budgets, and growing student populations, can view ICT as a means of alleviating some of their difficulties in a managerial context over enhancing the educational experience of students.[198] Students themselves are faced with a number of key issues when considering the adoption of ICT, several of which are tied to the concept of success – ICT is viewed as peripheral to their academic success, and in a stressful environment can be thought of as something to be used only to the extent required; with the ultimate post-graduate goal being employability, students feel they can acquire the minimum ICT skills and knowledge needed to be marketable, which contributes to the limited adoption of ICT into university curricula.[198]

In response researchers have called for a "*renaissance*" of how technology is used in education, "*exploring ways in which universities can utilize old and new technologies to reinvent themselves as places of encounter for cultures and knowledges from across the world*."[203]

3.3. Research methodology design

This chapter will include a discussion about the gathering of information for this project and its goals; and then a methodology review which will clarify, help determine and lead to the creation of a proper methodology for our own research.

What is the importance of following a particular research methodology? There is a risk of rendering the research project futile without deciding on and adhering to a particular method, as this structure is critical to the quality of the research.[204] Earlier social scientists used what is now considered a mixed methodology for their research, but soon this was replaced with an emphasis on quantitative methods. Qualitative methods developed as a counterbalance until recently -- in reaction to increasing division and polarization between the two, the mixed methods paradigm has become increasingly popular. "*We currently are in a three methodological or research paradigm world, with quantitative, qualitative and mixed methods research all thriving and coexisting*."[205]

Each methodology has advantages and disadvantages, but for the purpose of gathering and analyzing data from a limited group of subjects, and of achieving a deeper level of information, the mixed-method methodology is ideal.

3.3.1. Academic and Learning Analytics

The main goal behind the application of analytics in education is gaining new insights and information through an in-depth analysis of collected data about all aspects of the academic sector. "*Analytics marries large data sets, statistical techniques, and predictive modeling. It could be thought of as the practice of mining institutional data to produce 'intelligence*.'"[206] It is still a new area of research,[207] but the potential benefits to students and instructors have earned it widespread interest. Although initial efforts at the departmental level were more focused on science, technology and math disciplines,[208] the clear advantages and potential have made it an important area for further research and development, including in AEC courses. This thesis offers an initial step towards the use of data and its analysis to improve course effectiveness and student performance in architectural courses.

Siemans *et al*[209] have divided analytics in the educational context into two types, academic analytics and learning analytics. Academic analytics is focused on improving the effectiveness of an institution by looking at data about students, faculty, staff, facilities and the organization overall. In the context of higher education, analytics are concerned with issues like maximizing overall institutional effectiveness, identifying potential students or gaining more funding from donors; for example a university admissions office may have a complex formula for determining successful applicants based on test scores, transcripts, etc., a form of "*actionable intelligence*" that allows for more efficient use of staff time and budget.[206]

Learning, or learner, analytics is focused on improving the quality of the educational experience of the students and ensuring their success. Current programs work to predict and identify students who are facing academic trouble and can then allow for the realignment of the student's academic program by faculty and advisors to give him or her a better chance of success.[206] For example Sinclair Community

College in Dayton, Ohio in the United States has won national awards for its Student Success Plan that collects and collates student data from admissions (test scores, income level, employment status, etc.) as well as any counselor notes or comments from faculty that may trigger an alert for action by staff and the student to develop (or modify) an Individual Learning Plan.[206]

The hope is that learner analytics will move beyond identifying and assisting students who may struggle to customizing the entire educational environment to maximize benefits to each student. This thesis outlines just such a scenario in that it analyses architectural course data to determine a more effective method of instruction.

Elias[210] notes that currently instructors who are hoping to continuously improve their courses are limited to evaluations and data given at the end of the course; this means that any helpful information that leads to improvements is therefore only able to be implemented in a subsequent semester. However with the increasing use of online and IT tools and programs, data can be more readily collected and analyzed as part of learning analytics. The critical point will be to transform this data from mere knowledge to actionable steps to improve student experience. The obvious first step in enabling a more responsive method of analysis and improvement is the adoption of IT tools, such as BMI in architectural programs, which offer immediacy in student evaluation and flexibility to adjust to suit the needs of the students.

To create an effective analytics initiative, data must be collected from several systems, stored in a central data management system, and be accessible for continued interaction and supplementation. A program might begin with basic demographic data about a student along with his or her prior academic performance and the results of any personal aptitude evaluation, then be combined with continuous feedback about current coursework to monitor and predict student success. Such a system will require dedicated leaders, skilled data analysts, and the technology that can perform the required functions.[206]

Ferreira and Andrade[211] discuss the connection between academic and learner analytics, and how an integrated system, which moves from the "*micro*" (student participation and performance) to the "*macro*" (global business management) can be most effective following a "*bottom-up*" approach – individual students, professors and departments can work within their own areas to develop programs that maximize educational effectiveness and student learning, while also contributing data to the academic analysis and benefit the institution overall. Their research centered on Universidade Católica Portuguesa in Porto, Portugal that has a student learning content system (blackboard) and a quality assurance program at the university level, but no structure to connect these micro and macro aspects. In their work they proposed a method to extract and analyze data from the student portal as part of a learner analytics program that would contribute to a university academic analytical analysis.[211]

"*The broad promise of analytics is that new insights can be gained from in-depth analysis of the data trails left by individuals in their interactions with others, with information, with technology, and with organizations*."[209] However there are concerns that should also be kept in mind, including: privacy concerns, should overt permission be obtained from students before placing them in a data tracking system; limitations of data analysis, particularly in being unable to consider all possible factors in a student's success or failure that cannot be scientifically or mathematically quantified; reluctance of faculty or staff, for a successful program the active involvement and commitment of the faculty is key; misuse of the data, concerns about profiling, data privacy, access to information (even by university employees), and how to allocate resources.[206]

Review of the literature has shown that while macro, academic analysis systems need to be developed, as well as the mechanisms by which data is transferred between academic and learner analysis systems, the critical interaction is at the student-instructor level. There have been some developments in the area of micro, learner analysis systems but there is a need for further research in this area especially in fields where IT tools are still being developed and/or integrated into university curricula. This research offers both a means and a learner analysis for the introduction of BIM tools in academic curricula.

3.3.2. **Quantitative Methods**

Quantitative methods of research are "*randomized experiments, quasi-experiments, paper and pencil "objective" tests, multivariate statistical analyses, sample surveys, and the like*."[212] The methods grew out of the natural sciences. They are conducted in a controlled environment, where the researcher maintains a distance from the data as an "*outside observer*" looking for objective answers – the survey is the primary tool. The process is outcome oriented, with a goal towards "*hard*" data that can be replicated by others in similar environments, and can be used to generate a statistical analysis. It requires a broader pool of study subjects when generating data, so that generalizations can be accurately made. Often quantitative methods are used when trying to prove or disprove a theory.

The collected information from quantitative methods is numerical, used to generate statistics, graphs and tables. Common methods include surveys and questionnaires using close ended questions. The major advantages of quantitative methods are that, when conducted properly, the results are reliable; the data is easier to analyze and uncomplicated; and the results are verifiable and able to be replicated. Disadvantages include the possibility of gaps in information; questionnaires are necessarily limited in subject scope and details; and data collection can be more labor intensive, since a larger subject pool is required for adequate analysis.[213]

3.3.3. **Qualitative Methods**

Qualitative methods of research are "*ethnography, case studies, in-depth interviews, participant observations, etc*."[212] The methods are usually associated with the social sciences. They are more subjective, and rely on observation over a controlled measurement. A process-focused activity, useful results are obtained from fewer subjects or a single case study. The researcher is the tool, and is looking for an "*insider*" perspective with the goal of deeper information from the data. There is generally not a pre-determined theory, rather the researcher will "*follow the data*" to central questions and answers.

Common types of qualitative studies include case studies – in-depth study and analysis of a particular person, group or event; ethnography – immersion of the researcher in the target field, through extensive interviews, observation, etc.; and action research – collaborating with the study participants to solve a given problem, making observations and evaluations of the process and outcome. Researchers can collect data through interviews, journals, questionnaires, observation, etc.[214]

Data from qualitative methods answers how and why, and can lead researchers towards a theory (instead of being used to prove or disprove an already-established idea) and often are observations of attitudes or intentions. Qualitative methods are usually conducted with a smaller group of subjects to reduce the complexity and time needed to conduct more in-depth interviews. Data gathered through qualitative methods can be presented in quantitative ways – like graphs or charts – but is more commonly explained in case studies. Advantages include the ability to gather rich and detailed information; possibility of deeper and more meaningful analysis; fewer participants are needed, which also means fewer resources are needed to conduct the research. However the results are not objectively verifiable; the actual process of analysis is more labor-intensive than with quantitative studies; and the researchers need to be careful in how the questions are formulated and the research conducted.[213]

3.3.4. **Mixed Methods Methodology**

Johnson et al devised the following definition for mixed methods research: Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration.[205]

Reichardt identified three reasons why using a mix of qualitative and quantitative methods is the more effective and logical choice for research: there are usually several purposes that are addressed in a research project and tasks must be completed in different and often demanding conditions, this variance necessitates a variety of methods to accomplish; there are benefits to using both method types, where one can build on another and yield further data and insights not attainable by one method alone; and all methods have inherent biases that are only overcome by using a range of techniques.[212] In his 1979 article Reichardt was not confident about the popularity of combined, or mixed, methodologies in the future – "*we are not optimistic that the joint use of qualitative and quantitative methods will be commonplace*."[212] His concerns – namely the monetary expense involved in collecting data, the time needed to complete the research, the lack of researchers trained in both method types, and the difficulty of finding people willing to go against established norms (following either a quantitative or qualitative method) – have largely been rendered moot over time and with the rapid development of the internet and IT tools. Mixed method research is now recognized as the "*third major research approach or research paradigm*.[215]

The basic concept behind the mixed methodology is not a new one. Triangulation, or the idea that using a variety of methods will remove doubt that research findings are valid, has been advanced by researchers since 1959. [216-219]

Once a proposition has been confirmed by two or more independent measurement processes, the uncertainty of its interpretation is greatly reduced. The most persuasive evidence comes through a triangulation of measurement processes.[219]

Denzin took this a step further by suggesting that using triangulation but limiting methods to only quantitative or only qualitative, would limit effectiveness since any inherent faults in the approach used would remain. He therefore called for using "*between-method triangulation*."[220] Fonseca et al observed just such a weakness in the use of quantitative methodologies exclusively to evaluate the incorporation of IT tools into a classroom, where the sample sizes are necessarily small, too small for an effective quantitative evaluation. Using qualitative along with quantitative methods would enable researchers to extract more detail from the quantitative data, and conversely quantitative methods would overcome the insufficiencies of qualitative data – lack of generalization and subjectivity of the information.[221] A mixed method would enable the researcher to "*analyze the complex area of individual user experiences by not only observing their behavior but also defining the causes of it*."[222]

There are advantages to using a mixed methods methodology, such as the ability to collect more detailed and specific data using qualitative methods than would be possible with quantitative alone.[222] However there are challenges that should also be addressed. The main difficulty is in optimizing the different method types to maximize results and avoid differentiated data. For example quantitative survey questions would need to be worded carefully so as to correlate with potential answers in qualitative questions.

3.3.5. Mixed Methods Research Case Study

In a study conducted by Fonseca, Redondo and Villagrasa, the researchers wanted to determine the motivation and satisfaction of students in a university architecture program with the use of interactive and collaborative technology to visualize 3D architectural models.[222] Their approach was three-pronged: to establish teaching innovations to maximize student motivation, retention and satisfaction; to raise the general comfort and fluency of the students in IT tools and programs; and to then evaluate their efforts so as to determine areas of particular success and elements that could be improved upon. A

Individually these ideas are not unique, but their combination into one experiment at the university level was something new. [223,224] There is a general assumption that today's students would naturally gravitate towards IT tools and programs, they are common in all classrooms and conventional wisdom is that using IT naturally will result in increased motivation and academic achievement in students, but this is not a given.[225] It is not a matter of simply handing over a new IT element to a class and assuming the results will be positive –the introduction must be in a controlled and thoughtful manner; the instructor must be trained and able to give full-time support, offer clear and precise explanations as to its use, select proper applications and define clear objectives. Failing in any of these can result in critical errors in implementation that can cause negative reactions in students that could leave lasting impressions.[226-229]

Studies to date on the incorporation of technology into the classroom have often been flawed, resulting in incomplete data because of errors in the basic design of the study. The focus has been on quantitative studies in a classroom environment, which inherently will be flawed as the sample size is necessarily small (quantitative studies require a large number of participants to be effective).[230,231] Additionally the preselection of questions has been inadequate, in some instances allowing the possibility of biased answers.[232] This environment is ideal for a mix-methods methodology, which would allow for different data analysis methods and using quantitative and qualitative research cooperatively to maximize detail and minimize subjectivity and lack of generalization.[221]

The first aspect of Fonseca et al's study, a focus on "*teaching innovations within the university framework that cultivate higher motivation and satisfaction in students*",[222] is critical as university enrollment overall is on the decline.

The goal is to optimize students' understanding of academic subjects and the way in which they are taught. The use of "*friendly technology*" that is successfully adapted to the specific needs of each subject must help students better adapt to education at the university level and to the new sociocultural context in which IT has a massive presence.[222]

There have been numerous studies conducted on the successes and failures in incorporating IT into education.[233,234] Understanding the primary goal of this incorporation is "*to improve the student learning process*,"[222] Fonseca et al extrapolated four items from "*good educational practices*" in IT an e-learning:

- Emphasis on good instructor-student relationships with facilitated and effective feedback methods;
- Collaborative classroom environment, encouraging student development in a dynamic manner;
- Using heterogeneous learning methods to reach better and higher achievements;
- Incorporating innovative educational methods using new IT technologies.[222]

Using these dynamic practices will result in a more dynamic student, what Fonseca et al termed a "*3.0 student*," who would be more comfortable and capable in maintaining an active role in their own education and the learning process. Specific to IT, the successful integration of the technology into a classroom activity must address the curriculum (content, objectives, prerequisites), the pedagogy (instructional activities, material delivery, student/teacher roles, evaluation) and the technical aspect (training in relevant resources, equipment, proposed uses).[222] This approach is a move away from traditional methods that were oriented more towards the technologies being integrated rather than the learning needs of the student, which should hold primary place.

The second element was to utilize IT tools to the extent that the students would become "*digital natives*";[235] much as one would become a native speaker of a given language, digital natives would have natural fluency and comfort in IT programs and tools which would also facilitate the introduction of new programs. In this case study, architecture students were given an assignment and asked to compare the use of the traditional method of printed plans and conceptual mock-ups with the use of 3D model visualizations on mobile IT devices. The working hypothesis of the researchers was that the students would be more motivated to use 3D models and more satisfied with their results, and that in conjunction with having to spend less time completing the assignment digitally.[222]

Why mobile devices? The use of mobile devices is part of an effort to improve 3D architectural projects, to move beyond the traditional printed plans and physical models which are so time consuming and comparatively expensive. Sharing the plans and models, and making changes and adaptations are infinitely easier using mobile devices, and this results in a smoother and quicker workflow. Additionally these materials will be more accessible to a wider range of people, "*experts/nonexperts, with/without disabilities, local and foreigner*."[222]

The visual component is of critical concern for architects, and so it is important that architecture students are able to have the opportunity to discern information visually.[236,237] The AEC industry has become one of the main consumers of 3D technology through the development of CAD and BIM, but mobile access has historically been hindered by the lack of affordable and high-performing mobile devices that are capable of accommodating the excessive file sizes required. This is changing as smartphones and tablets are being developed with new processors, the cost of devices and device maintenance is less, and there has been a continuing increase in connection speed and Wi-fi connectability and availability. This explosion of IT opportunities has not been without its challenges, for example the proliferation of applications and formats has made it difficult to work with a single manufacturer or line of products.[238] In the context of a university course, if several applications are in use this then requires time spent to explain the different applications, to perhaps convert models from one display system to another, etc.

The last aspect of Fonseca et al's study was to analyze the different aspects of the study and its implementation, in particular to assess where future IT implementations and introductions could be improved. They used a mixed-method methodology to conduct their research to achieve "*multidimensional outcomes [that] make it much easier to propose solutions and further research steps*."[222] In doing so they sought to achieve the quantitative goal of gathering empirical data and the qualitative goal of defining the causes of student opinions. There were 79 students enrolled in the course under study, ultimately 48 of them took the two quantitative tests: one given before the introduction of the new technology, which measured the students' technological profiles and motivation; and one after the course material had been presented (but before final grades were given) to evaluate the efficacy of the material presentation and usability of the 3D technology. Both tests used the 5-point Likert scale for scoring (1-never, strongly disagree to 5-always, strongly agree).RA technology

The first quantitative test established a student's technological profile based on how and where he or she uses technology; obtained opinions on the theoretical and practical aspects of the 2D learning phase; and assessed the students' prior knowledge of and ideas about RA technology. The test enabled the researchers to gauge student readiness to utilize mobile technology and the internet to create, share and publish architectural content. The results also served as a baseline to which the results from the second test could be compared to evaluate change in student perceptions, motivations and satisfaction.

The second quantitative test sought to compare opinions on 2D modeling before and after introduction to 3D systems; to assess student perceptions and opinions of the technology for 3D viewing; and evaluate usability of the technology – content, structure, and methodology. Using the same questions on both tests provided the means of comparison. Results were mixed. The overall structure of the course was highly valued, but the students wanted more time for explanation and development, and were concerned that some aspects of the course may not have correlated with the university credit system. For a quantitative study the data was insufficient and generic, but using a qualitative method as part of the mixed methods approach permitted further corroboration and detail.

A balanced sample was selected to take the qualitative test, 10 students (5 male, 5 female) randomly chosen from a pool of students who agreed to participate. The qualitative method used was a Bipolar Laddering Assessment (BLA), where through the course of detailed interviews the researchers composed a list of positive and negative elements (positive and negative poles), to which the laddering technique was applied – continuing the interview to define why or how a certain element was on the positive or negative side and how these elements could be improved or solved. The results of the qualitative test showed on the positive side the subject organization, usefulness, and appeal and novelty of AR over 2D methods; on the negative side, lack of sufficient time/excess of course content, and difficulties with applications and their stability.

The researchers' original hypothesis – with a smaller amount of time and visual mobile devices, students could have greater motivation and satisfaction, and better course results with the introduction of a 3D visualization program – was partially proven. The students did show greater motivation and satisfaction, but required more time for program instruction and development. Through this mixed method study, the researchers were able to achieve a more focused analysis as the "*data were much more specific than those that would have been obtained through quantitative methods only*."[222]

Choosing and following a research methodology is crucial to the success of the research project. The three primary choices – quantitative, qualitative and mixed-methods – each have their own environments in which using that method would be ideal. Quantitative methods are suitable for larger target study groups, seeking empirical data to show trends or other computational outputs; qualitative methods are suitable for smaller subject groups, where the research goal is "*how*" or "*why*"; the mixed-methods methodology is a way to achieve the best of both worlds, although the research paradigm much be carefully constructed in order to maximize usable data.

4. Introduction of BIM based on Revit in the AE Curriculum at UAEU

The introduction of BIM is a very complex issue. It was decided to introduce BIM in the Architectural Engineering department of the UAEU, at the recommendation of the American Board of Engineering and Technology (ABET) accreditation assessment committee.

The first step towards this introduction was to research the areas of expertise which the departmental program aims to emphasize with this technology. It was decided at the department meeting to focus this introduction in two area -- design and construction. In the design area the students will gain better understanding of their projects, faster and more accurate modifications of their drawings, 3D imaging, and data from their virtual models to analyze energy performance, lighting, solar radiation, and structure. In construction courses, BIM will improve the students' construction documents, and the understanding of construction elements in their buildings. This is due to the 3D details, and the process requiring inclusion of material specifications to their models in order to use it as the first step of their construction/construction management careers, which is the ultimate focus of this Architectural Engineering program.

4.1. Planning vs Reality, Introduction of BIM in the AE Curriculum at UAEU

In the ideal scenario planned at the department meeting, the introduction of BIM based on Autodesk tools should begin in the fifth semester of the bachelor degree of the building systems course, continuing in the sixth semester in the introductory design studio and building components courses; for advanced students, at the fifth semester in intermediate design studio and advanced building systems, and ending in the sixth semester in integrated design studio. At this point the students should be capable of producing a standalone building information model which contains the architectural, structural, mechanical, electrical, and construction information, and a complete set of drawings.

Beyond this those students who want to continue to improve their BIM skills should take the elective modeling and simulation course, where they can learn how to collaborate in a BIM environment, and develop 4D simulations, schedules, cost management evaluations, sustainability analyses, and first parametric design approaches.

The actual result of the introduction of BIM was a bit different. As Kymmel and Barison[5,43,239] stated, we find that there is a lot of problems in BIM introduction into curriculum, which we will cover in depth in the next chapter. But as a summary, this where the difficulties were found:

- Professors who didn't want to re-design their courses.
- Professors who didn't allocate time to acquire these new skills.
- Professors who didn't update their own skills, even when the university provided a certified course.
- Few professors who allocated some time for this new ICT technology, while trying to keep their courses with the minimum number of changes possible instead of re-designing the course.

The first sketch for introducing BIM in the AE at the UAEU was barely recognizable, and it jumped from a well-designed and progressive BIM-inclusive working environment, to a smattering of BIM knowledge focused in a few specific courses. Nevertheless the students were able to use it, because most of the professors didn’t mind introducing it, especially if they did not have to make many adjustments or take on additional work.

At the end of this study introduction of BIM was done in some of the courses or sections depending on the professors. Few students got to the last skills, which the department was willing to do when we created the plan to introduce BIM. Those students who reached the end did so due to their own determination and the dedication of some professors.

It must be clearly stated and emphasized that the introduction of an ICT technology into the curriculum must be by design and in full consensus with the professors who are going to teach the courses; it should have clear outcomes and procedures for the introduction in order to succeed. If we leave this introduction at each course to the individual professors we will have inconsistencies that can hinder the progress of the students, creating a huge gap in their skills that will be difficult to overcome or compensate for in future courses.

The next table shows the courses where BIM was supposed to be introduced, and the final outcome.

Semester	Construction	Design	Electives and GP		BIM implementatition Comments	BIM
3	**Building Systems:**				Tried at the male section fall 2014-2015, refused by the other faculty. BIM will not be implemented in this courses.	NO
	Introduction to Building Systems					
	Introduction to Construction Drawings					
4	**Building Components**	**Introductory Design Studio**			BIM was implemented during the Fall 2015-2016. The implementation level depends on the Faculty will and not to a clear designed path.	YES
	Detailing	Introduction to Analisys				
	Construction Drawings	Design studio				
5	**Adv. Building Systems**	**Intermediate Design Studio**			Advance contruction is not using BIM but the studens, can use it. Some professors used BIM for Intermediate design some of them don't.	SOMETIMES
	Modular coordination	Design Studio				
	Precast	Sustainability				
	Long Span Structures	Structure systems integration				
	Construction Drawings.					
	MEP & Hvac systems integration.					
6		**Integrated Design Studio**	**Modeling & Simulation**		Most of the students choose to do the BIM elective course, Modeling and Simulation and after this course some of them use them for other courses and GP	STUDENTS CHOICE
		Design Studio	Design studio system integration process			
		Sustainability	Management and operation integration			
		MEP & Hvac systems integration				
7			**Modeling & Simulation**	**Graduation Project II**		
			Design studio system integration process	Construction problem solving.		
			Management and operation integration	Report Writing		
				Research		
8			**Modeling & Simulation**	**Graduation Project II**		
			Design studio system integration process	Construction problem solving development.		
			Management and operation integration	Construction documents		
				Report Writing		
				Research.		

Table 4.01 Current Introduction of BIM in the AE program at the UAEU

As seen in this table, BIM is mainly introduced in the fourth semester instead of the third as expected, and it only continues into the fifth semester depending on the professors and the course. Only the students who are really willing to progress in these skills will continue with it. In this research we will provide data about the students' usage of BIM based on Autodesk tools in the construction II course (BCC), their performance, satisfaction, motivation and opinion. The next paragraphs will explain the reaction of the professors in each of the disciplines where BIM was planned to be deployed.

In the construction courses we found three different situations. In the first course, after completing a successful trial, the main professor in charge of the course decided not to continue it and returned to the previous design of the course, using Autocad instead of BIM based of Revit. In the second course of construction the main instructor was willing to use these skills but not to modify the course. We tried to combine the previous course design, simply adding in BIM skills. As we will explain in the data and discussion, this created problems that were solved by splitting the lab sessions before and after spring break. For the third and last course of construction, the professor allowed the students to use the tools that they wanted, but he was not willing to allocate any time to practice the skills; the students were assumed to have enough skills on their own if they were interested in using it.

In the design courses there were two situations depending on the professor of each section. In the sections with one of the four professors who were willing to introduce BIM, they made lectures to improve their skills and encouraged them to use it. On the other side most of the professors let the students use whatever tools they wanted, but they didn't allocate any class time for learning skills and most of them could not assist their students because they didn't have the skills themselves.

In the modeling and simulation courses, the university changed the professor in order to acquire someone with a completed PhD; this new professor didn't have the skills yet, even though he did his best and improved his skills a lot doing a good job.

In the graduation project, it is up to the students if they are willing or not to use BIM. There are some great examples from those students who pushed themselves to use BIM; with the help of their professors they were able to develop the whole building, structure, sustainability and MEP, as if it was an actual, real-world project.

We need to cement a proper introductory methodology for BIM. Currently we are relying completely on each professor who is leading the course, which makes it very difficult to provide consistent and equivalent knowledge and skills across the board, and it is impossible to get a homogenous and constant level though out the years. A database of knowledge should be established that will detail what should be accomplished at each level of BIM skills, depending on the practice.

4.2. Difficulties in introducing ICTs and BIM into the AEC

Both in academia and the AEC industry, there are a lot people without the current ICT skills required.[5,240-242] Some are resistant to changing acquired and long-standing habits.[243] Among the younger generation there is a better attitude towards technological advances than to other type of changes,[244] whereas older people are typically resistant to this change. In order to maximize the possibility of adopting new and innovative improvements, we should focus on building the positive motivation of the target people towards accepting ITCs.[241]

When looking at introducing ICTs into academia, we can consider some of the problems identified with ICTs and BIM in the AEC industry[243]:

- complexity of the project due to the large amount of disciplines which are involved;
- immaturity levels of ICT and BIM;
- lack of understanding of the introduction process for ICT.

The lack of the understanding and framework about introducing ICT is the main concern of this thesis, which focuses on the introduction of BIM at the AE in the UAEU, as a first step towards creating an introduction framework for BIM in the AEC curriculum through construction courses. There are three features directly relevant towards people's behavior against change: first the perceived utility level, perception about the difficulty to use the ICT in question, [244] and lastly personal motivations.[241]

ICT Innovation in the AEC curriculum and industry is a very slow process compared to other engineering departments,[245,246] because of the artistic part of the process, the different disciplines involved, and also the lack of I+D investment[247] all of which mark the AEC industry and academia. There are significant differences between an AEC project and any other industrial product, which makes this introduction more difficult. One of them is the singularity of each product, which affects directly not only the industry but also academia. The ICT cannot be taught to be used in only one way in BIM, because each product will be different and may require a different approach, skills, or even tool as there are many different tools in BIM depending on the process, complexity or discipline. It is not the same procedure to create a model of a square building as a curve-shaped one, or one with movable and parametric elements; and also it is a totally different approach for developing the architectural design, structure, planning etc. -- each of them will require different levels of knowledge and skills in terms of the use of the same BIM concept.

In order to accomplish a proper ICT and BIM introduction in the AEC industry and curriculum we have to overcome people's conservatism and their resistance to change. These people prefer to continue with their traditional work and teaching methodologies, instead of applying new ICT. Part of this rejection is due to the uncertainty involved with new procedures and a lack of skills.[80]

There are two main studies about the primary difficulties in introducing BIM into the AEC curriculum, Kymmel in 2007 and Barison in 2012. Kymmel[5] divided the difficulties into three different categories:

- Academic environment -- the amount of time required, the nonexistence of a framework for the introduction, a lack of resources, and the difficulty in modifying the curriculum in order to introduce BIM.
- BIM concepts – the absence of collaborative practice in academia or a traditional teaching methodology.
- BIM tools -- how to accommodate creativity within the project, the new learning environment, and a lack of previous data.

On the other hand, Barison completed a much deeper study, where she identified four categories:

- Methodology – no introductory framework for BIM, and difficulty in teaching BIM concepts or skills.
- Faculty -- skepticism about BIM as an effective tool to teach in the AEC curriculum, lack of skills, an unwillingness to learn the skills and change the curriculum, and the difficulty in doing so.
- Certifications – a lack of framework for teaching BIM, insufficient space and time, no orientation in the curriculum that would facilitate adopting BIM skills and concepts easily (would necessitate a long time to accomplish), complexity in integrating different areas of expertise into the curriculum, and the range of disciplines and levels of knowledge that BIM requires.
- Resources – an absence of specific resources to teach BIM, such as powerful computers, to use the BIM tools and a diversity of software, which is in an early stage of development and use by the industry; difficulty in aligning schedules between different disciplines to accommodate the large number of students in the class.

After analysis of the current research, we can focus our own research experience during this thesis. We have collected data about the deviation between the program expectations and the real accomplishments. Here we will explain the different situations that occurred while trying to apply the plan that was approved and agreed upon in the AE department planning meeting. We can provide first hand examples that can easily be assigned to some of the categories from Kymmel and Barison.

- The University provided a Revit and Navisworks certification course for faculty at the UAEU for 25 people, only 1/2 of the faculty attended the whole course and obtained the certification, but no one attempted the exam to receive the official Autodesk Certification instead of the one provided by the supplier. Another 1/2 of the faculty just came once or twice to the workshop and then never come back.
- From those faculty who did the course, only four of them were using this knowledge in their courses.
- From the design courses only in those where one of these four professors were assigned were the students able to submit projects using Revit, and received some help to develop their skills, while in the other sections students who asked for this help did not receive any response.
- From the Construction courses:
    - In the basic construction course, the main professor directly refused to use BIM or Revit tools to avoid modifying the course, claiming that AutoCAD was best for students to deal with the exercises.
    - In the intermediate construction course, the main professor was trying to improve his skills and willing to add BIM into the course as soon as the course was barely modified.

- In the last course of construction, the main instructor didn't care if we added BIM, Revit or any other ICT tool or not. He would not modify the course at all, so those who already had the skills could use these new ICTs to deliver their assignments, but he wouldn't provide any time to help develop their skills or teach how to apply them in the course. His own opinion was that construction knowledge was the main part of the course, and the tools to deliver them should be taught in a specific course. This is very a respectable opinion but also a way to avoid the change.

These statements are not meant to underestimate, mislead, or suggest a lack of professionalism or something similar, but to confirm all the prior literature review conclusions regarding how people commonly are averse to change and are willing to continue with their habits and traditions as far as they are able when not motivated. The training and improvement of faculty skills is one of the keys to properly introducing ICTs at the higher education level. If the faculty attitude and motivation are not favorable towards ICT, changes will not be possible. [182]

As we can observe from all the literature research and data collected in our thesis, the main problem with introducing a new ICT into AEC academia is the resistance of people to change their habits and traditional working processes. In order to make this easier the literature review highlights that we should improve the motivation and satisfaction, and create a clear process to introduce it. This thesis works on these three aspects, adding a fourth point -- performance in the courses -- which is mainly related to academic content. This thesis aims to be a first step towards an introduction framework for BIM and new ICTs in the curriculum of AEC fields.

We must understand that nowadays IT technologies are everywhere, and they are changing our society. The way people interact and behave is being modified by ICTs; however the inclusion of a new IT technology into the learning process is not an easy experience and does not always succeed, as we already stated in this chapter.

In fact there are several documented problems and failures in educational IT implementation[233,248,249] Due to this difficulty there is a wide variety of articles which examines this issue from different points of view, including the teaching methodology, content design and effectiveness of IT technologies in higher education implementation;[250,251] the main barriers to accomplish this introduction;[5,96] and articles which are specifically identifying "*good teaching practices*,"[252-254] in order to reduce this resistance to change.

All efforts towards the implementation of IT into the curricula are focused on the improvement of the students' learning process. In order to succeed there are some so-called "*good practices*" and [255] recommendations based on previous studies:

- Promotion of a more communicative professor–student environment, allowing more interaction and an effective feedback process.
- Dynamic development among students, which is made possible by collaborative techniques.

- Contribution to better task realization by heterogeneous learning methods, meeting high expectations.
- Applying teaching/learning methods based on teaching innovation and new IT technologies.

It is very important to understand that to succeed in introducing a new ICT we need to engage the faculty and the students, increasing their motivation and satisfaction.

4.3. Introducing BIM skills into Construction I (BS)(male section)

The introduction of BIM based on Revit into the BS course was a positive experience, but it was done only one semester in the male section only. It was performed by two young professors as an experiment, in order to convince the department and other professors of the benefits of BIM and the project based learning (PBL) methodology; but after one semester the experiment was cancelled and the course has remained the same since 2013.

In this first approach to BIM introduction into the construction courses, we tested the method only at the male section, while both female sections remained the same. We used the same lectures in all sections to maintain some consistency. We modified the course assignments, from a traditional approach of lectures and assignments to a mixed method approach of lectures and project-based learning sessions. In the traditional approach delivered in this course, the student has to reproduce the content of the lectures to understand and memorize the topics. In our PBL experience, the students built and developed a 3D model of a building, analyzing, selecting and applying different construction systems. In the course of the assignment the project evolves and the students need to modify the structure, allocate stairs, and continuously add new components and systems.

During this process the students discover through their projects construction issues by themselves, research for alternatives, and apply different solutions. By all these processes they learn by themselves how to search, think, and select with criteria, in order to apply alternative solutions to solve the problems and modifications of their projects.

Lectures		Lab Sesions			
Week	Topic/Subject	Course with out BIM	Week	BIM Project based course	
1	Orientation & Course Overview		1	EX01 Basic Skills, Plan Section and elevation, drawn by Hand and AutoCAD	
2	Understanding Buildings & Load Distribution, Construction Terminology, Standards, and Codes	EX01 Basic Structural System	2		
3	Buildings Materials & Principles of Working Drawing Process		3		
4	Short Span Structural Systems: Bearing Wall System	EX02 Floor and Roof Systems Application of Masonry walls and Stud Partitions	4	EX02 Structure systems. Foundation, columns, retaining walls, one way and two way slabs.	PROJECT
5	Short Span Structural Systems: Skelton System		5		
6	Foundation Systems	EX03 Foundation Systems	6	EX03 External walls, flooring, add cantiliever to the structure.	
7	Floor Systems		7		
8	Mid-Term Exam				
9	Spring Break March 29th - April 9th				
10					
11	Roof Systems	EX04 Wall Systems	11	EX04 Structure modification. Metal decking, open web joist. False ceiling.	
12	Wall Systems	Presentation I	12		
13	Openings and Wall Components	EXOS Long Span Structure	13	EX05 interior partitions, wood and metal studs.	
14	Moisture and Thermal Protection		14	EX06 Add to the model Stairs. Reseach stair detailing and conections.	
15	Long-span Structural Systems	Presentation II	15		
16	Vertical Circulation	EX06 Vertical Circulation Application of staircase design and structure	16	EX07. Add doors, windows and create schedules and quantities. Research windows and doors details.	
17	Concrete Stair Cases		17	EX08 Create the site plan, print in pdf and A3 paper all the architectural and structural plans.	
18			18		
19	Final Exam				

Table 4.02 Traditional VS BIM Project Based Learning course Outline

4.3.1. **Student Performance Assessment & Grading Criteria**

Throughout this course the student gained knowledge and competencies that were evaluated using different assessment techniques. This course allocated 40% of the final grade to the students' performance in the lab sessions where we used a PBL-Revit methodology. The other 60% was allocated for exams and class participation. The following grading percentages were applied: assignments and presentations: 40%; class participation: 10%; mid-term exam: 20%; final exam: 30%.

The assignments were graded using the following criteria:

- Understanding of the construction problem; design of a solution based on the literature review, case studies and problem analysis;
- Application of criteria to select the appropriate construction systems;
- Integration of both these systems and its components into the project; proper integration and application of building standards and building codes;

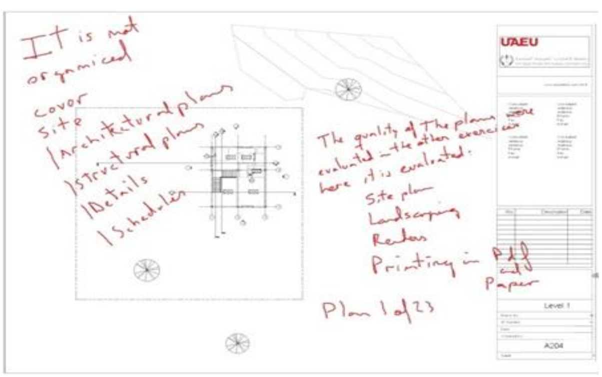
- Pre-calculation of structural elements;
- Capacity to produce quality and well-defined building construction drawings.

4.3.2. New Academic Approach to Building Systems Course

In a BIM environment, the program generates the plans from the model and the approach for the students is very different from the traditional one. The students work to understand the plans and improve them, so we develop critical thinking instead of mechanical processes. However the students need a proper background in drawing skills to understand the plans done by the program from the 3D model, and also to determine their level of detail, the type of connections, and correctly modify the ones that do not meet their design. After this step they learn all the construction drawings that should be delivered to define a project. We introduce and organize the drawings by categories and sub-categories, to create a whole set of plans from the beginning, which they develop further throughout the course.

As scholarship describes it "*the model's output would produce all the documentation that the team members would otherwise have to create in isolation and duplication*" [256], the integration of the whole project and subjects is a counterpoint to the isolation that the traditional learning process produces in each course. This has a huge effect in the learning environment and understanding that all of the courses are part of the same knowledge base.

BIM is represented in the BS course by Revit which is a very powerful tool to develop a BIM model. The students spend less time generating the plans, sections and elevations, and this extra time can then be used to guide them through a project where they apply all the concepts from the lectures. They can also use this extra time to understand the building systems concepts and develop other skills related to construction detailing, problem solving and design process.



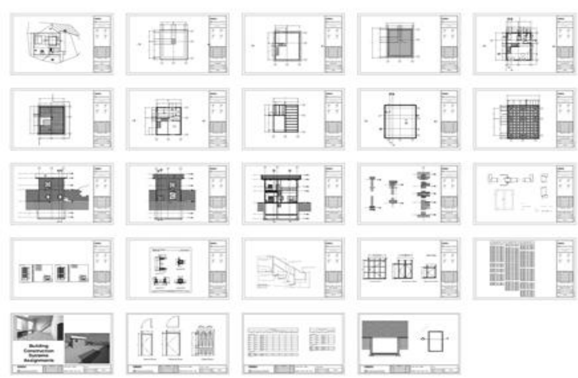


Figure 4.01 & 4.02 Student BS Spring14 submission

4.3.3. Building instead of Drawing

The project based learning environment that we created in the lab sessions simulated a construction building site process, while introducing design changes to develop the project. The students built their project in the same order that they would have done on a real construction site, but with the opportunity of modifying and trying alternatives.

The students began creating the columns, retaining walls and foundations. Then they created the main beams, the beam systems (one way and two way) and the concrete slabs. The student had to deal with different kinds of structures, modify the structure type during the project from concrete to steel, add a cantilever to the slab analyzing the proper direction of the beams, and reorganize the beam systems to place the stair.

The process of creating and modifying the building provides a more comprehensive methodology for the students to understand the building, its parts and processes by themselves. The students develop step by step the whole building while they study or research each building system. This learning process creates an interactive environment where the students build what they learned in the lectures or researched by themselves. This process checks their understanding and knowledge creating a very solid base. By this exercise they assimilate the function of each element, the proportion and order. Creating a cantilever and allocating the stairs are small exercises that make them realize the importance and function of each element of the structure.

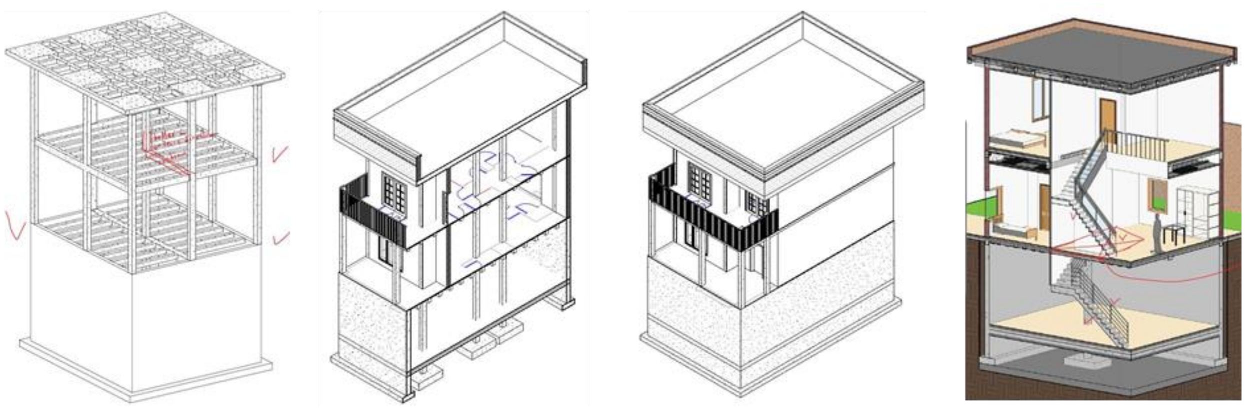


Figure 4.03 3D views of building during different exercises (Students BS Spring14)

4.3.4. Building Components in the BS Course

The approach to building components using BIM is completely different from the traditional academic one. The students have a large database, which gives us the opportunity to focus on the function of each layer instead of explaining the layers of the component itself. The first assignment is to analyze the needs of a building component and select two different alternatives and explain to the class the reasons for selecting each; this creates a debate about the alternatives chosen by the students and their reasons. As a second assignment they have to look for the physical properties of specific materials that we selected to create a new alternative that is not already in their database.

The students need to understand the hierarchy of the different elements and the layers inside of them. It is amazing that the problem that Revit has to create proper joints between different construction elements is a powerful opportunity for the students to learn. As a third exercise they have to point out the function of each material at the encounter of a wall and a floor system. After knowing the functions, they have to organize the layers manually. Again we can discuss with the students the different solutions proposed and their viability.

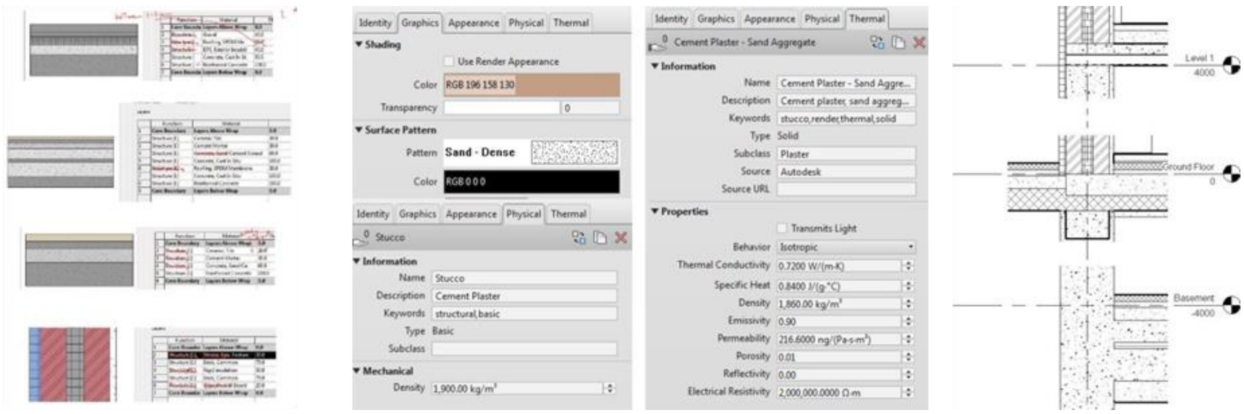


Figure 4.04 Created elements, joints between different elements (Students BS Spring14)

4.3.5. Multiple-dimension Approach

The model contains 2D and 3D aspects, and properties like dimensions, cost, areas, U value, CO_2 values, etc. The parametric design emphasizes several factors.

- First as we build instead of draw, when we need to modify an element we just have to change its type. This is not as quick as it seems because we have to check and remodel the joints between the new elements and the old ones to be the way we want. This forces the students to review and rethink the details each time we change an element. This is a good opportunity for the students to review their work and foster critical thinking.
- Second the parametric information of the project is updated in real time. This gives us the opportunity to have updated quantities, schedules, take off materials and key legends for the different design options and construction stages. As Dr. Bedoya [257] Stated in 2008 that the "*multi-dimensional approach allow us to see how the pieces of their project fit together in real time*."
- Third the use of a multi-dimensional approach for academic purposes gives us the opportunity to make more accurate and data-based decisions for our projects allowing a very quick and interactive lecture and analysis using 2D, 3D, quantities and schedules where we can compare properties.

As a sample for the opening lecture, we use the 2D approach to explain the doors and windows components, and the 3D approach for the students' research products; and we analyze how they will adapt the product or their walls to make them a proper fit, create schedules and quantities, and compare the properties and cost of the different types of windows.

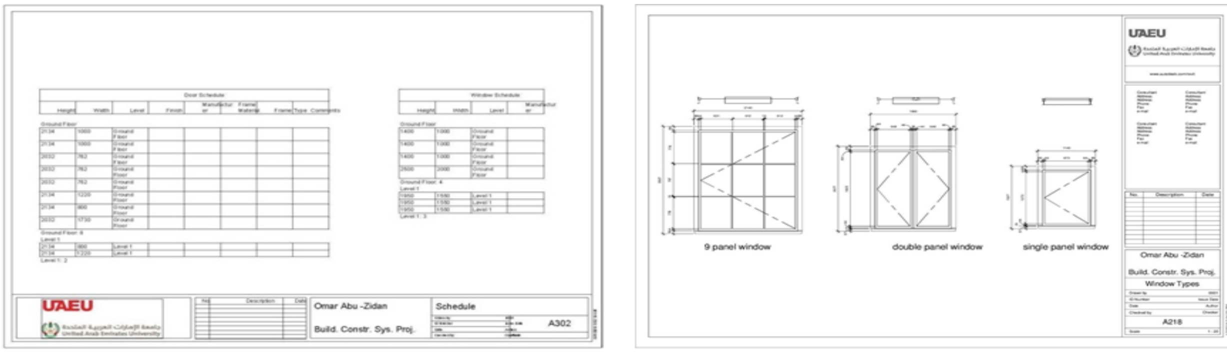


Figure 4.05: Windows assignments (Students BS Spring14)

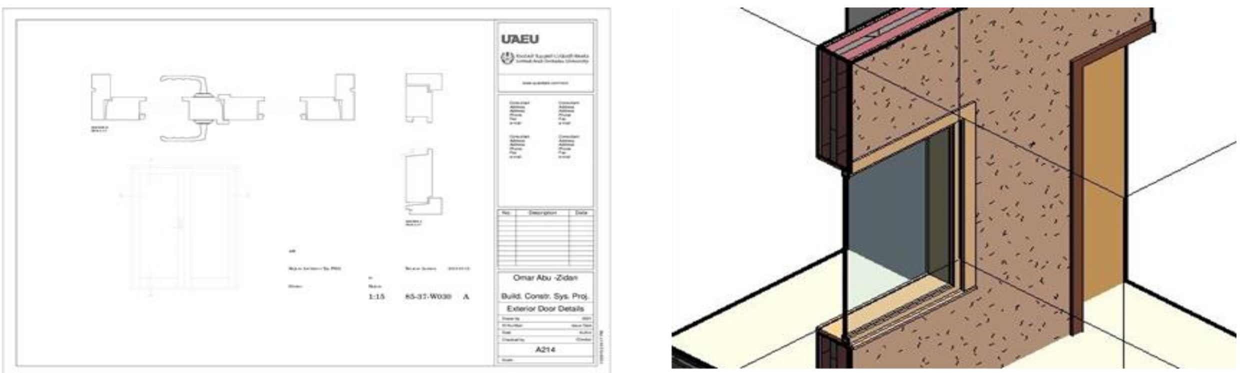


Figure 4.06 Windows assignments (Students BS Spring14)

4.3.6. **Remodeling, Redesign and Re-detailing, Keeping Drawings Updated.**

BIM simplifies the construction drawings and keeps them updated. We have to make sure that all the joints are properly done, as has already been stated, but also that they are updated. The students see the changes in real time in 2D and 3D. This makes the tool their perfect partner to learn, try, investigate and rethink the spaces and details of their projects.

During the course the staircase leads us into the first developing element of their project. As a project based learning course, the students have to analyze their project and find the most appropriate place for the stairs. After this location is defined they will have to analyze and modify their structure to make it suitable with the hole they need to create in the slab. This will make the students realize the consequences of each decision. They will also need to take care of the ceilings, walls and the space under the stairs.

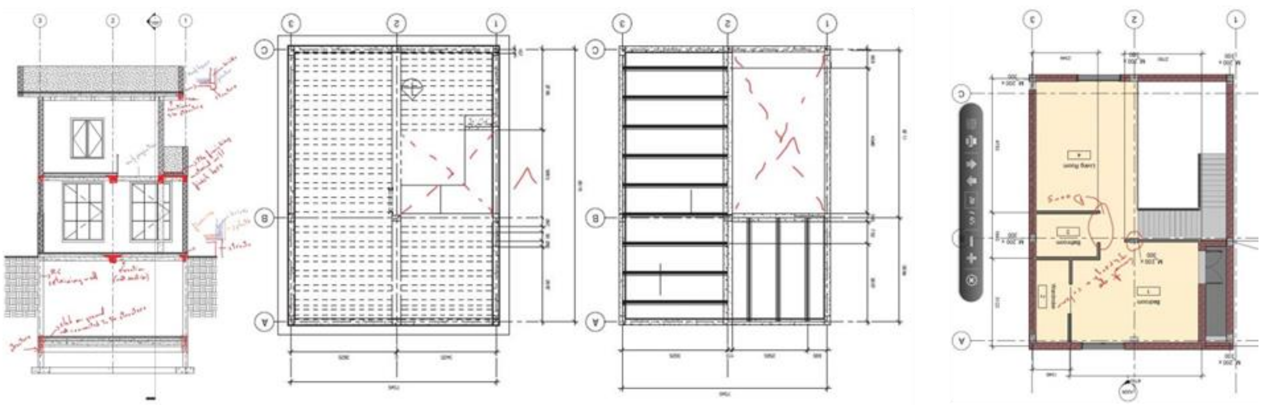


Figure 4.07 Section development, Structural plan alternatives, Final plan (Student BS Spring14)

4.3.7. Conclusions

The first and unfortunate conclusion is that despite all the evidence provided, the experiment was canceled and the main instructor decided to keep the course as it was, without introducing any changes to improve the course or introduce BIM as discussed it the department committee meeting. For the experiment conclusions we must say that it was a great experience which enhanced the students' learning and inspired them to achieve more in architecture and new technologies.

Even though the initial perception was that students would apply more effort in a 2D environment and they would learn more because of this effort, the results of applying a BIM 3D technology like Revit in the BS course revealed several factors which tilt the balance in favor of BIM.

The new strategy provided a better and quicker understanding of the course content by the students, due to the 3D model that they built instead of drew. This also helped the students to understand the relation between the elements by themselves. Each time a student created two different elements that intersected, they had to move from the plan to the specific section to adjust the type of connection and the level of each material. This forced them to make decisions which led them to develop knowledge and think critically.

The application of BIM 3D technologies reduced the time invested in physical drawing, time that was very beneficial for working further with the students. We could go deeper into each chapter, include new chapters, or let them think outside the box, developing the students' research, analytical and critical thinking abilities. The students spent less time drawing and modifying each plan, section and elevation, and had more opportunity to think about alternatives and solutions for each issue and connection.

BIM can be used to implement a whole set of working drawings, that the students will develop in their specific courses. This will help the students create an organized base from which to build their knowledge in an integrated manner.

BIM is the perfect way to introduce a project based learning environment, which creates a totally different learning environment. The students are not taught the solution, but the principles that lead them to solve problems by themselves under the supervision of their professor. The change is not based on BIM but it helps. The professor shifts his role during the lab sessions from instructor to become more of an advisor.

Project based learning enhanced by technology creates an environment where they can develop and integrate knowledge from all of their AEC courses. Using the information acquired in this course as a base, in their subsequent courses the students will have the opportunity to integrate MEP, HVAC, Structures, Sustainability, Scheduling, Quantity survey, Management and Maintenance into their projects. This will lead them to understand the whole process as one, and the relation that each of them has to their designs and construction projects. This makes a huge difference in the learning process and their understanding of the AEC industry.

To conclude, BIM gives the students an enhanced motivation due to the real time visualization of their projects. The students have the opportunity to have 3D sections, details and images of their projects. This encourages them to increase the effort and time they dedicate to the project.

Figure 4.08 Section development, Structural plan alternatives, Final plan (Student BS Spring14)

4.4. Introduction to the Experiment: Introduction of ICT in the BCC Course

After a brief analysis of construction courses, and several semesters of discussions to introduce BIM based on Revit at the construction cluster, we discovered that the professor of the Building Systems course was directly against the idea of introducing a new concept for a working environment and new ICT tools which would modify the course. As we explained in section 4.3 it was an attempt to introduce ICT in a BS course in the male section, but even though the results were good it was not enough to convince the main professor of the course to change his mind.

After this first trial at Building Systems, we attempted to begin the introduction in a Building Components course. The response from the professor was positive, letting us use half of the lab session to introduce BIM based on Revit and generate a model of the building they were detailing. At this first stage we were trying to complement the AutoCAD detailing assignments from the former course, by using a BIM model which created a set of working drawings instead of isolated assignments. After this first approach, we decided to re-design the course schedule and also the scope of introduction in this course due to the data of this study, as we will explain later. We improved the focus from only generic construction drawings to construction drawings and 2D-3D detailing. In this way the students will understand, create and deliver better designs and details.

Advanced building systems is the most complete and complex course of construction in the AE department, and the students do not have the capability to deliver all the required documents by BIM tools within their current level of skills. Due to this reason we provided the students the opportunity to deliver by CAAD or BIM as per the individual student's convenience. The few students who did a Modeling and Simulation elective course before ABS, tried using BIM tools and successfully did so in the course.

After this analysis, it was clear that our study would be performed in the Building Components course, because it was the only course where we could perform continuous data collection and analysis of the students' progress through several semesters.

4.4.1. Former Building Components Course (BCC) Description

The Building Construction Components (BCC) Course is the intermediate Building Construction Course in the AE program at the UAEU. At this stage the students learn the building construction components properties, specifications and application methodologies in order to be able to create their own details for their projects. During the BCC Course we introduce the students to different types of floor systems, interior and exterior wall systems, false ceilings, building joints, vertical circulation, and openings.

This course is primarily oriented around lectures, in-class discussion, on-line e-learning and hands-on activities during practical hours. The course is organized around a series of interrelated instructional topics. A significant portion of the course material is technical information that requires frequent class discussions and small group interactions. Development of students' ability to work in teams is an important element of this course. Students are required to come to class on time, take notes during classroom lectures and discussions, analyze assigned readings, and work in class during practical hours [Table 6].

The course has four main elements: lectures where each subject is introduced by the professor, individual research about products available in the region and innovations, in-class discussion about the lecture and research findings, and using sketching and AutoCAD. Each student is required to develop their own details for their project, using one of the products available in the market.

4.4.1.1. *Attendance & Conduct*

Perfect and punctual attendance is expected. UAEU attendance and conduct policies are fully implemented.

4.4.1.2. *Course Learning Objectives*

- To strengthen the student's vocabulary of both internal and external treatment and finishes of the building by enabling him or her to choose appropriate finishing materials, techniques, and construction methods for spaces, according to type and function.
- To acquire knowledge of vertical circulation elements needed for technically efficient buildings.
- To acquire knowledge of openings and their construction components.
- To understand basic construction terminologies and building codes.
- To utilize the student's knowledge of building materials, building components and openings in the construction process.
-

4.4.1.3. *Course Measurable Outcomes ABET (A – K)*

- Acquire knowledge of basic internal and external finishes, vertical circulation elements and openings needed for technically efficient buildings (C) [MQ, FQ, AQ, AR].
- Understand building joints and services needed for technically efficient building construction (E) [AQ, AR].
- Draw accurate details to allow authenticity in developing building design schemes (E) [MQ, FQ, AQ].
-

4.4.1.4. *Student Performance Assessment and grading criteria*

Throughout this course students are gaining knowledge and competencies that will be evaluated using different assessment techniques. This course devotes 50% of the final grade to the student's performance throughout the semester. The other 50% is devoted to exams. The following grading percentages were applied:

- Assignments and presentations: 40%
- Class Participation: 10%
- Mid-Term Exam: 20%
- Final Exam: 30%

The following are the main assignment grading criteria:

- Understanding: well-defined problem and clear design intent based on literature review, establishment of needs, and case study analysis.
- Application: Selection and integration of appropriate construction system, its components, and relevant construction methods.
- Standards and Building Codes: Application of Building Standards and Building Codes.
- Calculation: Relevant to the selected construction system/components.

- Building Construction Drawings: Technical and graphical expression of building materials, structural system(s), and construction methods.

4.4.2. Course Outline

Week Number	Session Topics	
	1st Session	2nd Session
Week 1	Introduction to the BCC Course (Syllabus + Revision)	Lecture 1: Internal Finishes: Plastering & Paint
Week 2	Assignment 1: Group Research for Plastering & Paint [In class – Submission by the end of the class]	Lecture 2: Internal Finishes: Floorings
Week 3	Assignment 2: Individual CAD drawing for Internal Finishing [Start In class]	Lecture 3: Internal Finishes: light weight partitions
Week 4	Assignment 3: Group Research for Demountable Partitions [In class – Submission by the end of the class]	Lecture 4: Internal Finishes: Suspended Ceilings
Week 5	Assignment 4: Individual CAD drawing for Demountable Partitions & Suspended Ceiling. [Start In class]	Lecture 5: External Finishes: Plastering + Cladding
Week 6	Assignment 5: Group Research in Cladding Systems [In class – Submission by the end of the class]	Lecture 6: External Finishes: Metal & Glass Curtain walls
Week 7	Assignment 6: Individual CAD drawing for Cladding and C [Start In class]	Quiz 1: Internal and External Finishing
Week 8	General Revision & Open Questions Session	Mid-Term Exam
Week 9	Mid-term Revision	Lecture 7: Building Joints
Week 10	Class Activity: Individual CAD drawing for Building Expansion Joints	Lecture 8: Openings: Doors and Windows Components
Week 11	Field Trip	Class Activity: Discussion (Field Trip)
Week 12	Assignment 7: Group Research in Doors & Windows Components [In class – Submission by the end of the class]	Lecture 9: Service Components: Ducting, Floor Trench, Floor and wall Chase
Week 13	Assignment 8: Individual CAD drawing for Doors and Windows [Start In class]	Quiz 2: Openings
Week 14	Assignment 9: Group Research about Steel Staircase [In class – Submission by the end of the class]	Lecture 10: Vertical Circulation: Steel Staircase
Week 15	Assignment 10: Individual CAD drawing, Steel Staircase [Start In class]	Lecture 11: Vertical Circulation: Elevators, Escalators and Conveyors in Building Construction Drawings
Week 16	General Revision	Open Questions Session
Final Exam [date/time as announced]		

Table 4.03 Course outline Lectures and Assignments Fall 2014/Spring 2014

5. Methodology

The methodological approach for this study is a mixed method methodology, which uses quantitative data to evaluate the performance of the students during the course, and qualitative data to understand the reasons behind it. This methodology is based on the studies of Fonseca and the Gretel group and their publication about the introduction of new ICTs in the Architectural curriculum,[41,222,255,258-265] all of which provide the proper background of a well-tested and trusted methodology.

The quantitative data allow us to evaluate the performance, motivation and satisfaction of the student population. The data is tested by a nonparametric test due to the smaller number of samples, which do not provide an accurate normality test. The test used for this will be explained during this chapter, and we will analyze both dependent and independent samples. Nonparametric tests are more accurate for non-normal distribution than the usual P-test and two different groups of students are represented by Anova.

We will study the introduction of this technology in several courses of the Architectural Engineering department of the UAEU. We will analyze the quantitative data and then we will interview the students in order to understand how the introduction of these new technologies affect the students and the approach to the course. Based on our hypotheses, the data obtained from the academic files, the interviews with the students and analytic study of the data, we will discuss and conclude a set of recommendations to introduce Revit into the construction courses in the AEC curriculum to prevent a drop in the performance, skills and knowledge acquisition of the students.

In order to understand properly our methodology design, we should first review the most important research design methodologies, their differences and uses.

5.1. Research design methodologies

There are three main groups of research methodologies -- qualitative, quantitative and mixed methods. The quantitative method is used to test a hypotheses quantifying with statistical data the relationships between specified variables.[266] The qualitative method represents a wide variety of data collection methods such as interviews, observations and ethnography where the results are not statistical;[266] this type of research emphasizes the case and context of the research to determine "*authentic interpretations that are sensitive to specific social-historical contexts*."[267] The mixed method approach uses both types of data to reach the best explanation for a problem, creating a specific method designed to provide the ideal opportunities to explain the research hypotheses using the quantitative method to reach a conclusion and a qualitative one to understand the reasons behind that conclusion. We should take into account that simply using both methods does not add substantial value to the research in and of itself – there must be a proper design.[268]

Once we understand the three different types of research methods, we will turn to the different research designs in order to understand and allocate our quantitative, qualitative and mixed method approach for the research. We won't consider in this thesis the survey as a research design but a type of data collection method.

TABLE 2.1 Research Designs

Quantitative				
Experimental	Nonexperimental	Qualitative	Mixed Method	Analytical
True experimental	Descriptive	Ethnographic	Explanatory	Policy analysis
Quasi-experimental	Comparative	Phenomenological	Exploratory	Concept analysis
Single-subject	Correlational	Case study	Triangulation	Historical analysis
	Survey*	Grounded theory		
	Ex post facto	Critical studies		
	Secondary data analysis			

*Surveys are classified here as a type of research design. Surveys can also be classified as a type of data collection technique.

Table 5.01 Research design typologies [268]

True experiment (quantitative research method). Even though we are not going to perform a true experiment, it is included in this research design section because it is considered in many disciplines as the main research design methodology. The definition for a true experiment is a consensus in the research community and we can define it as an experiment which manipulates one or more independent variables, using a control group and randomly selected subjects. We can find alternative definitions from different articles,[269-274] but all of them are synonymous.

Quasi experiments (quantitative research method). This is the quantitative type of experiment that we are using in our research. There are a lot of definitions for quasi-experiments but the one which we use for this study states that a quasi-experiment is an experiment where the subjects of study are not chosen randomly. This kind of study allow investigations of cause–effect relations in settings in which randomization is inappropriate, impractical, or too costly.[270] In our research, as we are studying the effects of introducing new ICT in a specific case, we cannot randomly choose our subjects, they have to be the students in our courses.

One of the main and first definitions for quasi-experiments is a set of settings that permit some control over the scheduling of data collection even though one does not have complete control over the scheduling of experimental stimuli as provided by randomization.[269,273] Different types or examples of quasi-experiments include the simple interrupted time series design, the time series design with a control group, and the nonequivalent control group design. [258]

Descriptive (quantitative research method). During this research we will use this methodology in order to analyze the students' profiles. This design methodology provides a summary of the existing phenomena by using numerical data to characterize the group under study, which in our case are groups of students, and by these means assessing the nature of existing conditions. [268]

Comparative Descriptive (quantitative research method). In this type of study there is no intervention, only analysis and comparison to understand the similarities and differences between two or more groups. We will use this design in order to compare the groups of students that we will describe and to understand the confidence level when we compare the data from different groups.[268]

Case study (qualitative research method). This is one of the most used qualitative research design methodologies used in architectural research, which is defined as an empirical inquiry investigating a contemporary phenomenon within its real-life context, using multiple sources of evidence and striving to explain how or why something happened by logically linking the data to the propositions supporting one rival hypothesis versus others.[269] If we look for other definitions we can see that Robson states that "*a Case study is a strategy for doing research that involves an empirical investigation of a particular contemporary phenomenon within its context using multiple sources of evidence*;"[275] Yin states that "*a Case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and its context are not clearly evident*;"[276] and Benbasat states that "*a case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups, or organization)*."[277] The boundaries of the phenomenon are not clearly evident at the outset of the research and no experimental control or manipulation is used.[278]

The three definitions agree that a case study is an empirical method aimed at investigating contemporary phenomena in their context. Robson calls it a research strategy and stresses the use of multiple sources of evidence, [275] Yin denotes it an inquiry and remarks that the boundary between the phenomenon and its context may be unclear,[276] while Benbasat makes the definition somewhat more specific, mentioning information gathering from few entities (people, groups, and organizations) and the lack of experimental control.[277] The three definitions together emphasize important characteristics of case studies.[278]

After the analysis of the actual definitions, we find that in a case study analysis there is no control in the experiment. In this study we will have small control over the course of study, so it is not strictly a case study analysis.

Action research (quantitative research method). This method is closely related to a case study but with a purpose to "*influence or change some aspect of whatever is the focus of the research.*"[275] In some definitions, a case study is purely observational while action research is focused on and involved in the change process. In software process improvement[279,280] and technology transfer studies[281] the research method has clear characteristics of action research, although it is sometimes referred to as an "*iterative case study*."[282] In IS, where action research is widely used, there is discussion on finding the balance between actions and research [283,284,278].

In this research, the course of study is lightly modified by introducing a new ICT skill which is needed for the students' future careers. The objective is to improve the students' experience and performance while they learn a necessary tool. As we have a small part of control over the course content and deliverables, we have to consider that our qualitative study will be an iterative case study or action research more than a pure case study, which by the definitions provided would be a purely observational case. Finally there are two last types of research that need to be explained to fully understand this current research.

Explanatory (mixed-method research). In this methodology the quantitative data is collected first, and depending on the data analysis the qualitative data will be collected in order to explain, support and improve the understanding of the statistical data.

Triangulation (mixed-method research). In this type of design both data quantitative and qualitative data are collected at the same time, and are used when the strengths of one method offset the weaknesses of the other, so that together they can provide a more accurate set of data. Theoretically this approach is applied to provide a more complete, accurate and valid result.[268]

5.2. Thesis Methodology Design

After understanding these different types of research, we will explain deeply all parts of our research. The main picture of the study is defined as an Explanatory Research Design, or also called a Sequential Explanatory Design. We will first collect quantitative data, and afterwards conduct interviews of the students and the professors to be able to understand the effects on the students of the modifications done in the course.

The quantitative data of this research is divided in four types: performance, student profile, motivation, and satisfaction. For the performance data collection and analysis we created two types of experiment design -- a quasi-experiment at the course of BC where we introduced the new ICT skill, where we modified the course content and evaluated the direct effect of the changes in the students' performance; and a comparative descriptive design for the previous and following courses to analyze.

The qualitative data of our research was collected as three different elements:

- samples of the students' work, which is proof of the changes implemented in the courses; mainly a documentation of the process and an element to double check the performance that we analyzed with the grading;
- students' survey comments at the end of the courses, where they had the opportunity to share their feelings and issues within the course;
- and finally, and most importantly, the interviews that were performed with three students from each group, who were selected randomly to discover the reasons under the quantitative data.

All this qualitative data together should provide reliable explanations for the quantitative data and the hypothesis.

Our mixed methods research design is an explanatory design, using a quasi-experiment in order to collect the data from our sample, which is small in number so therefore we cannot select the subjects of study randomly.

5.3. Research Methodology

This thesis studies the introduction of BIM based on Revit in the BCC course, and its consequences on the students. It is very important to comprehend the experiment as a whole before getting into details. Table 7.1 allows us to understand the dimension of the study while providing the timeline where each piece of data was collected.

From the first view we divided the groups of students between groups of control or subjects of the study. The first two groups are the control groups where none of the students received BIM instruction, and the following four groups were under control of their motivation, satisfaction performance and opinion. The last group we have only data until the building components course because the author no longer has access to UAEU data. This study will remain as a closed period of design, development and improvement of the BCC course.

As we can observe in table 5.02, we studied the continuous process of development of four groups of students through the construction courses. We will evaluate the variance in their grading, motivation, satisfaction and opinion to come to improvements that can be made to increase what the students gain from the course, by the proper introduction of BIM technology in the intermediate course of construction.

There are five data collection actions in each semester.

- We collected the grades from the main instructor of the course, divided into theoretical, practical and final grades for each student.
- We ran a pre-test survey during the second and third weeks of the course to understand the students' profile before beginning the course.
- We conducted a post-test survey during the last two weeks of classes to understand changes in the students' knowledge and skills, and their motivation and satisfaction with the course.
- We conducted interviews to understand the reasons underpinning all the data collected and the process.
- Finally we collected graded student samples from the course to really understand the students' work during the course.

Table 5.02 explains the data collection progress, giving us a clear view of the data which will be available for each group, course, and semester. Our analysis and conclusions will be related to the information collected, which is also shown in the table. Each group of students will have data for three progressive semesters in the courses of (BS) Building Systems (construction I), (BC) Building Components (Construction II) and (ABS) Advanced Building Systems (construction III). Our research at UAEU began in the fall semester of 2015, which means that the previous semesters we can only collect the grading data, and it finished in the spring semester of 2017, when the author left the UAEU.

			Fall 2014-15			Spring 2014-15			Fall 2015-16			Spring 2015-16			Fall 2016-17			Spring 2016-17		
GROUP		**BS**	**BS**	**BC**	**ABS**	**BS**	**BC**	**ABS**	**BS**	**BC**	**ABS**	**BS**	**BC**	**ABS**	**BS**	**BC**	**ABS**	**BS**	**BC**	**ABS**
BIM		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**YES**	**?**	**NO**	**YES**	**?**	**NO**	**YES**	**?**	**NO**	**YES**	**?**
1	Grades	X		Got				Got	Control group 1 (only grades available)											
	Pre-test																			
	Post-Test																			
	extras																			
2	Grades		Got				Got				Got	Control group 2 (grades available for BS, BC and ABS, pre-test and post-test only available for ABS)								
	Pre-test										Got									
	Post-Test										Got									
	extras																			
3	Grades	Group of study 1				Got				Got				Got						
	Pre-test									Got				Got						
	Post-Test									Got				Got						
	extras																			
4	Grades	Group of study 2							Got				Got				Got			
	Pre-test												Got				Got			
	Post-Test												Got				Got			
	extras																			
5	Grades	Group of study 3										Got				Got				Got
	Pre-test															Got				Got
	Post-Test															Got				Got
	extras																			
6	Grades	Group of study 4 ABS won't be studied													Got				Got	
	Pre-test																		Got	
	Post-Test																		Got	
	extras																			

Table 5.02 Data collection graphic

As we can read from the table, we collected from the Building Systems course the performance data and the graded samples, to ensure that the students' performances in construction are similar and we can therefore compare the groups. From the Building Components course we collected the performance data, surveys and graded samples but not the interviews, with the exception of the last group which we could not control during Advance Building Systems; and last in the Advanced Building Systems course, we collected all the data, and the interviews which we performed after the course was finished, and the data analysis, to focus the interview in the results to try and understand the students' side, and the reasons for the data we discovered during the analysis.

As we can easily observe in table 5.02 we continuously analyze the construction cluster courses in order to understand the consequences of the changes made in the BC course and how we can improve it to provide better knowledge and engagement of the students in this subject.

Analyzing the table we can read that with this schedule we will have three groups (3, 4 and 5) of students where we will have all the data collected after the BIM implementation; two groups (1 and 2) with partial data before we introduced BIM which will help us to validate, with a certain criteria, results from the students; and the last group (6) as a backup.

As part of the analysis data we will collect extra information that will support the data. These extras will have mainly two elements -- graded assignments as samples of the students' work, and interviews with students who already finished the three courses of construction.

5.4. Quantitative Data Collection and Analysis

The quantitative data was collected from two different types of sources:

- The first one is the main professor of the course, who gave us a nameless copy of the grades submitted in to the academic system database.
- The second one is two surveys, one given prior to the course and another one after the course; each of them provides different data individually, together they show evolution of the students' profile, motivation and satisfaction.

5.4.1. Pre-test/Post-test Methodology Design

The design of the "*test of user*" is a common topic inside the scientific research realm, and experimentation based on user response will provide the needed data. The main objective of these tests is to assess usability of the new learning environment. In this specific case, the learning environment change is due to implementation of BIM technologies in the courses of design, construction and computer tools.

In the university framework there are successful studies to design a survey process that we will take into account in developing our methodology. These studies analyze the implementation of new technologies in the curriculum based on the user profile. The focus of these studies is the efficiency and effectiveness of the course, and the level of satisfaction and preferences of the students.[285] The most common parameters considered in this type of survey are the degree of knowledge of the technologies, the use made of social networks, the level of computer tools application, and the theoretical knowledge of the course applying the new technology studied that will be implemented.[264]

For this specific research, which is based on the implementation of BIM technologies in the Architecture Engineering curriculum, we will develop a pretest/post-test survey -- the pre-test is designed to provide the students' profile, proficiency and expectations, and the post-test to know their motivation and satisfaction with the course.

We will develop a cyclical process in order to validate or improve the test methodology for this study. This cyclical process is composed of three phases: the first phase is the development, validation or improvement of the test; the second phase is the extraction of the data for the main research; and the third phase is the analysis of the results of the survey, looking for unnecessary and lost data that we should collect for the main research.

5.4.1.1. *Pre-test.*

To begin the research with a solid foundation, we developed the first test from one already published,[264] which has been used in several respectable studies,[261,262] already tested and validated. The first step was to review this test and check which chapters could be useful and which ones should be replaced for our specific research.

There were six chapters in the initial profile test -- new technologies, internet social network and other tools, applications, computers and laptops, mobiles, and augmented reality. After the analysis of the questions we decided that the last chapter focused on technology that was being implemented but was not the same as what we were testing, therefore it was not needed. All the others would be used to create a user profile that would be useful to realize a better analysis of our results. We decided to change the augmented reality chapter, creating a new chapter to analyze the students' proficiency and expectations of BIM technology applied to the courses. The chapters that we used from their test were rewritten for easier understanding by our students.

The BIM chapter that we developed intended to extract three main items: student level of BIM knowledge before starting the course; their expectations towards technology; and finally their technology preferences to be applied in the construction, design and other type of courses.

NEW TECHNOLOGIES

How keen are you on Computer tools, Software and technology?
Nothing Few Some Much A lot
Which of these technologies do you usually use?
A- Mobile B- Camera C- MP3/4 D- PC
E- Laptop F- Game G- Smartph H- Tablet
Console
Which of these technologies do you own?: How many hours a day do you use the laptop?
<1 1-2 2-4 4-8 >8
What do you use your PC/Laptop for:
Study Work Entertainment Oters:

INTERNET & SOCIAL MEDIA

Which device do you usually use for internet?
Mobile Laptop PC Tablet Smartph
how many hours do you spend on internet?
<1 1-2 2-4 4-8 >8
Where do you usually connect to internet?
Home Univ. Work Ciber
Public WIFI Mobile Oters:
which conecction do you usually use?
WI-FI ADSL 3G TV Others:
What do you usually use?
E-mail Chats Search tools games
Architecture Blogs Sports News Others
Do you usually use social media? What do you use the social media for?
Professional studies Friendship Otrers:

TOOLS

Which social media tools do you use?
Facebook Twitter Tuenti Linkedin Taringa
MySpace HI5 Orkut Other:
Which tools do you use to share files? (photos, video, text, CAD, etc.)
Dropbox mega Rapidshare yousendit
Picasa Flickr Other:
Which photo-editor and CAD programs do you use?
Tell us your level in the programs: 0-None, 1-Low, 2-Medium, 3-High
AutoCAD REVIT MicroStation Rhinoceros Ilustrator
MAX M Design SketchUP Adobe Other:
Do you play video games?
What video game system do you use? Which kind of games do you use?

PC & LAPTOP

Do you own a PC or Laptop?
Brand:
Model: Processor:
Which software do you use to develop and show up your design proyects?
AutoCAD REVIT MicroStation Rhinoceros Ilustrator
MAX M Design SketchUP PhotoShop Other:

Mobile

Do you have mobile?
Brand: Modelo:
Internet: 3G 4G Wifi
Other: Screen: <4" 4.-5 5-6 ≥6
Which options of your mobile do you usually use?
Internet SMS MMS APPS Music Video
Camera Others:
Type of contract?
Pay as you go Contract
Which company do you usually use:
Etisalat Du Other:

BIM

Do you know what is BIM? How did you know about BIM?
Which is your level in BIM
Do you think that BIM will be useful in your studies?
Do you think that BIM can be useful in your construction learning? How
Do you think that BIM can be useful in your design?
Do you think that would be difficult to apply BIM to your projects?
Do you think that BIM will be a limitation in your designs?

DEVICES

Which learning platform would you like to use?

	Construction	Design	Other courses
Hand drawing	☐	☐	☐
Autocad	☐	☐	☐
Computer tools:	☐	☐	☐
0 Autocad	_	_	_
0 Revit	_	_	_
0 Other:	_	_	_
Tablet	☐	☐	☐
Mobile	☐	☐	☐
On line	☐	☐	☐
Other:	☐	☐	☐

COURSE NAME:

Table 5.03 Pre-test example design

This item was then used to create a student's profile for each course that we studied. This helped to achieve a better analysis of the data and allowed us to adjust the course to the students' level, as we are in a transition process.

The first and the second pre-test were run during the third week of the semester after the students finalized their registration process. The third one was done before the fourth week, once the students finalize their registration.

After the first semester tests, we collected the data and began the first analysis in order to improve the tests. The main issue that popped up was that the BIM chapter was developed as qualitative while the rest of the test was quantitative. This made it difficult to provide statistical data about the BIM initial level of the students, although because the level was between low and null it did not have a major impact. For this reason and to improve the reliability of the study and the survey, the BIM section of the test was changed to offer possible answers on a 1 to 5 scale, where 1 is nothing or none and 5 is the maximum. With this minor change in the questions, the new pre-test was much easier to analyze and more helpful.

5.4.1.2. *Post-test*

After reviewing the mixed method literature, we chose a post-test survey[258] as the base to develop our second one. We reviewed the test carefully and decided to implement their general assessment part of the questionnaire, and create two new chapters specifically about BIM technology to fulfil our requirements.

The first chapter evaluated the satisfaction of the students in relation to the BIM technology contribution in their studies and future career in order to understand their motivations. During this chapter we asked questions such as: how useful will BIM be in your studies? And, do you think that BIM will improve your grades?

The second chapter assessed the users' perception of the BIM tools in different disciplines of the AEC (architecture, engineering and construction management) industry and the usability of these technologies to improve the AE curriculum. We asked questions such as: Evaluate Revit as a tool to understand building systems, components and joints; evaluate Naviswork as a tool to review your projects using clashes and comments. These questions evaluated the satisfaction of the students on specific tasks, as we aim to understand and quantify the usefulness of BIM technologies to improve their skills and learning process. The results will enable us to create a map of the students' understanding and perception towards the tools and the courses where it is applied. The second questionnaire was administered during the last two weeks of the course in class.

5.4.1.3. *Data Collection Design*

As this entire project is about introducing ICT into the curriculum, the first approach to produce the surveys was online. We sent an email to all the students of the course and informed them during the class that they were required to complete the survey which was sent to them. This method had only a 10% response, and we had to print the test and distribute it during the last class of the course in order to achieve a reasonable number of survey responses, obtaining a total response of 85%. The hard copy survey process was more difficult and resulted in less reliable data, as it had to be transferred into a digital data base by the members of the study which took time and allowed for the possibility of mistakes. There were additional problems -- the answers could be omitted for some questions, or could be answered differently from our expectations. In the soft copy version online, the program allowed the respondent to establish the type of answers (numerical or text), permitted answers of differing length, and other variable options which negatively impacted the collection of regular data.

In the following semesters the test was redesigned, again online, using Google Forms, which is a free survey online application. This allowed us to create any survey and share it with an infinite number of people, and download the data directly into Microsoft Excel. The program also allowed us to organize the completed surveys, notified us when someone accessed the survey, and how many people responded. It produced simple graphics which enabled the data to be read easily, and after the surveys were completed it enabled us to produce an Excel file which we could export into any statistics tool we chose.

Figure 5.01 Google Forms survey application management

The survey served different courses and levels of knowledge, and it evolved over the semesters in order to obtain more reliable data. This centered on two main improvement areas -- avoiding asking the students about knowledge they didn't have, and not repeating the same test with the same students during a given semester. These issues could be easily solved thanks to the Google Forms application. We could ask the students if they knew one area of expertise and avoid it if they don't have the skills. To address only those students who really had advanced until that level.

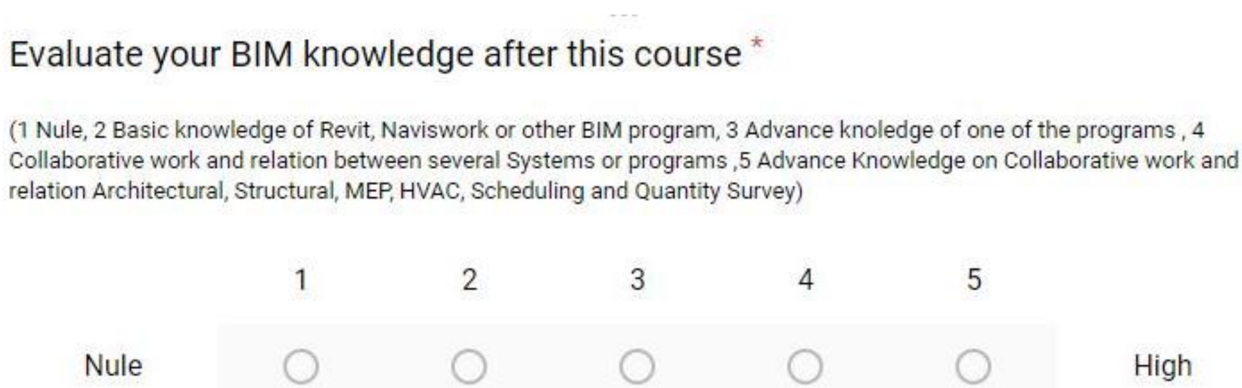


Figure 5.02 Survey development, quantitative question

The second improvement was avoiding duplication and repetition, which was achieved by asking the students in which course they are currently registered. The survey would ask the specific questions about that course in which the student was registered, and also the generic questions that were common to all surveys across courses. By this method, if there is a person doing a course in construction, which is introducing BIM, and a computer tools course about Revit, the program will only allow the student to complete one survey but we will still get the relevant information for both plus the general data.

Figure 5.03 Survey development, Courses Registered

In this study the data was analyzed using the XLSTATS tool which provides one month free access for all the tools and live service for the main ones like the t-test, p-test, Anova, distribution, descriptive statistics, Man-Whitney and Whitney, with two sample variables for each user.

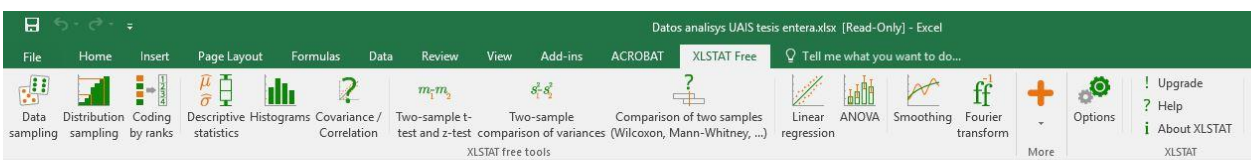


Figure 5.04 Statistics tools used

In order to use the online test with a similar or better response than the paper one, we decided to do the survey during the class and wait until we got all the answers, in this way and with the restrictions of the online survey, all the surveys completed by the people who came to the lecture. It has the inconvenience that part of the class time is lost, but it provides better and more reliable data.

5.4.2. Statistical Analysis Tools for this Research

In order to analyze the quantitative data we needed first to understand the type of data we had. First the size of our classes was less than 25 people; such small samples cannot be tested correctly for normality, so we could not assume their normality. If we cannot prove the normality of the sample, we could not use the P-test, T-test or Anova, as all these tests are only accurate when we use them with normal distribution samples. Due to this we had to use non-parametric tests which are more accurate for non-normal samples.

On the other side we were testing two kinds of data:

- Student groups at different stages of their construction courses. This kind of data is to be considered dependent samples, as we are testing the same samples in different stages. It is tested two-by-two (as pairs) using the Wilcoxon Signed Rank Test as studied by Wilcoxon in 1945.[286]
- Different groups of students in the same course. This kind of data is to be considered as independent samples, as we are testing the results in the same course of different study subjects. It is tested two-by-two (as pairs) using the two samples comparison test developed by Wilcoxon in 1945 and Mann-Whitney in 1947, as Fay, Proschan, Depuy and Neuhaser recommended in their studies.[287-290]

For the analysis of the day by day study, we used the test described. However, when we arrived to a document, which necessitates analyzing a bigger amount of data and comparing it in a common margin, we followed the multiple pairwise comparison using the Steel-Dwass-Critchlow-Fligner procedure/two-tailed test. This test compares the median/means of all pairs of groups using the Steel-Dwass-Critchlow-Fligner pairwise ranking nonparametric method and controls the error rate simultaneously for all k(k+1)/2 contrasts.[291]

In this manner we can test all the values for one variable at the same time for all the courses, so we can understand the overall evolution of the variable, as can be seen in this table that is explained in more detail in chapter 8.4. Looking at both approaches A and B to introduce BIM into the same course, they had very different outcomes over the variable analyzed. While all the courses with approach B will have certain similarity between them, as more semesters passed and the course was further refined the variable improved its effectiveness. We can reach this conclusion because each time it is more different than approach A, while if each semester went in the direction of approach A we should read a bigger number instead of smaller with this comparison.

As we have just demonstrated, the global overview provided by this kind of analysis results in more data and is more accurate than the pair data sample analysis.

p-values:

	BC g1	BC g2	BC g3	BC g4	BC g5	BC g6
BC g1	**1**	0.793	0.866	0.994	0.275	0.173
BC g2	0.793	**1**	0.360	0.987	0.934	0.628
BC g3	0.866	0.360	**1**	0.514	0.082	**0.026**
BC g4	0.994	0.987	0.514	**1**	0.525	0.237
BC g5	0.275	0.934	0.082	0.525	**1**	0.919
BC g6	0.173	0.628	**0.026**	0.237	0.919	1

Table 5.04 Statistical Analysis, P value table sample

5.4.3. Performance Analysis Development

To create a proper assessment we followed the performance of each group of students through all the construction courses analyzing their grading evolution. The grades were collected directly from the main instructor of each course, divided into theoretical, practical and final, so we had the same evaluation criteria and approach. As we can see in table 5.02, our performance assessment process is based on a continued follow up of the construction groups of students.

The first step for the performance assessment was to analyze the (BS) course as a control point, where we can statistically proportion the percentage of a confidence interval for the students' performance to provide the reliability percentage of the samples for comparison. To test this assumption we ran a Wilcoxon Mann-Whitney test comparing the final grades of the BS course for the students from groups 2 and 3; none of these groups had yet been introduced to BIM, so we should get a P value near 1, which would confirm that our different groups of students had a similar overall performance level in the construction course.

The second course (BC) was the one where we implemented the new IT technology (BIM based on Revit) which is our variable. In this course we checked the difference of the performance due to the modification of the course tools. In this case we used the same test comparing the groups 1 + 2 against group 3. But the result of the P value should be near to 0 in this case, which would mean that their performance is different. We also checked the means of the groups, the standard deviation and type of distribution of the data to identify which groups had a better performance. We could also test if the performance of groups 1 and 2 is better or worse than that of group 3.

Finally we controlled the same group of students in the third course of construction (ABS) which had no modification, to check whether the implementation of this technology in the previous course impacted or not the students' performance in other courses without this new IT. In this case we used the same groups as in the second test, but we read the values to check the results without an expected value.

In the previous analysis we found the relation of the variables between the different courses at each group. However to properly understand the whole concept and the evolution of each variable in each course, as mentioned in chapter 5.4.3, we analyzed the performance of all the groups in each course following the multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure/two-tailed test.[291] This provided a clear and broad picture of the development situation.

5.4.4. **Student Profiles**

This part of the analysis was mainly from the pre-test survey which yielded statistical data about the composition of our students and their profiles providing nationality, gender, and starting level of AutoCAD and Revit. This data provided the background for our research, which created a more comprehensive image of our study, and may lead to future comparisons or further research.

5.4.5. **Motivation and Satisfaction**

The students' motivation and satisfaction analysis was done only in the courses of BCC and ABS. The satisfaction about BIM based on Revit was measured using four questions as part of a large survey used for the motivation and satisfaction with BIM and the courses.

In this study we compared the satisfaction of the students with Revit tool as a BIM software in the courses BCC and ABS, to understand the evolution of the students' satisfaction with this tool depending on the introductory approach used in the BCC course. The analysis done used the results for all four questions, considering the data as only one variable. The study was done using descriptive statistics to understand the sample and the Steel-Dwass-Critchlow-Fligner procedure/two-tailed test[291] in order to analyze each course's satisfaction development over time, comparing the samples and providing the certainty of the hypothesis, thereby achieving an understanding of the entire concept and of evolution of the specific variable through the course's evolution.

The motivation analysis in this study is divided into four categories -- BIM to improve student grades, BIM to help their studies, BIM to improve their future career, and future use of BIM skills. With these four categories we can understand the reasons behind student satisfaction, and which areas they consider these new skills more profitable. As explained, the analysis was done in the BCC and ABS course using descriptive analysis and non-parametric Anova.[291]

In order to understand the whole concept, and the evolution of each variable in each course, we analyzed -- as mentioned in the chapter 5.4.3 -- each variable across all the courses following the multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure/two-tailed test.

5.4.6. **Qualitative Data**

There are three kinds of qualitative data in this research: first feedback extracted from the questionnaires, second interviews after all the students finished all their construction courses, and finally the graded samples.

In both pretest and post-test questionnaires we introduced one last qualitative chapter where we received different inputs from our students. In the pretest is was about the different tools they thought should be used to teach construction, design and other courses; and in the post-test was the opportunity to highlight the best things and worst issues in the course and how they could be (further) improved. The reality is that most of the students were reticent about these questions and if they were included as mandatory in the online questionnaire, most of them would write very few things or comments that were not really relevant. Those who highlighted truly relevant issues were the same ones which popped up during the interviews. These facts caused us to delete the qualitative questions on the post-test and to focus the qualitative data mainly in the interviews where there is a more accurate and relevant interaction with the students.

Student interviews were performed after they finished the ABS Course. The interviews were conducted in a very relaxed environment at the UAEU under the direction of Jose Ferrandiz. It is very important to highlight that as the questions were done after they finished all the construction courses, the students could be more sincere, honest, and open to talking about the issues encountered during the courses. The questions were directed to find out and understand student opinions about the BC course, suggested improvements, ideas for how to deal with the use of two different IT technologies at the same time, their satisfaction towards BIM tools, their motivation and intention to use Revit in their future studies and work, and the need to implement Revit, or not, in the university.

In these interviews the students had the opportunity to explain their reasons and feelings about the BC Course, their performance, how they felt about using the new IT, and the reasons to succeed or not in the use of it. The data collected in the quantitative tests were on a scale of 1 to 5, but there they did not have the possibility to explain themselves. So after finishing all the construction courses, when they have the whole picture, we gave them the opportunity to provide feedback and their sincere opinion about the process, the course, the new IT, how they dealt with it and if they will continue using it after this stage.

During the interviews the interviewer took notes of their comments. Right after finishing the interview, these comments were read back to the interviewed to make sure the notes were correct, and they were allowed to make rectifications or modifications in the notes to ensure that they represented their real opinion. After all this the statements from the interviews were categorized and organized in a way that we can create conclusions and understand which percentage of the people interviewed had one opinion or another.

The students' graded samples were collected and organized by course, group, grade and assignment. These samples were used to double check the grading, but most importantly it provided a data base which allowed us to compare the courses completed and the introduction of BIM to other courses which were not a perfect match of the one in our study. As an example of this we have the chapter 11.1

which will be published at IJEE journal. it this journal we compare the BCC course at UAEU and the CIII course at the American University of Ras al-Khaimah (AURAK), using not only statistics but also qualitative data in order to understand the content and context of each course.

The qualitative data is one of the main elements at a mix method research because it provides a measure of depth to the consequences of our study that a purely quantitative data approach cannot provide by any means.

6. Student Profile Analysis

The UAEU is a traditional, national and governmental university, which follows the law of the Qur'an. The university is separated by student gender, while the faculty and staff of both genders are allowed in both areas. The UAEU currently has one main location which is divided into two different campuses, male and female, however there are several buildings which serve both genders like administration which is mainly for the staff, the IT building which inside duplicates every space for male and female, and finally the labs which are open alternate days for men or women.

In the department of architecture the number of male students is very low, around 5 per section, and this makes our research less accurate. For this reason we focused on the female sections were we had numbers from 8 to 25 students per section, and in some courses we had up to three sections, which allowed us to conduct more accurate research.

The UAEU University was mainly created to provide free and high quality programs for UAE citizens, in order to prepare their own people to rule and manage the country and companies. It should be noted that in the UAE every company must have a citizen partner who owns at least 51% of the company. Local citizens represent only 10% - 11% of the total population living in the UAE, depending the sources. Getting the nationality is almost impossible and all of those who have done so received it as a special favor from the government and companies. Most of the national students receive grants after their second or third year of studies from companies where they will have a job after finishing their degrees, these grants do not only pay for the university but also serve as a salary while they are finishing their studies.

The UAE companies need to hire one citizen for every ten people they hire and their minimum salaries are established by the government and are usually around double those of expats in the same category. This process they call it Emiratization, and they are looking forward to be able to manage the country with their own people in the near future in order not to be dependent on the international experts.

All this information creates a higher necessity to motivate the students in order to help them accomplish knowledge goals. The situation is very different from that of an international student who knows that they have to be as prepared as they can in order to get a good job, while the Emirati knows that they will easily find a well-paid position.

Also there is a huge difference between the male and female students. While the males have total freedom to move around and receive these grants, the females receive less grants and the freedom for most of them is limited to inside their own dedicated campus where they have shops, restaurants, a gym, and many other facilities. This makes the female students more competitive between them than the boys.

Our student samples were studied mainly in the BCC course, as the group was progressing largely together and few students failed, or modified the curriculum due to the few electives they got.

6.1. Student Nationality

As already stated, the UAEU is a governmental national university which was established to provide UAE citizens a high standard of education, in order to improve the wealth and further the development of their country. The students in this university are mainly of three typologies: National UAE citizens who are the main group of students, influent families who have lived in the country for many years, and the sons and daughters of faculty members.

In each of the semesters studied during this research, and also in the previous two years when the author of this study was teaching at UAEU, UAE nationals have always been the majority of the students, and if we analyze the data we can observe that it has never been less than 60% during this study. The UAE is a country which does not provide nationality easily, the people who are born and raised here take the nationality of their parents even if they have never been to that country. With this statement and analyzing the data we can assume that most of the people who are from different Arab countries in this table are either people who were born and raised here or the daughters of faculty.

It is not unusual to not have a student from Europe or America, having more than one or two in the same group of students would be even rarer.

UAE nationals have almost certainly a well-paid job available to them after graduation, and those who have lived in the UAE for a long time usually have enough contacts to easily find a job after finishing their studies, both of which make it a fundamental issue to inspire motivation in the students.

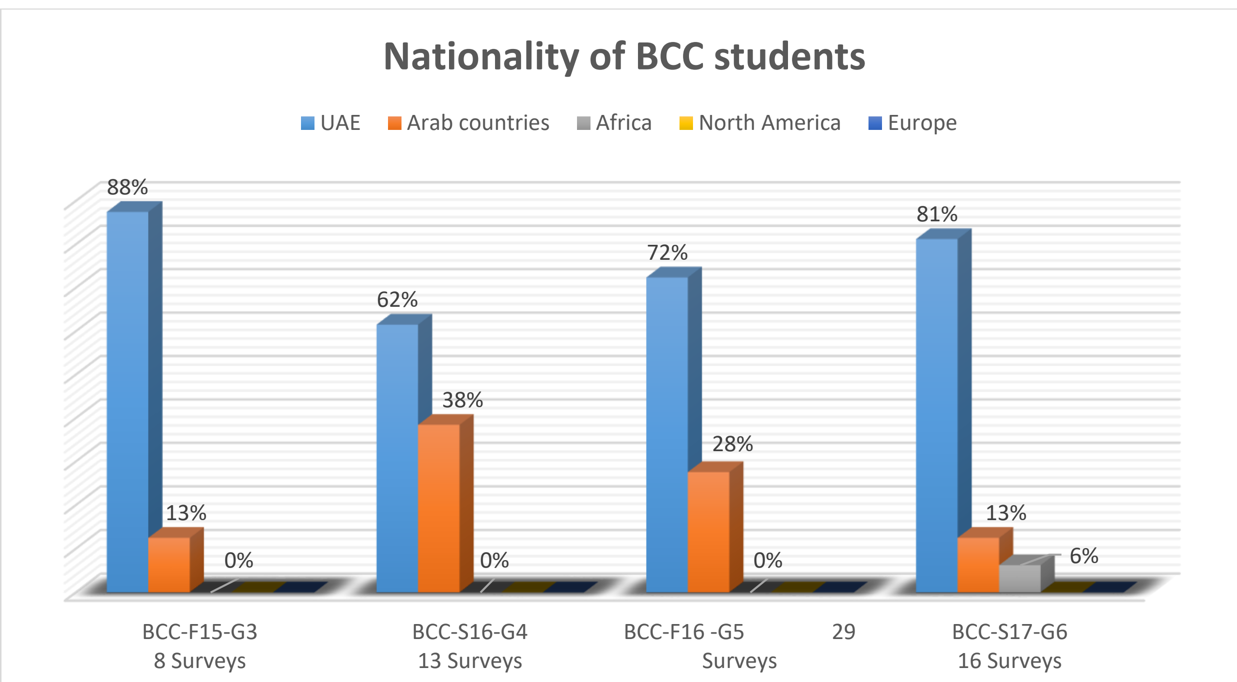


Figure 6.01 Student Nationality

6.2. **Age**

The UAEU is an institution where the primary language used is English, which means that all students must get a 5 score mean in the IELTS test in order to enter the university. If they do not achieve this score they enter the foundation program where students are trained in English in order to be able to continue their education in English instead of their mother tongue. This results in students of a range of ages. The Architectural Engineering program at the UAEU is a specialization within the Engineering department; for the first two years the students are studying Engineering and after that they will enter the Architectural specialization, meaning that the students can easily move from one to another engineering program during the first year of specialization.

The average age to arrive to the BCC course is 20-21 years, although we have exceptionally good students who can arrive at 18-19 although this is rather rare due to the IELTS and the two prior years of engineering requirement. On the other side there are always late students which can be from many different causes such as transfer students, graduates of foundation programs, those who changed specialization, etc.

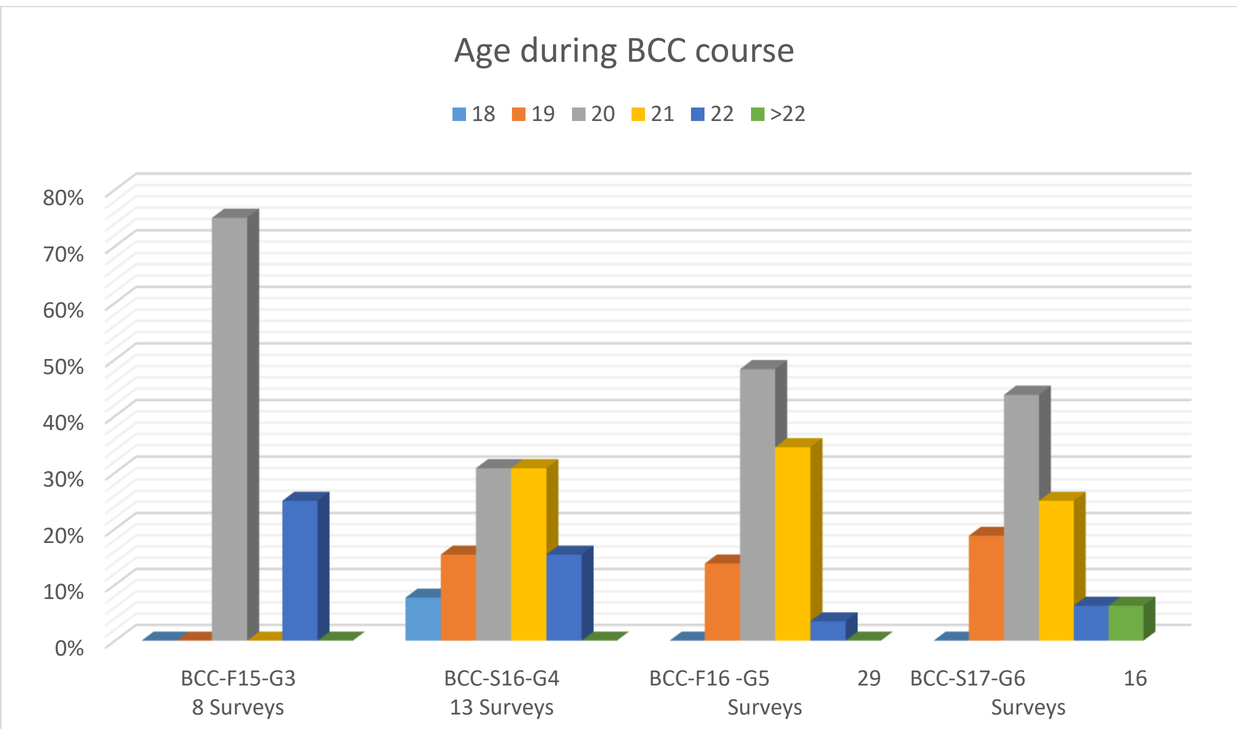


Figure 6.02 Student Age

6.3. Motivation to Use ICT in Architecture

As discussed in chapter 3 the current generation is very motivated to use new technologies, which helps us to engage them in the digital learning environment, and to introduce new ICT skills like the one we are currently studying.

Analyzing the data we can observe that only around 10% of students are not into new technologies and the digital era, while at least 60% are very motivated or enthusiastic. This should help us to motivate and achieve higher satisfaction from the students when introducing these new ICT skills.

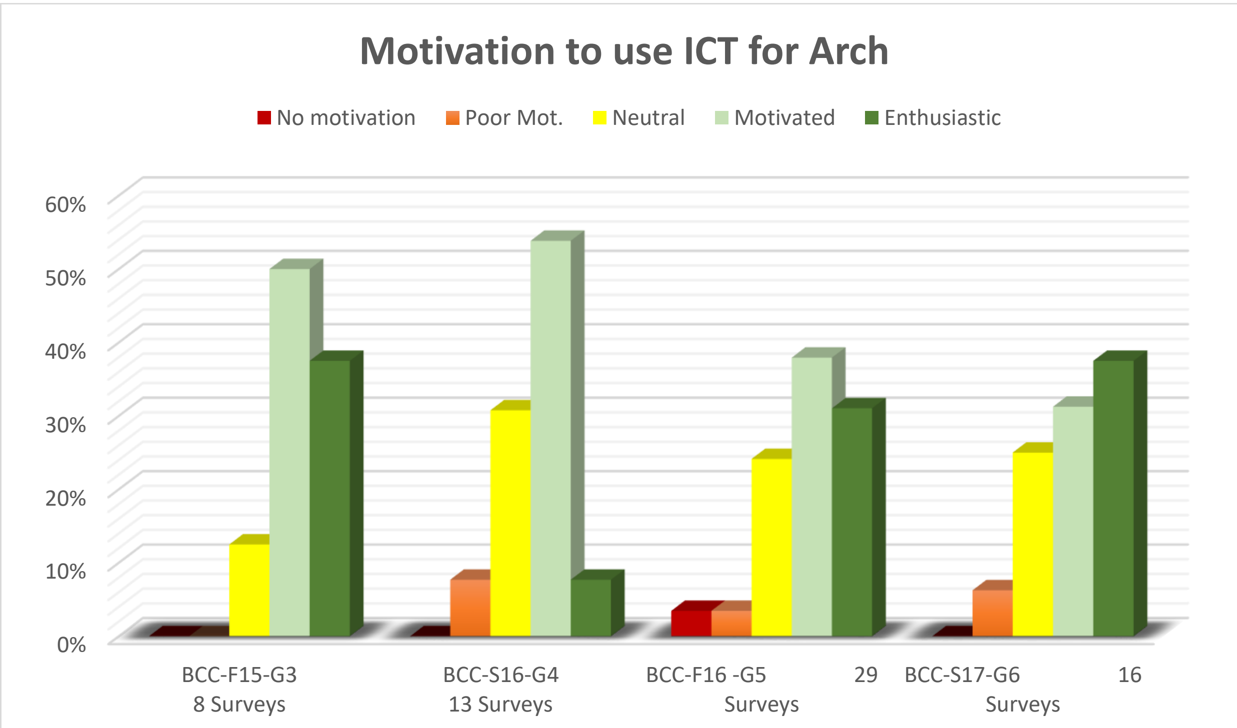


Figure 6.03 Student ICT motivation for Architecture

6.4. Skills of Students when Beginning BCC Course

In this part of the student profile analysis, we studied the students' skills and knowledge in both AutoCAD and Revit tools, in order to understand how people with differing levels of previous skills will behave in the courses where we introduce BIM. When discussing with the students skills perception, which does not equate to their current actual knowledge, we observed that their skills level perception expertise revealed only a slight change when we asked the same question before the course or right after the end of it.

6.4.1. AutoCAD Level

When discussing the level of AutoCAD skills perception by the students, we have to have a global picture. Very few students didn't have any knowledge of it, and those who admitted they had no knowledge only answered that way in the beginning of the post-test, while in their pretest the answer was more moderate.

We noticed that the students' perception of their own skills was moderate when these skills were not tested, but once evaluated their opinion was more accurate as it came from the experience they have had during the course and traditional assignments done with this tool.

With this we can understand that only in the post-test were there values from 'no knowledge' to 'expert' which were represented in the quantitative survey as 1 and 5 points in a 1 to 5 scale. However in the pretest all the answers were moderate and we did not find any student who would say that they are in-experienced or expert in the tool.

If we focus only in the post-test, that in our opinion is more accurate than the pretest survey to evaluate this matter, we find that group 3 had 38% of people with low skills in AutoCAD, while all the other groups less than 20% of the students were poorly skilled in this tool. If we look at the good or excellently-skilled students all the groups have a superior rate of 40% of the students, which means that these students have been trained previously in this skills.

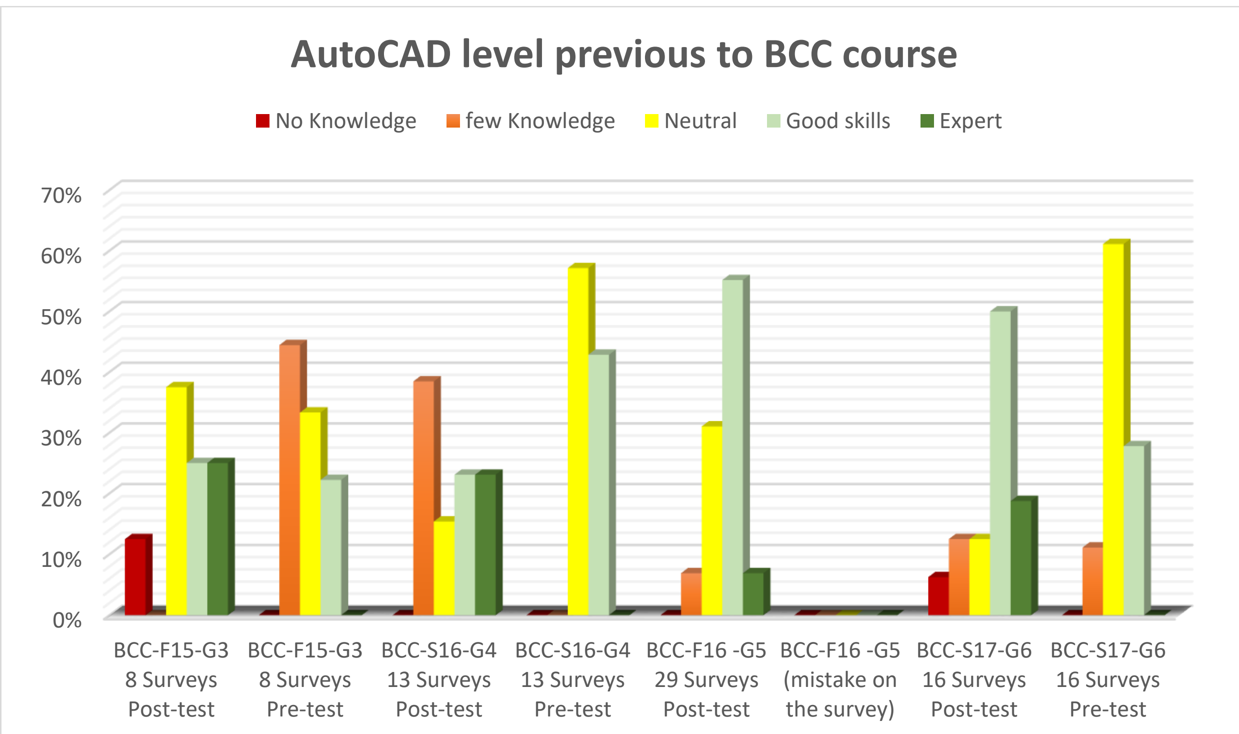


Figure 6.04 Students AutoCAD level at the start of BCC

6.4.2. **Revit Level**

When talking about the BIM tool Revit which we were planning to introduce in the BCC course, and according to the designed plan should have been previously taught in the BS course, we discovered that at least 60% of the students had poor or no skills in Revit. This means that this course could be an advanced BIM course without causing our students to straggle.

The curve of Revit skills prior to this course decreased across the semesters, which means that the more we advance the fewer skills students had when they arrived to our course. We do not have the tools in this study to understand the reason behind this, although we can state that in the author's opinion, after the meeting when we decided to introduce BIM at AE in the UAEU, most of the professors tried to introduce BIM but after some time only the BCC core course and some elective courses introduced BIM. This was discussed further in chapter 4.1.

As the courses fall back into their traditional methodologies, the BIM knowledge prior to BCC at the UAEU will continue decreasing until it does not exist at all or another attempt to introduce BIM is done at the AE department.

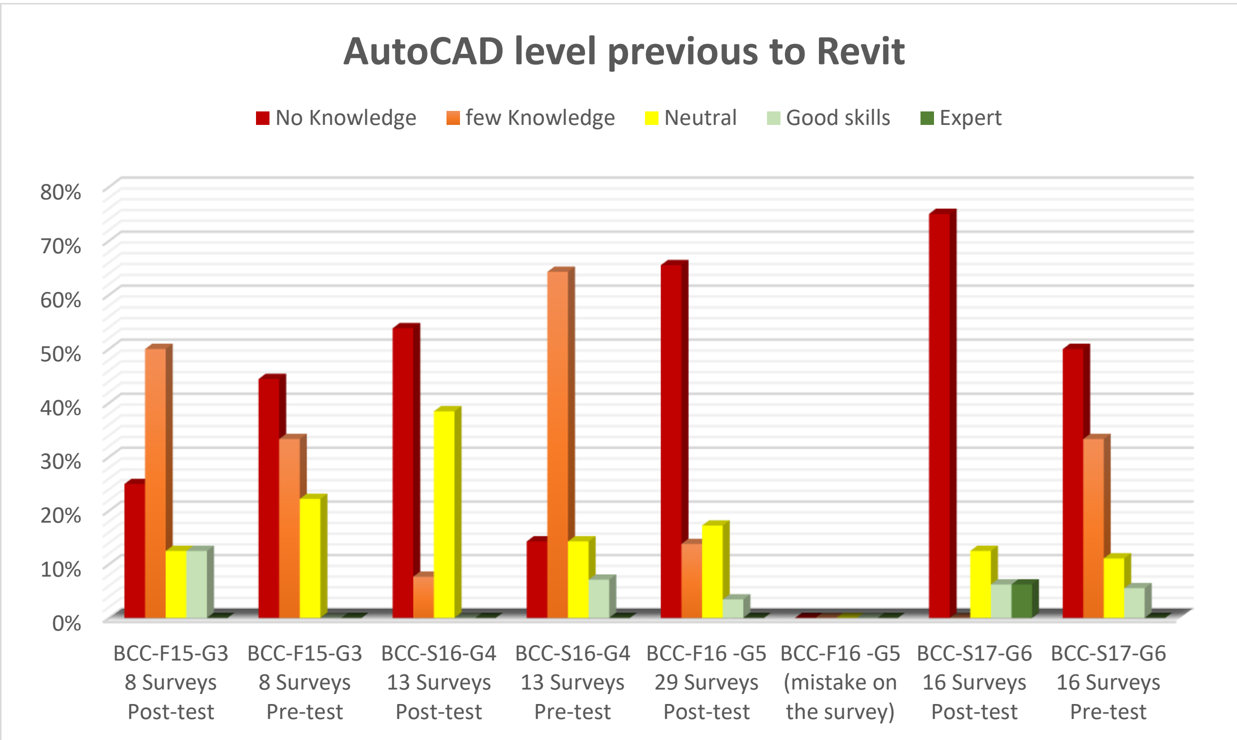


Figure 6.05 Students Revit level at the start of BCC

7. BCC BIM First Approach, Student Group 3

The implementation process of BIM is a very complex topic with several obstacles, as discussed in chapter 4.2. These difficulties have been identified and categorized into three groups as defined by Kymmel:[5] difficulties in learning and using BIM software; misunderstanding of the BIM process; and issues related to the circumstances of the academic environment.

In order to accomplish the greatest interest in our new ICT skills, which considerably increases the scope of our measures, we decided to test during this first stage the simplest option which is to introduce Revit as a tool to develop a BIM model, which most faculties would find easy to introduce. If this test was favorable, it would be easy to convince most of the professors to get help from a specialized instructor and introduce BIM in their subjects. In the case that this approach is tested as not valid, we would face the problem of re-designing the courses, with all the discussions, problems and rejection from some faculty and institutions that accompany such a re-design.

The method proposed was very simple, the course would remain as it was. The traditional lectures would continue, and we would split the lab sessions into two sessions. The first part of the lab sessions would follow the same conventional approach and assignments as they were planned in the former course. The second part of the lab would introduce BIM concepts and Revit tool to create a 3D model of the building and its details that we were already developing in the course. This approach provided at the same time the traditional 2D learning environment along with a 3D BIM one. We developed the hypothesis that this 3D environment provides visual engagement, better comprehension and motivations towards the building construction knowledge, which should lead to a better performance, motivation and satisfaction.

The table 7.01 reflects the schematic and schedule of the course when we applied this methodology which we will call method A in order to differentiate it from other approaches.

Week Number	Session Topics		
	1^{st} Session		***2^{nd} Session***
Week 1	Introduction to the BCC Course (Syllabus + Revision)		**Lecture 1:** Internal Finishes: Plastering & Paint
Week 2	**Assignment 1:** Group Research for Plastering & Paint	**BIM Session 1:** Introduction to BIM concepts and Revit	**Lecture 2:** Internal Finishes: Floorings
Week 3	**Assignment 2:** Individual CAD drawing for Internal Finishing [Start In class]	**BIM Session 2:** 1^{st} delivery, walls and slabs connections.	**Lecture 3:** Internal Finishes: light weight partitions
Week 4		**BIM Session 3:** Model development	**Lecture 4:** Internal Finishes: Suspended Ceilings
Week 5	**Assignment 3:** Individual CAD drawing for Suspended Ceiling. [Start In class]	**BIM Session 4:** 2^{st} delivery, suspended ceiling connections.	**Lecture 5:** External Finishes: Plastering + Cladding
Week 6		**BIM Session 5:** Model development	**Lecture 6:** External Finishes: Metal & Glass Curtain walls

Week 7	**Assignment 4:** Group Research in Cladding Systems [In class – Submission by the end of the class]	**BIM Session 6:** Model development	**Quiz 1:** Internal and External Finishing
Week 8	General Revision & Open Questions Session		**Mid-Term Exam**
Week 9	Mid-term Revision		**Lecture 7:** Building Joints
Week 10	**Assignment 5:** Individual CAD drawing for Cladding and Curtain wall [Start In class]	**BIM:** 3^{st} delivery, project plans, courting wall details, and resubmit 1^{st}, 2^{nd}.	**Lecture 8:** Openings: Doors and Windows Components
Week 11		**BIM:** Model development	**Lecture 9:** Service Components: Ducting, Floor Trench, Floor and wall Chase
Week 11	**Trip Field** **Class Activity:** Discussion (Field Trip)		**Class Activity:** Discussion (Field Trip)
Week 12	**Assignment 6:** Group Research in Doors & Windows Components [In class – Submission by the end of the class]	**BIM:** Model development	**Quiz 2:** Openings
Week 13	**Assignment 7:** Individual CAD drawing, Steel Staircase, Door and Window.	**BIM:** 4^{rd} delivery: project sections, stair details, and resubmit 1^{st}, 2^{nd} & 3^{rd}.	**Lecture 10:** Vertical Circulation: Steel Staircase
Week 14		**BIM:** Doubts and course review	**Lecture 11:** Vertical Circulation:
Week 15	General Revision		Open Questions Session
Final Exam [date/time as announced]			

Table 7.01 BCC course weekly plan G3

7.1. Analysis and Results of Method A

Before we could continue with this study, we analyzed the data collected in order to understand properly the effects of method A on the course and the students. At first sight and before analyzing the data the author, who was the instructor in charge of introducing BIM into this course, realized that there were several severe problems already. There was a lack of student basic skills in order to follow properly the proposed assignments in the course. There was a big rate in drop and failure while in the UAEU -- the people who drop courses are rare but it happens mainly in order to change the major, and very few people fail courses. This institution is mainly intended to help national students to receive a good education, where the students, and their advising and help, are the top priorities of the university over research and bureaucracy.

However a serious scientific study cannot take actions based on intuition and loose data, but with quantitative and qualitative scientific data, and the proper statistical analysis which provides proof and reliable results. This is required in order to accomplish real improvements which are publishable in scientific journals. The initial methodology of this study was published in the lecture notes of Springer.[41] The rest of this chapter covers the analysis and results of this part of the research, explaining how introducing BIM using method A affected the performance, motivation, and satisfaction of the students; it has been published in the ISI journal Universal Access in the information Society (UAIS)[42].

The results and analysis in this chapter of the study do not assume any results for the research questions and may or may not validate our previous assumptions. The data obtained and analyzed will establish the starting point of BIM implementation of the framework. The analysis for the collected data was done via a non-parametric analysis due to the small size of the study sample, which did not allow us to test the normality of the data itself. The first type of study explained used dependent samples represented by the comparison of data from the same group of students at different stages of the curriculum. Tested by the Wilcoxon Signed Rank Test [286]. The second type of study used independent samples represented as the study comparing two different groups of students at the same stage of the curriculum. For those we use the two samples comparison developed by Wilcoxon in 1945 and Mann-Whitney in 1947 [288,289,292]. These tests are more accurate for non-normal distribution than the usual P-test and Anova. We have run 13 tests divided into three categories: Motivation, Performance and Satisfaction. Motivation and Satisfaction tests were measured on scale from one to five, where one is ‘no interest or disagree’ and five is ‘very keen on it or totally agree’. Performance is measured on scale from zero to 100 points.

Description							Analysis					
Hypothesis	Variable	Observations	Min.	Max.	Mean	Std. deviation	U(independent) Z (dependent)	Expected value (independent)	Variance (U) (independent)	p-value (one-tailed)	alpha	Trust in the Hypothesis
MOTIVATION												
motivation to use revit at their studies and future career from 1-5												
1.1	BC-g3	16	1.0	5.0	3.000	1.317	-2.796c			0.005	0.05	99.5%
	ABS-g3	26	0.0	5.0	4.269	1.699						
1.1	ABS-g2	28	1.0	5.0	3.679	1.188	264.0	364.0	2966.9	0.034	0.05	96.6%
	ABS-g3	26	3.0	5.0	4.269	0.667						
Used of BIM to improve their grading												
2.1	BC-g3	8	1.0	5.0	3.000	1.309	-.108b			0.914	0.05	91.4%
	ABS-g3	13	2.0	5.0	3.385	0.870						
2.2	ABS-g2	14	2.0	5.0	3.857	0.949	116.5	91.0	384.611	0.101	0.05	89.9%
	ABS-g3	13	2.0	5.0	3.385	0.870						

Table 7.02 Motivation statistical descriptive and analysis results from our UAIS 2017

IT technologies are supposed to help students engage more often and get motivated during classes, which leads to better performance and grades. The first test was to measure the student's motivation towards learning BIM using Revit platform for their studies and after graduation. Test 1.1 showed that the students from group3 (labeled as g3 in the tables) were more motivated to use Revit for their studies and future career, and this increased from one year to another. The data is 99.5% accurate for this statement, however analyzing the data shows that for the building components (BC) courses there is a high deviation together with a neutral mean and a bimodal distribution. This means two groups of students with very different levels of motivation -- one very motivated and other not so motivated. The motivation of this group of students increased to over four up to five with a low deviation after the Advanced Building Systems (ABS) course. This could be due to many factors, which will be discussed after the students' interviews. Test 1.2 showed that the level of motivation of the students in g3 was higher than the previous students who did not study BC courses implementing Revit, with a statistical confidence of 96.6%.

The second analysis measured the student's confidence of BIM applying Revit to improve their grades. The g3 students after BC had almost the same results than in the previous tests. We found groups of students split into two subgroups. Referring to table two, we see that their performance was related to their motivation about or confidence in Revit to improve their grades. The data from the 2.1 and 2.2 tests showed 90% confidence that the students who went through the BC course with Revit had a lower perception of this tool to improve their grades.

The analysis of the motivation tests provided the first turning point to our research questions. The motivation of the g3 students towards BIM increased after finishing the ABS course in comparison to the students of g2. Meanwhile g3 students had less confidence in Revit to improve their grades than the g2 students did.

Description							Analysis					
Hypothesis	Variable	Observations	Min.	Max.	Mean	Std. deviation	U(independent) Z (dependent)	Expected value (independent)	Variance (U) (independent)	p-value (one-tailed)	alpha	Trust in the Hypothesis
PERFORMANCE												
3.1	BS-g2	10	70.0	90.3	84.120	5.812	41.0	40.0	125.490	0.964	0.05	96.4%
	BS-G3	8	70.0	91.5	81.625	8.794						
3.2	BC-G1+G2	29	54.0	97.0	77.310	11.926	183.0	130.5	847.229	0.037	0.05	96.3%
	BC-G3	9	0.0	88.0	51.889	35.279						
3.3	ABS-G1+G2	28	60.5	78.5	71.268	4.951	111.5	70.0	394.943	0.020	0.05	98.0%
	ABS-G3	5	60.0	70.0	66.400	4.336						

Table 7.03 Performance statistical descriptive and analysis results from our UAIS 2017 article [42]

The performance analysis consists of three parts. The first one (test 3.1) of Table 3 is the performance comparison of the student groups to see whether the students are at the same level. The statistical analysis showed that the students of g3 had performed similarly in the Building Systems (BS) course to the former group of students with a confidence of 96.4%. This result validated our hypothesis that the student's level in the AE department is similar, so we can compare the performance of different groups of students at different stages of their studies to understand how the implementation of Revit may or may not modify their performance.

The statistical analysis in test 3.2 shows that the g3 student's performance decreased by 25%, which means it split the class into two different groups: those who succeeded using Revit and improved or maintained their performance, and those who did not succeed and failed or dropped the course. In addition, we can see that it is the first time that any of our students failed or dropped the course. Finally test 3.3 shows that the grades also decreased by 10% in the ABS course from those students who passed the course of BC using Revit. This means that even for those who succeeded to use both IT tools at the BC course, their performance had been affected by the BIM implementation.

These results do not satisfy the performance improvement research question, and it will be analyzed at the student interviews. We provide some answers and recommendations that were implemented in the next semester of BC Course.

Description							Analysis					
Hypothesis	Variable	Observations	Min.	Max.	Mean	Std. deviation	U(independent) Z (dependent)	Expected value (independent)	Variance (U) (independent)	p-value (one-tailed)	alpha	Trust in the Hypothesis
SATISFACTION												
BIM based on Revit												
4.1	BC-G3	32.0	1.0	5.0	3.250	1.3	-1.892c			0.1	0.05	94.2%
	ABS-G3	52.0	2.0	5.0	3.827	0.9						
4.2	ABS-G2	56	1.0	5.0	3.107	1.303	993.0	1456.0	24770.143	0.002	0.05	99.8%
	ABS-G3	52	2.0	5.0	3.827	0.879						
tools usage for their following projects												
AutoCAD												
5.1	BC-g3	8	1.0	5.0	3.125	1.642	-1.069c			0.285	0.05	71.5%
	ABS-g3	13	1.0	5.0	4.000	1.155						
5.2	ABS-g2	14	1.0	5.0	4.429	1.158	118.5	91.0	344.167	0.073	0.050	92.7%
	ABS-g3	13	1.0	5.0	4.000	1.155						

Revit												
6.1	ABS-G2	8	1.0	5.0	3.125	1.553	-1.510c			0.131	0.050	86.9%
	ABS-G3	13	3.0	5.0	4.231	0.725						
6.2	ABS-G2	14	1.0	5.0	2.857	1.292	34.5	91.0	393.556	0.002	0.050	99.8%
	ABS-G3	13	3.0	5.0	4.231	0.725						

Table 7.04 Satisfaction statistical descriptive and analysis results from our UAIS 2017 article [42]

On the satisfaction level, the students were asked about two main issues. The first one was their satisfaction with Revit to develop their projects. The second one was about their intentions to use either AutoCAD or Revit to develop their future projects. In the first analysis, tests 4.1 and 4.2 of Table 4 show that their satisfaction with the Revit tool increased.

When talking about their future intention of using AutoCAD, the BC course where we implemented Revit had the lowest intention, despite the decrease in the student's performance with Revit. This could be explained because it is the only course where the students have to use Revit to improve their skills.

The intention of using AutoCAD in future projects increased for g3 students after the ABS course. Even though this increase of g3 student's intention is still lower than the intentions of g2 students.

The 6.1 and 6.2 tests were about intentions to use Revit to deliver projects after graduation. BC g3 data shows that the students were neutral, but with a high deviation. This effect is seen in all data analyzed for the BC G3. The delineation into two groups of students has already been explained. The statistical data of the 6.1 and 6.2 test showed increased student motivation with Revit and intentions to use it in their future projects compared to g2 students. This increased effect continued after finishing the course.

7.1.1. **Interviews**

We conducted three interviews with a group of seven students from group 3 who finished the BC course with Revit. In these interviews the students gave their points of view and reasons for the data that we have just analyzed. These seven points are the main reasons and conclusions from the three interviews validated by the students:

- Two out of three students interviewed finished the exercises on AutoCAD, instead of Revit (as they were asked).
- All students lacked previous skills, and even the ones who succeeded in using Revit agree that they needed more time to learn and apply it properly.
- All of them thought that Revit saves time, so they have continued improving their BIM skills after the course, to use it properly in their projects.

- All of them said that Revit is faster to develop projects and helped them understand the course materials; however AutoCAD provides more freedom to develop custom building details.
- Only one student said that it was fine to use both programs at the same time, while the other two got confused and after trying Revit they finished their exercise using AutoCAD because they were used to working with it.
- All of them would like to focus on Revit, but two of them felt AutoCAD is necessary to create 2D detailing due to the freedom.
- One of them pointed out that it would be necessary to have an introductory course for architectural skills before using Revit in another course.

It is obvious from the interviews that students had difficulties in implementing BIM. The results showed that half of the BC g3 course did not respond well. This has led us to create a set of recommendations for implementing BIM for better outputs. These recommendations will be discussed in the next section.

7.1.2. **Conclusions**

The students believed that BIM improved their work efficiency and the understanding of the course materials, which led them to improve their motivation and satisfaction in the use of Revit. We did not accomplish, however, the improvement in their actual performance in the course due to the students' lack of skills with the new ITC and the wrong approach of the course. The Building Components course should be redesigned to use several ITCs as delivery methods. A deep analysis of the results will conclude that:

- From the group who used Revit during the Building Components (BC) course, motivation decreased during the BC course, and increased a lot after finishing their construction courses. After the ABS course, the students realized that Revit is faster for developing, improving and understanding their projects.
- Half of the students became confused by the use of two ITCs simultaneously which can deliver similar outputs, so they dropped the ITC in which they had fewer skills.
- The satisfaction with Revit to develop their projects increased since they began to use it and was constantly growing as they improved their skills.
- The performance of the BC using Revit decreased because half of the students did not succeed in working simultaneously with AutoCAD and Revit, due to their lack of previous skills and sufficient time. This situation confused those students. Students explained in the interviews that they were highly motivated and they would rather have had that course separating AutoCAD and Revit into two different stages of the course.
- The intention of using Revit in their future projects grew at the same time as their skills due to the work efficiency improvement.

A conclusion from the BIM implementation should be that a properly designed course would make a perfect fit for the new IT tool. That would improve the students' efficiency to develop working drawings and a better understanding of the construction concepts explained in the course. This change would let us improve not only student motivation and satisfaction but also their learning process and performance. Due to this recommendation, the BC Course has been redesigned completely to fit both IT tools without overlapping them.

8. BCC BIM Second Approach, Student Groups 4, 5 & 6

This section will introduce the changes done in each semester after the first analysis of the data, which we collected from the students and in the interviews. This study aimed to collect data and test different methods to introduce BIM in order to be the first steps towards a BIM introduction framework methodology. However at the same time it was a quick scientific tool to improve the course and address problems which can show up in any course. By this tool we completed a statistical analysis of the performance, satisfaction and motivation of the students and then looked for the explanations from the students' point of view which is usually lost because the developers are the faculty, and they already have their opinions which they look to be confirmed or neglected.

8.1. Group 4, BCC Course Improvement Due to Previous Assessment

Due to our study results explained in chapter 7.1.2., we redesigned the course in order to modify the BIM introductory method A into a new method that we will call "*method B*". During the redesign part of the course, the main professor decided to redesign his lab and combine several of the assignments to reduce the duration of the traditional course lab in order to accommodate five weeks for the introduction of BIM based on Revit and develop skills.

The course was regarded as a process where the students will obtain construction knowledge and the BIM skills will be allocated as a 5-week workshop which is not really integrated in the course, although the assignments and skills gained are focused on the course lectures.

This redesigned schedule addressed the comments of the students and was tailored to meet learning process objectives that the building construction cluster at the department agreed upon. We re-designed the course activity schedule [Table 2]. First, we will introduce the students into construction knowledge and detailing as has always been done before, and then we will introduce concepts and some Revit skills in order that they can begin their own projects in a better-comprehended environment.

Week Number	Session Topics	
	1st Session	***2nd Session***
Week 1 1	Introduction to the BCC Course (Syllabus + Revision)	**1 - Lecture 1:** Internal Finishes: Plastering & Paint
Week 2 1	**1 - Lecture 2:** Internal Finishes: Floorings	**1 - Lecture 3:** Internal Finishes: Suspended Ceilings
Week 3 1	**1 – Assignments:** Assign 1: Group Research for Internal Finishing [In class – Submission by the end of the class]	**1 – Assignments:** Assign 2: Individual CAD drawing for Internal Finishing [Start In class]
Week 4 1	**1 – Assignments:** Assign 2: Individual CAD drawing for Internal Finishing [1st Draft Submission by the end of the class]	**1 – Assignments:** Assign 2: Individual CAD drawing for Internal Finishing [Final Submission]
Week 5 2	**2 - Lecture 4:** External Finishes: Ext. Plastering + Cladding	**2 - Lecture 5:** External Finishes: Metal & Glass Curtain walls

Week 6 2	**2 – Assignments:** Assign 3: Group Research for External Finishing [In class – Submission by the end of the class]	**2 – Assignments:** Assign 4: Individual CAD drawing for External Finishing [Start In class]
Week 7 2	**2 – Assignments:** Assign 4: Individual CAD drawing for External Finishing [1st Draft Submission by the end of the class]	**2 – Assignments:** Assign 4: Individual CAD drawing for External Finishing [Final Submission]
Week 8 3	**Mid-Term Exam [in Internal & External Finishing]**	**3 - Lecture 6:** Joints in Buildings
Week 9 4	**4 - Lecture 7:** Service Components: Ducting, Floor Trench, Floor and wall Chase	**Intro to in BC:** Revit Model for Building Structure (a)
Week 10 5	**5 - Lecture 8:** Openings: Doors and Windows Components	**Intro to in BC:** Revit Model for Building Structure (b)
Week 11 6	**6 - Lecture 9:** Vertical Circulation: Elevators, Escalators and Conveyors	**Intro to in BC:** Revit Model for Building External/Internal Finishing (a)
Week 12 6	**6 - Lecture 10:** Vertical Circulation: Steel Staircase	**Intro to in BC:** Revit Model for Building External/Internal Finishing (b)
Week 13 6	**s 5&6 – Assignments:** Assign 5: Individual CAD drawing for Openings & Steel Stair [Start In class]	**Intro to in BC:** Revit Model for Stairs and Elevator Shafts (a)
Week 14 6	**s 5&6 – Assignments:** Assign 5: Individual CAD drawing for Openings & Steel Stair [1st Draft Submission by the end of the class]	**Intro to in BC:** Revit Model for Stairs and Elevator Shafts (b)
Week 15 6	**s 5&6 – Assignments:** Assign 5: Individual CAD drawing for Openings & Steel Stair [Final Submission]	**Intro to in BC:** Revit Model Rendering & Documentation
Week 16	Final Revision	**Intro to in BC:** Final Revit Model Submission
Final Exam [date/time as announced]		

Table 8.01 BCC course weekly plan G4, G5 & G6

8.2. Group 5 Improvement in BIM Introduction Approach in the BCC, the YouTube Channel

Since the changes in the Group 4 BCC course, it was running properly so few additional changes were made. The main two changes were due to an increase of the number of students. We had to open two more sections, which necessitated the hiring of another faculty member who joined the course. Each faculty have their own sections of the course while following the same syllabus, lectures and assignments. The second change was in the BIM approach. We included a YouTube channel where the students could review some parts of the lectures of Revit again, and we could also reply to doubts to all the students. This was very effective because when any student had a doubt or question, all the others could also watch the video and improve their understanding and BIM skills.

8.3. Group 6 Improvements in BIM Introduction Approach in the BCC, the Workshops

The last semester was a bit different; while it was designed to change the BIM part in order to provide the best BIM skills and concepts we could to the students in only five sessions, in order to get some comparison data we redesigned the BIM part as workshops. The students were asked to watch online lectures about Revit, and they would then do their exercises under timing during the lab sessions. The students were divided in two groups -- one working with AutoCAD, and the other working with Revit, and then exchanging positions to test both examples.

The reality of this semester was that the author of this thesis went through a challenging medical situation and couldn't introduce the methodology changes designed. In this case we conducted the course as groups 4 and 5, but with less YouTube videos due to the lack of time. In this case group 6 was one group more for method B, where the professor was more absent, and couldn't help as much as he did during the other semesters when he was available to advise students at any time.

9. Student Evaluation Data Analysis

In this chapter we will provide all the data-collected analyses, in order to understand each aspect of this research individually. We will discuss the meaning of these analyses in order to provide a clear picture of how the introduction of this new ICT skill modified the students' performance, motivation and satisfaction.

9.1. Student Performance

The performance analysis in this study was conducted on all three courses of construction in the AE at the UAEU. It consists of three different phases, which coincide with the different courses of construction:

- Analysis of the first course of construction in order to understand whether the entire group of students has similar potential and consistent performance in the construction courses. This study will provide the background of our students. Chapter 9.1.1
- Analysis of the effects on the students of the different approaches to introduce BIM into the second course of construction. Chapter 9.1.2
- This last performance analysis on the last course of construction, where BIM tools were optional, will provide the effects on the students' construction knowledge due to our modifications in the previous course of construction. Chapter 9.1.3

9.1.1. Building Systems (BS)

The first step in the performance study of this research is the comparison of the marks obtained in the course of "*Building Systems*" Construction 1. The intention of this analysis is the verification of performance consistency in the construction courses, comparing the different groups of students used in this study in such a way that our conclusions are rigorous. By this analysis we can discover whether our students are similar or if we have an outstanding or inferior performance group, which will affect the results of the following studies.

Course	Construction 1 (Building Systems)				
BIM approach	No BIM				
Professor Lecture	**A**	**A**	**A**	**A**	**A**
Professor lab	**D**	**D**	**E**	**E**	**C**
Descriptive statistics (Quantitative data):					
Student Group:	G2	G3	G4	G5	G6
Statistic	F 14-15	Spr 14-15	F 15-16	Sp 15-16	F 16-17
Nbr. of observations	19.0	19.0	19.0	19.0	19.0
Nbr. of missing values	9.0	10.0	10.0	7.0	0.0
Sum of weights	10.0	9.0	9.0	12.0	19.0
Minimum	70.0	44.3	78.0	77.0	0.0

Maximum	90.3	91.5	91.5	91.0	87.0
Freq. of minimum	1.0	1.0	2.0	1.0	1.0
Freq. of maximum	2.0	1.0	1.0	1.0	3.0
Range	20.3	47.2	13.5	14.0	87.0
1st Quartile	83.1	70.0	84.0	84.0	76.5
Median	84.0	85.0	87.0	84.2	82.0
3rd Quartile	87.8	87.5	90.0	85.7	84.3
Sum	841.2	697.3	769.5	1015.4	1451.0
Mean	84.1	77.5	85.5	84.6	76.4
Variance (n)	30.4	197.7	22.0	12.7	345.3
Variance (n-1)	33.8	222.5	24.8	13.9	364.4
Standard deviation (n)	5.51	14.06	4.69	3.57	18.58
Standard deviation (n-1)	5.81	14.92	4.97	3.72	19.09
Variation coefficient	0.066	0.182	0.055	0.042	0.243
Skewness (Pearson)	-1.355	-1.246	-0.480	-0.152	-3.604
Skewness (Fisher)	-1.607	-1.510	-0.581	-0.175	-3.921
Skewness (Bowley)	0.613	-0.714	0.000	0.826	-0.419
Kurtosis (Pearson)	1.660	0.667	-1.057	0.190	12.043
Kurtosis (Fisher)	3.899	2.413	-0.870	1.035	16.337
Standard error of the mean	1.838	4.972	1.658	1.075	4.380
Lower bound on mean (95%)	80.0	66.0	81.7	82.3	67.2
Upper bound on mean (95%)	88.3	88.9	89.3	87.0	85.6
Standard error of the variance	15.9	111.2	12.4	5.9	121.5
Lower bound on variance (95%)	16.0	101.5	11.3	7.0	208.1
Upper bound on variance (95%)	112.6	816.5	90.8	40.0	797.0
Standard error(Skewness (Fisher))	0.687	0.717	0.717	0.637	0.524
Standard error(Kurtosis (Fisher))	1.334	1.400	1.400	1.232	1.014
Mean absolute deviation	3.624	11.469	4.000	2.472	9.036
Median absolute deviation	1.850	6.500	3.000	0.650	4.500
Geometric mean	83.9	75.9	85.4	84.5	
Geometric standard deviation	1.075	1.255	1.061	1.045	
Harmonic mean	83.7	74.0	85.2	84.5	

Table 9.01 Building Systems, Performance Descriptive Analysis

As a first analysis of the data, we can observe that the average in terms of academic performance based on the students' grades is quite similar in the courses, although there is a decrease in the mean in groups G2 and G6. If we analyze the data deeply we can see that if we remove the worst student, the average rises above 80, approaching the average of the other groups. The student with the worst grades, apart from affecting the mean, also generates a significant increase in the variance and standard deviation, which can lead to confusion but does not significantly modify the consistency of the whole group, and should not lead us to a misinterpretation.

In order to confirm the first analysis, we should do a deeper statistical analysis. For this second analysis, we use the statistical value "*p*" which provides us the level of trust about the statement analyzed. In our case the hypothesis used is that all of these groups of students have a similar performance.

p-values:

	BS g2	BS g3	BS g4	BS g5	BS g6
BS g2	**1**	0.988	0.988	1.000	0.376
BS g3	0.988	**1**	0.866	0.998	0.983
BS g4	0.988	0.866	**1**	0.978	0.115
BS g5	1.000	0.998	0.978	**1**	0.212
BS g6	0.376	0.983	0.115	0.212	1

Table 9.02 Building Systems, Performance Statistical Analysis

It is significant that when we statistically analyze the performance of the students, all the groups except G6 give us great confidence in terms of the equality of student performance. This is a warning that we have to take into consideration, with all the other analyses aside, whether this group can be part of the study or if it is not trustful as their performance is different from the others. The findings about G6 lead us to look for a possible explanation, and we find that in this semester a new teacher joined the course.

The author of this study taught the courses of construction together with all the professors involved in this study. From his expertise and knowledge of the other professors, and despite this being the same course conducted exactly the same, we should highlight as a possible explanation:

- All the students fear this professor, because the grades in the courses he teaches are lower than from the rest of the professors; this could cause the minimal difference triggered by statistical analysis -- perhaps it was not due to the students but to the professor who has joined the course. This puts us on notice and forces us to pay special attention to this group of students in the rest of analyses and courses as stated before.

After these analyses it is concluded that all the groups of students that participated in this study excluding G6 had a similar performance. Special attention should be paid to G6, because it had a lower performance than the other groups, which we correlate to the new professor in this course.

9.1.2. Building Components Course (BC)

The second analysis carried out focuses on the analysis of student academic performance in the course of "*BC*" construction 2, where we incorporated BIM into the curriculum through Autodesk products. To do this we studied the variation in student performance in each semester, taking into account the different tools incorporated, the time of their introduction, and other modifications in the methodology of the course. Therefore we are analyzing the global level of the group as it affects the performance of adding Revit to a construction course designed to be carried out with AutoCAD. The difference is that while AutoCAD is a drawing tool, Revit is a BIM tool that allows you to build a 3D model that incorporates information about the project such as physical properties, energy efficiency and cost of materials.

Although it has already been mentioned, it is necessary to emphasize that there are three different approaches to the BC course that we study and compare.

- G1 and G2 experienced the course as they had been during prior years until the implementation of BIM in the UAEU, using AutoCAD as a production tool;
- With G3, due to the teacher's pressure not to modify the course, it was decided to carry out the same course, with the same exercises, adding Revit and other new tools;
- Finally in groups G4, G5 and G6 the course was reorganized in such a way that the exercises of the course and the BIM part did not coincide, combining AutoCAD exercises to reduce the number and displacing Revit to the last 5 weeks of the course instead of integrate it, to reduce conflicts.

Course	Construction 2 (building components)					
BIM approach	No BIM		Add Revit to the existing course	Re-schedule the course	+ YouTube	Professor sick
Professor Lecture **Professor lab**	**B** **B**	**B** **B**	**B** **B & Jferrandiz**	**B** **B & Jferrandiz**	**B & F** **B & F & Jferrandiz**	**F** **B & F & Jferrandiz**
Student Group:	G1	G2	G3	G4	G5	G6
Statistic	F 14-15	Sp 14-15	F 15-16	Sp 15-16	F 16-17	Sp 16-17
Nbr. of observations	29.0	29.0	29.0	29.0	29.0	29.0
Nbr. of missing values	17.0	12.0	20.0	12.0	0.0	11.0
Sum of weights	12.0	17.0	9.0	17.0	29.0	18.0
Minimum	54.0	56.0	0.0	32.0	65.0	75.0

Maximum	94.0	97.0	88.0	90.0	92.0	93.0
Freq. of minimum	1.0	1.0	2.0	1.0	1.0	1.0
Freq. of maximum	1.0	1.0	1.0	2.0	2.0	2.0
Range	40.0	41.0	88.0	58.0	27.0	18.0
1st Quartile	63.3	73.0	31.0	65.0	81.0	80.3
Median	73.0	80.0	71.0	80.0	83.0	86.5
3rd Quartile	83.3	89.0	79.0	87.0	86.0	89.6
Sum	885.0	1357.0	467.0	1281.0	2386.5	1534.0
Mean	73.8	79.8	51.9	75.4	82.3	85.2
Variance (n)	156.2	108.7	1106.3	213.9	49.1	26.8
Variance (n-1)	170.4	115.5	1244.6	227.2	50.8	28.4
Standard deviation (n)	12.50	10.43	33.26	14.62	7.01	5.18
Standard deviation (n-1)	13.05	10.75	35.28	15.07	7.13	5.33
Variation coefficient	0.169	0.131	0.641	0.194	0.085	0.061
Skewness (Pearson)	0.162	-0.288	-0.517	-1.449	-0.968	-0.179
Skewness (Fisher)	0.187	-0.317	-0.627	-1.593	-1.021	-0.196
Skewness (Bowley)	0.025	0.125	-0.667	-0.364	0.200	-0.333
Kurtosis (Pearson)	-1.173	-0.367	-1.326	1.935	0.549	-1.086
Kurtosis (Fisher)	-1.130	-0.047	-1.383	3.111	0.896	-1.037
Standard error of the mean	3.768	2.607	11.760	3.656	1.324	1.257
Lower bound on mean (95%)	65.5	74.3	24.8	67.6	79.6	82.6
Upper bound on mean (95%)	82.0	85.3	79.0	83.1	85.0	87.9
Standard error of the variance	72.7	40.8	622.3	80.3	13.6	9.7
Lower bound on variance (95%)	85.5	64.1	567.8	126.0	32.0	16.0
Upper bound on variance (95%)	491.2	267.6	4567.9	526.4	93.0	63.9
Standard error(Skewness (Fisher))	0.637	0.550	0.717	0.550	0.434	0.536
Standard error(Kurtosis (Fisher))	1.232	1.063	1.400	1.063	0.845	1.038
Mean absolute deviation	10.583	8.325	30.568	11.190	4.987	4.586
Median absolute deviation	10.500	9.000	17.000	8.000	2.500	4.750
Geometric mean	72.7	79.1		73.5	82.0	85.1
Geometric standard deviation	1.195	1.150		1.289	1.095	1.065
Harmonic mean	71.6	78.4		70.8	81.6	84.9

Table 9.03 Building Components, Performance Descriptive Analysis

Analyzing the data obtained there is a very clear first analysis: introducing BIM into a course designed for another ICT without modifying anything was a disaster. This attempt divided the course into two groups, some that failed or left the course (which somewhat held the average) and another group adapted and received very good grades. This leads us to the fact that it is not a good learning method. The increase in teaching load increases the productivity of good students, but frustrates the rest leading them to suspend or even surrender and abandon the course halfway.

Regarding the analysis of the second method, student performance has grown in each new semester, presumably due to the maturity of the material and the introduction of new tools such as video tutorials on tools and complicated elements. The G4 group data allow us to affirm that the performance of the course without BIM was recovered and groups G5 and G6 improved performance by 5%. It is very curious that the G6 group, that was the worst performer in the BS course, is the one that had the best performance in the BC course. This may be due to the change of teacher from the previous section of the practical part of the course, who evaluated the students more strictly. This aspect could confirm the theory that the quality of the students had not fallen, but simply the evaluation criteria had changed during the BS course of G6.

p-values:

	BC g1	BC g2	BC g3	BC g4	BC g5	BC g6
BC g1	**1**	0.793	0.866	0.994	0.275	0.173
BC g2	0.793	**1**	0.360	0.987	0.934	0.628
BC g3	0.866	0.360	**1**	0.514	0.082	**0.026**
BC g4	0.994	0.987	0.514	**1**	0.525	0.237
BC g5	0.275	0.934	0.082	0.525	**1**	0.919
BC g6	0.173	0.628	**0.026**	0.237	0.919	1

Table 9.04: Building Systems, Performance Statistical Analysis.

As for the statistical analysis, we observe how the "*p*" value in terms of the homogeneity of the yield is equalized between groups G1, G2 and G4, reaching values close to 1 which would be 100%. G3 differs from all the others as we observed in the descriptive data due to the separation of the class between students who excelled and those who did not reach the minimum level, or even left the course. G5 and G6 are increasingly different from G1 and G2 because they are improving beyond the performance of the previous groups; even so we can verify that G2 and G5 are still quite similar although the average of G5 is higher.

9.1.3. **Advanced Building Systems (ABS)**

The third and last performance analysis of this study was done on the ABS course, which is the last course of construction at the UAEU. During this course BIM tools were optional and the students could use it with the professor's support, but it would not be allocated skills lectures. In this analysis we test if the modification of the curriculum affected their construction knowledge, understanding that most of the assignments performed were based on previous knowledge, as the major assignment was a working drawing set.

Course	Construction 3 (advanced building systems)				
BIM approach	No BIM implemented but they can use it as will				
Professor Lecture	**C**	**C**	**C**	**C**	**A**
Professor lab	**C & Jferrandiz**	**C & Jferrandiz**	**C & Jferrandiz**	**C & Jferrandiz**	**C**
Student Group:	G1	G2	G3	G4	G5
Statistic	Spr 14-15	F 15-16	Sp 15-16	F 16-17	Sp 16-17
Nbr. of observations	20.0	20.0	20.0	20.0	20.0
Nbr. of missing values	8.0	4.0	15.0	6.0	0.0
Sum of weights	12.0	16.0	5.0	14.0	20.0
Minimum	64.5	60.5	60.0	63.5	30.5
Maximum	77.5	78.5	70.0	82.0	92.0
Freq. of minimum	1.0	1.0	1.0	1.0	1.0
Freq. of maximum	1.0	1.0	2.0	1.0	1.0
Range	13.0	18.0	10.0	18.5	61.5
1st Quartile	67.9	68.8	64.0	69.8	79.4
Median	72.8	71.5	68.0	75.0	82.0
3rd Quartile	75.1	74.3	70.0	77.8	85.5
Sum	863.5	1132.0	332.0	1034.0	1606.0
Mean	72.0	70.8	66.4	73.9	80.3
Variance (n)	17.8	27.4	15.0	23.2	150.5
Variance (n-1)	19.4	29.2	18.8	24.9	158.5
Standard deviation (n)	4.215	5.235	3.878	4.812	12.269
Standard deviation (n-1)	4.403	5.407	4.336	4.994	12.588
Variation coefficient	0.059	0.074	0.058	0.065	0.153
Skewness (Pearson)	-0.254	-0.463	-0.612	-0.486	-3.233
Skewness (Fisher)	-0.292	-0.512	-0.913	-0.547	-3.501
Skewness (Bowley)	-0.345	0.000	-0.333	-0.313	0.143

Kurtosis (Pearson)	-1.244	-0.753	-1.184	-0.444	10.665
Kurtosis (Fisher)	-1.244	-0.560	-0.738	-0.065	14.279
Standard error of the mean	1.271	1.352	1.939	1.335	2.815
Lower bound on mean (95%)	69.2	67.9	61.0	71.0	74.4
Upper bound on mean (95%)	74.8	73.6	71.8	76.7	86.2
Standard error of the variance	8.3	10.7	13.3	9.8	51.4
Lower bound on variance (95%)	9.7	16.0	6.7	13.1	91.6
Upper bound on variance (95%)	55.9	70.0	155.2	64.7	338.0
Standard error(Skewness (Fisher))	0.637	0.564	0.913	0.597	0.512
Standard error(Kurtosis (Fisher))	1.232	1.091	2.000	1.154	0.992
Mean absolute deviation	3.708	4.125	3.520	3.969	6.410
Median absolute deviation	4.250	3.000	2.000	3.000	3.500
Geometric mean	71.8	70.6	66.3	73.7	78.8
Geometric standard deviation	1.064	1.081	1.069	1.071	1.259
Harmonic mean	71.7	70.3	66.2	73.5	76.2

Table 9.05 Advanced Building Systems, Performance Descriptive Analysis

Based on the data obtained we reaffirm the convenience of incorporating BIM by reorganizing or redesigning the construction courses. We can observe that as in the ABS course, the performance curve corresponds to the same pattern as in the BC course. In this pattern the performance of the students decreased in G3 while in G4 the performance was recovered and in G5 it improved. It has not been possible to obtain data from G6 in the ABS course because our research period in this center ended in that semester.

The main professor of this course "*C*" was the same one who joined the BS during G6. We can verify that the average performance in this course was lower than that of the other two studied. When we add this last statement to the previous observations, which highlighted that G6 was the best in BC after dropping their performance in BS. We must conclude that the data proves that the inclusion of the new professor in the BS course caused a drop in the course performance, which has nothing to do with their knowledge acquisition as they continued to perform well in the subsequent courses, but rather with a more strict evaluation criteria than of the others.

p-values:

	ABS G1	ABS G2	ABS G3	ABS G4	ABS G5
ABS G1	**1**	0.990	0.288	0.632	**0.001**
ABS G2	0.990	**1**	0.314	0.549	**0.000**
ABS G3	0.288	0.314	**1**	0.152	**0.019**
ABS G4	0.632	0.549	0.152	**1**	**0.003**
ABS G5	**0.001**	**0.000**	**0.019**	**0.003**	1

Table 9.06 Building Systems, Performance Statistical Analysis

As for the statistical analysis, we observe how the "*p*" value in terms of the homogeneity of the yield is equalized between G1, G2 which didn't receive BIM skills, reaching values close to 1 which would be 100%; G3 differs with all the others as we have observed in the descriptive data as it happened during the BC course, due to the drop in performance. However G4 and G5 were also very different from all the others, but in this case it was the opposite **--** the grades and the performance increased with G4, and later with G5.

G5 and G6 are increasingly different from the G1 and G2 because they were improving over the performance of the previous groups; even so we can verify that G2 and G5 are still quite similar although the average of G5 is higher.

Considering all the data we have and not only the grades, the qualitative jump in G5 in all the statistics has been quite large. However we cannot attribute it only to the introduction of BIM, but also to the inclusion of a new professor in the subject during the semester, which produced a variation in the criterion of grades as already happened in the subject BS in G6.

During the spring of 2016 the professors of the BS and ABS courses, instead of teaching the courses individually, began sharing both courses which produced an intermediate range in the grading criteria.

9.1.4. **Student Performance Analysis Conclusion**

Conclusions based on student performance with BIM introduction based on Revit at the BC course:

- Re-design/re-organize the course and the assignments in order to properly introduce, understand and practice the content of the course relying on the new BIM skills.
- Use video tutorials and other means of communication that increase the students' interaction as well as commitment to the course and motivation, in order to have a positive influence on the acquired knowledge and therefore the academic performance.

9.2. Student Satisfaction with BIM

When we are talking about BIM skills, the tool "*X*" which in our case is Revit, student satisfaction is not derived from the BIM itself and how useful it may be in terms of its future, but how useful it is to develop their designs, plans and projects in the different courses. To evaluate their satisfaction we interspersed these four questions within a larger test:

- Evaluate Revit as a tool to model your designs.
- Evaluate Revit as a tool to develop working drawings.
- Evaluate Revit as a tool to improve your designs.
- Evaluate Revit overall to develop your projects.

From this survey and the satisfaction-related questions, we measured how satisfied the student was with the BIM tool Revit. As we have already discussed, the satisfaction and motivation from the students and the professors will make the skills training worthy or meaningless, since satisfaction and motivation are key to engaging the students. BIM is a constantly developing environment where every year the tools are improved, updated or even replaced with new ones. We need the students to use the skills which we provide as background knowledge, upon which to expand and constantly update themselves in the use of this new tool and the BIM concepts that necessarily will be a boon for the professional future of our students.

9.2.1. Student Satisfaction in BC Course

As has already been stated, student satisfaction with the tool derives from their feelings, the use of the tool and their achievements at that moment, which relate to the subject in which they are using it. For this reason G3 has the lowest average and a large standard deviation as seen in Table 9.07. The students who succeeded in the course were very satisfied, but those who failed or abandoned it, were obviously not so happy. The mean between these two groups of students brings the motivation to a neutral medium. It is therefore easy to understand that once the problems of this first approach methodology were detected and solved, the satisfaction of the students would grow. The analysis of the introduction of Revit in the BC course of G3 has led to a scientific publication in the high impact journal "*Universal Access to Information*",[42] which explains this methodology, the problems that were encountered, and how we can approach a solution.

Satisfaction						
BCC						
Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
51.889	BC-g3	32	1.000	5.000	3.250	1.270
75.353	BC-g4	52	2.000	5.000	3.827	0.879
82.293	BC-g5	104	2.000	5.000	3.904	0.757
85.222	BC-g6	64	2.000	5.000	4.047	0.844

Table 9.07 Components, Student Satisfaction Descriptive Analysis

We can observe in Table 9.07 that there is a direct correlation between the change of methodology in G4, G5, and G6 and their performance and satisfaction. The satisfaction of the students grew as long as the course improved each semester, providing continuous improvement. We can confirm this statement as for the statistical analysis in table 9.08. We observe how the "*p*" value in terms of the homogeneity of the yield is differentiated between the groups, getting smaller until the values of certainty which provide a 98% differentiation between G3 and both G5 and G6.

		BIM A		BIM B	
	p-values:	BC-g3	BC-g4	BC-g5	BC-g6
BIM A	BC-g3	**1**	0.135	**0.021**	**0.010**
	BC-g4	0.135	**1**	0.972	0.517
BIM B	BC-g5	**0.021**	0.972	**1**	0.562
	BC-g6	**0.010**	0.517	0.562	1

Table 9.08 Components, Students' Satisfaction Statistical Analysis

By all these analyses, we can conclude that student satisfaction increased while the course and the introduction of the tools were refined. Student satisfaction moved from neutrality or indifference in the course with difficulties in introducing BIM tools, to a higher satisfaction level when the problems were solved. The last group satisfaction arrived at over four on a scale from 1 to 5, where 5 is the maximum.

9.2.2. Student Satisfaction in ABS Course

In the third course of construction we evaluate the evolution of BIM student satisfaction over time, once the skills training stopped. To avoid misinterpretations when analyzing the data of ABS, it should be understood that the composition of the student group G3 had changed and was not the same we have studied in the BS and BC courses. In the AE program of the UAEU, there are few students who do not pass all the subjects yearly. However in our first approach to introduce BIM at BCC half of G3 failed or dropped the course. This means that G3 at ABS level changed from an average group into a good one, when the worst students moved to G4 in the BC course. This must be considered when we do all the analyses.

Satisfaction						
ABS						
Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
70.750	ABS-g2	56	1.000	5.000	3.107	1.303
66.400	ABS-g3	24	3.000	5.000	3.792	0.588
73.857	ABS-g4	32	1.000	5.000	3.094	0.995
80.300	ABS-g5	52	1.000	5.000	3.731	0.689

Table 9.09 Advanced Building Systems, Students' Satisfaction Descriptive Analysis

As G3 changed from an average group in ABS to a good one, the students with a lower performance did not pass the course. The analysis clearly shows that the level of satisfaction is the highest in the study, as there were no students with problems in the course or the BIM skills.

G4 in BCC and ABS showed the opposite effect. In this group we gathered all low-performance students from G3, who had difficulties dealing with the BCC course and/or the BIM skills, which could skew down all the means of the study. This affected the G4 satisfaction mean, which was low down into a neutral zone. The neutral outcome can be considered as an increase from the satisfaction ratio in G2, as this mean is the result of including the results of the BS G4 students and the lower-performing ones from the BS G3 students.

We have to congratulate ourselves about the methodological improvements in terms of satisfaction. An average group, such as G5, has almost the same mean and standard deviation of G3 where all the students succeeded with the tools and had very good grades. What this indicates is that in understanding the new methodology all the students were very satisfied.

	p-values:	No BIM ABS-g2	BIM A ABS-g3	BIM B ABS-g4	 ABS-g5
No BIM	ABS-g2	**1**	0.107	1.000	**0.036**
BIM A	ABS-g3	0.107	**1**	**0.021**	1.000
BIM B	ABS-g4	1.000	**0.021**	**1**	**0.004**
	ABS-g5	**0.036**	1.000	**0.004**	1

Table 9.10 Advanced Building Systems, Students' Satisfaction Statistical Analysis

As for the statistical analysis, we observe how the "*p*" value in terms of the homogeneity of the yield is equalized between two groups. G2 and G4 with neutral mean and G3 and G5 with high satisfaction means, in both cases the "*p*" value reaches values close to 1, which would be 100%.

G2 and G4 differ from G3 and G5 as we observed in the descriptive data: G2 because the students did not have any background about BIM; G4 because the group of students was different due to the inclusion of those who had problems with the BIM skills and did not reach the minimum level; G3 at ABS because we only had the students who excelled expectations in the BCC course and BIM skills; in addition G5 was an average group, and as we discussed in the descriptive analysis, the cause was the ICT introduction improvement process, realized in the BCC course.

Even so, we can also observe that when the tool is not compulsory and therefore the course is not designed for it, satisfaction falls a small percentage with respect to the BCC course. Considering the level of satisfaction of the G3 students who passed the BC course, this suggests their motivation is very high and very similar to that of the G5 group, which leads us to corroborate the affirmation made that the student will be more or less satisfied with the tool according to the direct utility in the course.

9.3. Student Motivation for BIM

For this analysis we directly asked the students their level of motivation for BIM based in Revit to improve their grades, for their studies in general, and for their future career.

9.3.1. BIM to Help Improve Their Grades

In this first motivation analysis, we are checking the students' expectations about the BIM tools to help them improve their performance. This concept is important because it will strengthen their confidence in the tool, its use and usefulness. As it has happened at many of the points of this study, each section is related to the others but these relationships will be discussed at the end of this chapter.

9.3.1.1. *BC Course*

We can see from the table that the better the course was, the better the acceptance of the tool and its adaptation to the exercises. This suggests that as a course is improved and stabilized, the student's opinion grows and improves on this point. G6 lowered their appreciation of the tool as a method to improve their grades, but this may be because during that semester the professor in charge of BIM skills was ill. This affected the course, as the professor was unable to devote as much attention to the students and reduced the sessions about BIM skills by 20%. Remember that G4 in the BCC and ABS courses was a worse group of students, due to the reasons already discuss before several times. Even with this disadvantage, the motivation after changing the BIM introduction methodology improved.

BIM to improve Grades						
BCC						
Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
51.889	BC-g3	8	1.000	5.000	3.000	1.309
75.353	BC-g4	13	2.000	5.000	3.385	0.870
82.293	BC-g5	26	1.000	5.000	3.885	0.952
85.222	BC-g6	16	1.000	5.000	3.625	1.455

Table 9.11 Building Components, Students' Mot. Improve Grades Descriptive Analysis

Regarding the confidence of the assertions made in the previous paragraph. we can see how the difference of G3 is growing, reaching a 78% differentiation between the opinion of G3 and G5, which would be the maximum exponent of this investigation since we do not have all the data for G6, and the author's participation in the course was affected due to health issues.

		BIM A		BIM B	
	p-values:	BC-g3	BC-g4	BC-g5	BC-g6
BIM A	BC-g3	**1**	**0.890**	**0.260**	**0.626**
	BC-g4	**0.890**	**1**	0.314	0.678
BIM B	BC-g5	**0.260**	0.314	**1**	1.000
	BC-g6	**0.626**	0.678	1.000	1

Table 9.12 Building Components, Students' Mot. Improve Grades Statistical Analysis

When analyzing the homogeneity data from the "*p*" calculated value, G5 and G6 are 100% similar. While G4 is more similar to G3 than to G6, and as we highlighted the composition of G4 makes it a special case of study, which as the "*p*" value indicates is in the middle point between G3 and G4, sometimes yielding confusing readings.

All the data obtained confirms that the second introduction methodology is an improvement over the data collected from the previous one.

9.3.1.2. *ABS Course*

It is very striking, and it has to be analyzed, that the opinion of the students radically changes from one course to the next.

If we look at the means obtained in this section for the BC and ABS courses and we compare them, we can see that in those groups with low motivation in this section about using BIM to improve their grades, they managed to increase it as soon as they were not forced to use it; those who dominated used it and those who did not do as well simply remained neutral instead of giving a negative evaluation.

It is also surprising that the groups that valued this tool during the BC course as an aid to improve their notes when it was an obligation, lowered their opinion as soon as they were not obligated. Our hypothesis, that we hope to confirm in the interviews, is that those students who had good support from the teacher to develop their projects in Revit, when this support was withdrawn without having the program strengthened, their confidence was lowered and therefore their motivation.

BIM to improve Grades						
ABS Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
70.750	ABS-g2	14	2.000	5.000	3.857	0.949
66.400	ABS-g3	6	3.000	5.000	3.833	0.753
73.857	ABS-g4	8	3.000	5.000	3.500	0.756
80.300	ABS-g5	13	1.000	5.000	3.231	1.363

Table 9.13 Advanced Building Systems, Students' Mot. Improve Grades Descriptive Analysis

This is very intriguing because G4, which should have been the lowest motivated due to the large number of students with problems during BCC, has a better motivation than G5.

		No BIM	BIM A	BIM B	
	p-values:	ABS-g2	ABS-g3	ABS-g4	ABS-g5
No BIM	ABS-g2	**1**	0.999	0.742	0.605
BIM A	ABS-g3	0.999	**1**	0.794	0.773
BIM B	ABS-g4	0.742	0.794	**1**	0.980
	ABS-g5	0.605	0.773	0.980	1

Table 9.14: Advanced Building Systems, Students' Mot. Improve Grades Statistical Analysis.

Regarding the statistical distinction of the students' opinions calculated by the "p" value, it is very curious to observe that the average value seems similar in the ABS course to BC although applied to different groups. The statistics reject this first impression, affirming that while in the ABS course there is no group that reaches 50% differentiation in terms of their opinions, in the BC course there is a statistically proven differentiation among some groups greater than 80%. This is surprising because of the great similarity in the averages obtained in both courses.

The opinions of the students regarding the satisfaction, motivation and suitability of a tool are accentuated when it is a requirement and must be put it into practice by decree. When these skills are optional, the opinion becomes less relevant and more stable. We can confirm this with a high homogeneity value in all the groups and all the different cases, even the group that did not use the tool.

9.3.2. **BIM to Help in Their Studies**

The opinion of students of the usefulness of a new tool for their studies is determined by many factors such as difficulty of learning to use the tool and the ability of the student, but there are two main indicators of whether the student will continue along this path or not -- the first contact with the tool and evaluation in the introductory course.

Their opinion can change while they continue using the tool, but if the experience is very bad initially and they are not conditioned to continue using it, they can simply abandon the tool and all the effort to introduce it correctly and teach them useful skills would be in vain.

9.3.2.1. *BC Course*

It is shocking that in this section in the course of introducing the tool, the opinion about the program and its usefulness for the students' learning and the development of their studies is much more marked than their opinion in terms of the benefits to their academic performance. This indicates that it does not only depend on the evaluation obtained; we observed that in the course in which the students suffered more and the evaluation of their performance was much worse, the opinion was negative, or what is the same below the neutral media, while in the other groups their opinion was much higher than neutral.

This confirms what we discuss at the beginning of the chapter, that although many factors influence the opinion of the student, the first impression and academic performance in the course will have a great impact on student opinion.

BIM helps in their studies						
BCC						
Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
51.889	BC-g3	8	1.000	4.000	2.750	1.165
75.353	BC-g4	14	3.000	5.000	4.214	0.802
82.293	BC-g5	26	1.000	5.000	4.077	1.017
85.222	BC-g6	16	1.000	5.000	4.250	1.125

Table 9.15 Building Components, Students' Mot. Help in their studies Descriptive Analysis

The opinion of the students in G3, in which the introduction of the tool had problems that affected the evolution of the course and the evaluation of the students, differed completely from the rest of the groups which had a very favorable opinion regarding the tool. As we can read in the statistical study of the "*p*" value, all the groups but G3 are homogeneous. Even G4, which holds the underperforming students from G3, was similar -- at 95% -- to G5 and G after modifying the BIM skills introduction.

`		BIM A		BIM B	
	p-values:	BC-g3	BC-g4	BC-g5	BC-g6
BIM A	BC-g3-M14	**1**	**0.035**	**0.037**	**0.028**
	BC-g4-M14	**0.035**	**1**	0.995	0.948
BIM B	BC-g5-M14	**0.037**	0.995	**1**	0.850
	BC-g6-M14	**0.028**	0.948	0.850	1

Table 9.16 Building Components, Students' Mot. Help in their studies Statistical Analysis

9.3.2.2. *ABS Course*

As already discussed in chapter 9.3.2.1, the means obtained in ABS do not follow the ones obtained in the previous course. The fact that the BIM skills were not mandatory modified the students' opinion. It is curious that while there is such a large differentiation from the opinion of the BC course in which the tool is introduced. The students, insofar as they are not instructed and demand such a tool, tend to neutralize their opinion both in the negative case and in the positive. If we observe the data the analysis is very easy, all the groups have a fairly similar opinion, with a slightly positive difference in G4.

So we can observe that when the students in the ABS course were asked, we did not obtain any result below the neutral average, but also no result much higher than the neutrality, which leads us to think that if we only introduce the tool in a course, little by little the positive or negative effect of the experience is diluted for most of the students. This statement causes us to recommend including these tools in various courses progressively in experience and difficulty, giving the student a pleasant experience that reinforces their opinion and building a solid base of knowledge, not only in skills but also in BIM concepts.

BIM helps in their studies						
ABS						
Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
70.750	ABS-g2	14	1.000	5.000	3.500	1.092
66.400	ABS-g3	6	3.000	4.000	3.500	0.548
73.857	ABS-g4	8	3.000	5.000	3.875	0.641
80.300	ABS-g5	13	1.000	5.000	3.538	1.198

Table 9.17 Advanced Building Systems, Students' Mot. Help in their studies Descriptive Analysis

As we already discussed in the chapter 9.3.2.1, the fact that the BIM skills were not required modified the students' opinion. In that case the students' opinion became homogeneous, and at this new stage of our research the means are less homogeneous from what they used to be. We can easily describe that while introducing the tools the opinions are more different, so the means will be more equal or different but not in the middle. But when we move to the next course where the tool is not a must, the opinion is more neutral but the homogeneity of the samples are not that similar or different but in a range from 60% to 98%, changing from one group to another.

		No BIM	BIM A	BIM B	
	p-values:	ABS-g2	ABS-g3	ABS-g4	ABS-g5
No BIM	ABS-g2	**1**	0.993	0.881	1.000
BIM A	ABS-g3	0.993	**1**	0.688	0.993
BIM B	ABS-g4	0.881	0.688	**1**	0.940
	ABS-g5	1.000	0.993	0.940	1

Table 9.18 Advanced Building Systems, Students' Mot. Help in their studies Statistical Analysis

9.3.3. **BIM to help improve their future career**

It is very important to understand the students' feelings towards their future career and not only their present life in academia. The students will remain at the university for a short period, while they will be using the knowledge acquired there all their lives. For this to happen they need to feel it is useful to continue mastering their skills.

9.3.3.1. *BC Course*

We can see from the data that the G4, G5 and G6 students were more confident than those of G3 about BIM and Revit and their ability to help them in their future careers. However, we do not understand why G5 had less motivation and confidence than G4 and G6. Even so, the motivation is still higher than the average and G3. Despite the unknown complication, in G5 the motivation of the students is almost 4 on a scale from 1 to 5. This indicates that those students who dealt with the second methodology proposed to introduce BIM based on Revit saw improved motivation to use these skills for their future.

We can also observe how the affirmations that we saw in the data are reinforced and are obvious in all the sections of this study, from which we conclude that the incorporation of a new ICT requires a previous study and the re-design of the course in which it is intended to be implemented in order to achieve a positive effect on motivation, satisfaction and academic performance.

BIM will help in their future career						
BCC Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
51.889	BC-g3	8	1.000	5.000	3.250	1.488
75.353	BC-g4	12	4.000	5.000	4.333	0.492
82.293	BC-g5	26	1.000	5.000	3.846	1.008
85.222	BC-g6	16	1.000	5.000	4.125	1.147

Table 9.19 Building Components, Students' Mot. For their careers Descriptive Analysis

The statistical analysis of the data leads us to confirm that there has been some differentiating factor between the G5 and G4 / G6 courses, which we will try to discern in the interviews with the students, although it may be difficult to find out since no student has experienced the two semesters. We can also observe that the G5 is more similar to the G3 than the G6. We do not really have a clue about this last statement and we hope to find the solution during the interviews. However, the last thing is that in terms of the sense of usability of BIM for their future career, looks like each group is completely different as none of them has at least a 75% of certainty to confirm that both groups have a homogeneous opinion.

		BIM A		BIM B	
	p-values:	BC-g3	BC-g4	BC-g5	BC-g6
BIM A	BC-g3-M15	**1**	0.337	0.741	0.451
	BC-g4-M15	0.337	**1**	0.455	1.000
BIM B	BC-g5-M15	0.741	0.455	**1**	0.677
	BC-g6-M15	0.451	1.000	0.677	1

Table 9.20 Building Components, Students' Mot. For their careers Statistical Analysis

The analysis of the "*p*" value table allows us to relate this question to the personal wills and desires of the students towards their future career, not only their skills and the advantages and disadvantages of this BIM in the AEC market. This is an opinion or discussion, which has no real scientific proof.

9.3.3.2. *ABS Course*

During the ABS course the students' opinions become milder, as we have observed in all the data obtained in the different sections of this chapter. The students continued to be motivated to use the tool but their motivation decreases in groups with great motivation, and increases in those with low motivation. This is due to the neutralization of people who have not mastered the tool, so in cases of high general motivation their motivation decreases neutralizing, while in cases of low motivation there is the same effect but these individuals pass from demotivation to indifference.

We can see how motivation is maintained. The most motivated group has decreased motivation but still is the most motivated, while with the lowest motivated the mean grows but it is still the least motivated. In this case, specifically in terms of the motivation of students towards the utility of BIM and Revit for their future careers, it is quite high although without reaching over 75% motivation, as it was in two of the four cases analyzed in the previous course.

BIM will help in their future career						
ABS						
Grade mean	Variable	Real Obs.	Min	Max	Mean	Std. deviation
70.750	ABS-g2	14	1.000	5.000	3.857	1.292
66.400	ABS-g3	6	3.000	4.000	3.500	0.548
73.857	ABS-g4	8	3.000	5.000	4.000	0.756
80.300	ABS-g5	13	1.000	5.000	3.615	1.261

Table 9.21 Advanced Building Systems, Students' Mot. For their careers Descriptive Analysis

The statistical analysis does not give us any surprise and confirms all the statements made in this section. Seeing how the differentiation between the groups is lower than during the BC course, we can observe how the differentiation of G3-G4 falls from 65 % during the BC course to 42% during the ABS course. As stated, this is a very different section, where it seems that not many of the rules really apply. All but G3 looks to be very homogeneous with a certainty using the "*p*" value higher than 93%.

		No BIM	BIM A	BIM B	
	p-values:	ABS-g2	ABS-g3	ABS-g4	ABS-g5
No BIM	ABS-g2	**1**	0.731	1.000	0.938
BIM A	ABS-g3	0.731	**1**	0.579	0.976
BIM B	ABS-g4	1.000	0.579	**1**	0.931
	ABS-g5	0.938	0.976	0.931	1

Table 9.22 Advanced Building Systems, Students' Mot. For their careers Statistical Analysis

9.3.4. **Future Use of BIM skills**

During this part of the chapter we will analyze the change from AutoCAD drafting tools to Revit as a BIM tool. By this final analysis we can truly understand if our students are really gaining the motivation and necessary skills, or if the final stage of the BIM introduction at the UAEU is not sufficient and should be increased in order to continue this transformation process towards a new working environment in the AEC industry.

9.3.4.1. *BC Course*

We can see how all the data are interrelated, therefore in those courses where motivation, satisfaction and performance are higher, there is a desire to continue using the application and the success of its implementation as a useful tool for the future of the students. So we can easily describe how the G3 is the neutral mean, while with all the other groups that used the re-designed course, their motivation was over 4 on scale of 1 to 5.

Revit continuity				
BCC				
Grade mean	Variable	Real Obs.	Mean	Std. deviation
51.889	BC-g3	8	3.125	1.553
75.353	BC-g4	13	4.231	0.725
82.293	BC-g5	26	4.192	0.749
85.222	BC-g6	16	4.313	0.793

Table 9.23 Building Components, Students' Revit continuity Descriptive Analysis

As for the statistical analysis, we observe how the "*p*" value in terms of the homogeneity of the yield is equalized between G4, G5 and G6, reaching values close to 1 which would be 100%. G3 differs from all the others, as we observed in the descriptive data, due to the different design of the new ICT implementation. This resulted in differences in the desire for continuation with the tool, where different groups with the same course design had a similar desire. In this way we see how the differentiation of this factor is less than 6% within the groups at the same methodology, and 95% for those courses with different methodologies.

		BIM A		BIM B	
	p-values:	BC-g3	BC-g4	BC-g5	BC-g6
BIM A	BC-g3	**1**	0.302	**0.235**	**0.212**
	BC-g4	0.302	**1**	0.999	0.981
BIM B	BC-g5	**0.235**	0.999	**1**	0.944
	BC-g6	**0.212**	0.981	0.944	1

Table 9.24 Building Components, Students' Revit continuity Statistical Analysis

9.3.4.2. *ABS Course*

Regarding the ABS course where BIM and the new tool was not obligatory, we have observed as a step in all the previous sections that when a tool is not fully consolidated and is no longer mandatory, the values of motivation, and satisfaction come closer to neutrality. Nevertheless, as per the data available in this section, in terms of skills continuity it is not totally true. G3 and G5 raised their will to continue with the tool, and G4, which lowered its will a bit, was still 4 in a range from 1 to 5, where 5 is the maximum.

The correlation with all the other analyses is a bit complicated without the qualitative data from the interviews, but it is a very salient point that most of the students were willing to continue with the BIM skills we introduced. This is already a success in and of itself. From this success we have to confront the need to change the negative opinion that some of the students had after the initial approach to introducing BIM. We not only solved the issue for new students by changing the methodology, but also changed the mind of those students who did not want to continue using the skills because they had failed the course and had a bad first impression.

Revit continuity				
ABS				
Grade mean	Variable	Real Obs.	Mean	Std. deviation
70.750	ABS-g2	14	2.857	1.292
66.400	ABS-g3	6	4.167	0.983
73.857	ABS-g4	8	4.000	0.926
80.300	ABS-g5	13	4.615	0.650

Table 9.25 Advanced Building Systems, Students' Revit continuity Descriptive Analysis

As for the statistics, considering the "*p*" value as the comparison of the homogeneity of the student groups, they confirm that the courses with different methods had different outcomes in terms of willingness to continue the skills introduced, with the exception of G3 and G4, which had a huge homogeneity which was a pleasant surprise. As discussed previously G3 in ABS were only the high performing students, while G4 in ABS was an average group, with the addition of the underperforming students from G3. The homogeneity not only in this section but also in some other analysis done in this thesis, means that we increased the level of motivation, performance and satisfaction of the students with the new methodology causing a demotivated group to become motivated, satisfied and performing better than expected.

		No BIM	BIM A	BIM B	
	p-values:	ABS-g2	ABS-g3	ABS-g4	ABS-g5
No BIM	ABS-g2	**1**	0.191	0.213	**0.002**
BIM A	ABS-g3	0.191	**1**	**0.986**	0.737
BIM B	ABS-g4	0.213	**0.986**	**1**	**0.365**
	ABS-g5	**0.002**	0.737	**0.365**	1

Table 9.26 Advanced Building Systems, Students' Revit continuity Statistical Analysis

9.4. Interviews

Fourteen interviews were conducted with students from the different groups -- one interview with G2 before we introduced BIM, three interviews with G3, G4 and G5 where we have all the data collected for our research methodology, and four interviews with G6, which had the same methodology but we do not have complete data from the last course of construction.

In these interviews the students gave their points of view and reasons for the data that we have just analyzed.

9.4.1. Pre-BIM

Once the data for all the research was collected, and before the students from G2 and the author left UAEU on different paths, we had an informal discussion. They said that it was a pity not to learn BIM and Revit while they were studying, but half of them will look for a course, certificate or other way to learn a tool that now they consider necessary.

They felt that the tool can be more useful in the ABS course that in the BCC course, because BCC is focused on detailing while ABS is focused on the whole project -- structure, architectural drawings, details and MEP.

This was not properly documented, but we felt is necessary to have the starting students' point of view before they use the tools. We have to agree with the students in the last statement, but there is a considerable problem in trying to achieve it. In order to be able to accomplish an ABS course using BIM tools, the students will need a lot of expertise. BCC is only architectural and detailing which makes it suitable as a starting point, but during the ABS course the students need not only the architectural model but the structure and MEP which require a lot more skills.

9.4.2. Method "*A*" First Approach

These seven points are the main reasons and conclusions of the first approach to introduce BIM in the curricula based on G3 student opinion in the interviews:

• Two out of three students interviewed finished the exercises using AutoCAD instead of Revit (as they were asked).

• All students lacked previous skills; even the ones who succeeded in using Revit agree that they needed more time to learn and apply it properly.

• All of them think that Revit saves time, so they have continued improving their BIM skills after the course in order to use it properly in their projects.

• All of them said that Revit is faster to develop projects and helps them understand the course materials; however AutoCAD provides more freedom to develop custom building details.

• Only one student said that it was fine to use both programs at the same time, while the other two got confused and after trying Revit they finished their exercise using AutoCAD because they were used to working with it.

• All of them would like to focus on Revit, but two of them feel AutoCAD is necessary to create 2D detailing due to the freedom it offers.

• One of them pointed out that it would be necessary to have an introductory course for architectural skills before using Revit in another course.

It is obvious from the interviews that students have difficulties in implementing BIM. The results show that half of the BC G3 course did not respond well. This has led us to develop a set of recommendations for implementing BIM for better outputs, which we applied in the following semesters.

9.4.3. **Method “*B*”**

In order to get a better picture of the final results, where most of the students focus their opinions in the same direction, we grouped the opinions from G4, G5 and G6 in the same discussion as they used the same course methodology. We interviewed ten people for this section, four from G6 and three from G4 and G5.

We can summarize student opinions from these samples into three main areas or concepts:

- The lack of skills in BIM tools, focused in this research on Revit, where the students stated:
    - 30% finished their Revit assignments in AutoCAD due to the lack of skills and time.
    - 90% had no previous experience with Revit before the course.
    - 90% thought they needed more Revit skills to meet their expectations.
    - 80% felt YouTube videos were helpful as support and to review the lectures.
- Revit should be given more importance in the course.
    - 80% noticed the course was designed for AutoCAD, the time for the exercises was enough.
    - 100% thought that the Revit assignments where rushed and didn’t have enough time
    - 90% thought that Revit should begin from day one of the course.
    - 60% would like to use only Revit in the course
    - 80% used Revit in the ABS course, where it was not required; with those who didn’t use it, it was due to the lack of skills.
- Benefits of BIM and Revit in their studies and career.
    - 70% thought that it will be useful in their careers, and also that the market is asking for this kind of skills.
    - 50% pointed out that Revit helped them understand the content of the course.
    - 50% said out that Revit made the preparation of the project easier.

9.4.4. Discussion and Conclusion

The students believe that BIM improves their work efficiency and the understanding of the course materials, which leads them to improve their motivation and satisfaction in the use of Revit. During introduction method "*A*" we did not realize, however, the improvement of their performance in the course due to the students' lack of skills with the new ICT and the wrong approach, which was redesigned to use several ICTS as a delivery method. A deep analysis of the results interviews concludes that:

• G3 decreased their motivation during the BC course, and increased a lot after finishing their construction courses due to using method "*A*" to introduce BIM. After the ABS course the students realized that Revit is faster for developing, improving and understanding their projects and their motivation grow.

• Half of the G3 students became confused by the use of two ICTs that can deliver similar outputs simultaneously, so they dropped the ICT in which they had fewer skills; this problem was solved in introductory method "*B*".

• The satisfaction with Revit to develop their projects increased from when they began to use it and is constantly growing as they improve their skills.

• The performance of the BC using Revit decreased during introduction Method "*A*" because half of the students did not succeed in working simultaneously with AutoCAD and Revit, due to their lack of previous skills and time. This situation confused those students. Students explained in the interviews that currently they are highly motivated and they would have preferred the course had separated AutoCAD and Revit into two different stages. During Method "*B*" the performance of the students increased, not only during the BC course but also in the following construction course.

• The intention of using Revit in their future projects grew at the same time as their skills and motivation.

BIM tools cannot be simply introduced in a course; the course needs to be re-designed to make it a perfect fit for the new IT tool. That would improve the students' efficiency in developing working drawings and give a better understanding of the construction concepts explained in the course. This change will improve not only student motivation and satisfaction but also their learning process and performance.

9.5. **Work sample comparison**

Method "*A*" Samples:

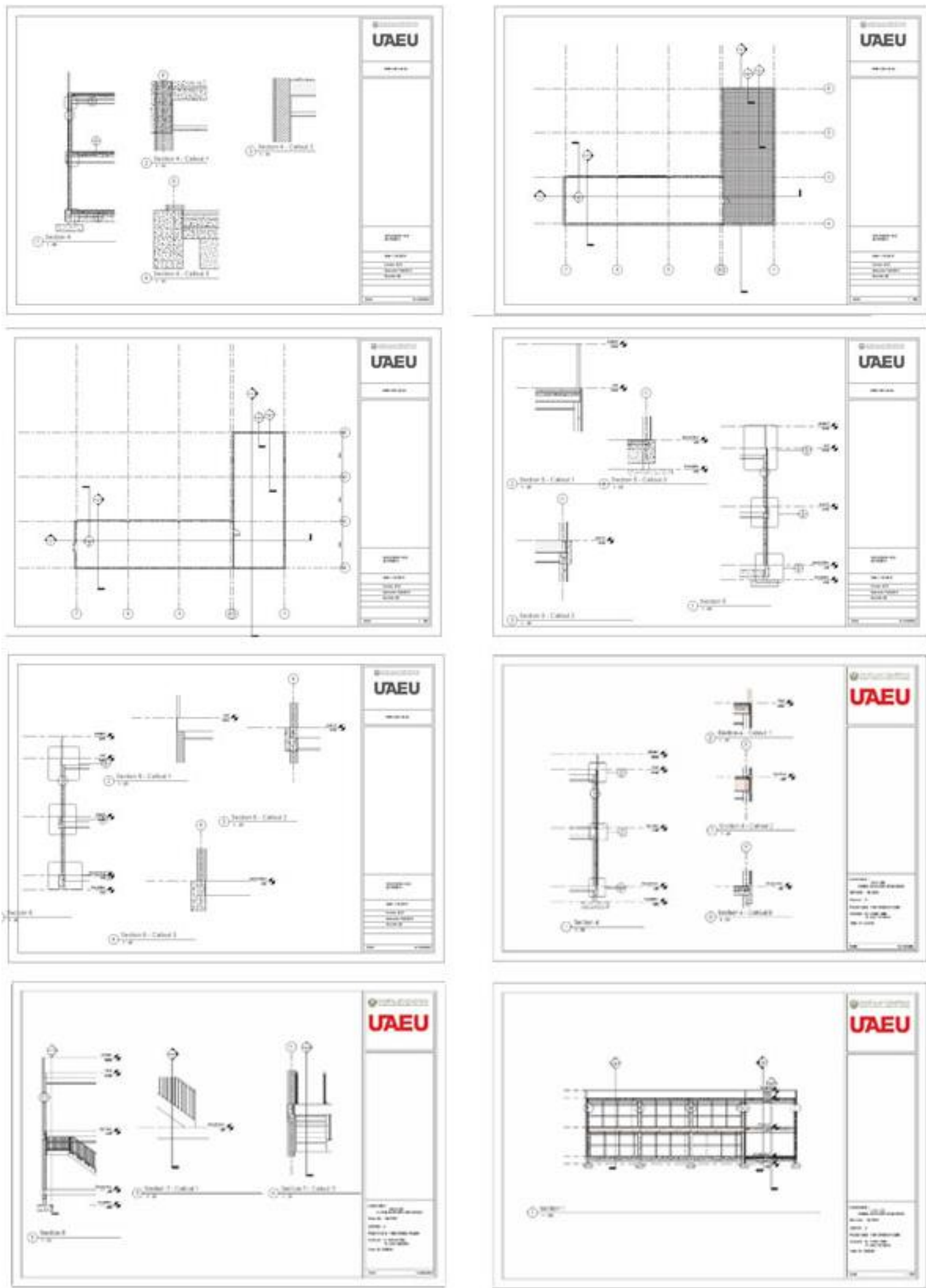


Figure 9.01 Building Components, BIM Assignments Samples Method "*A*"

Method "*B*" Samples:

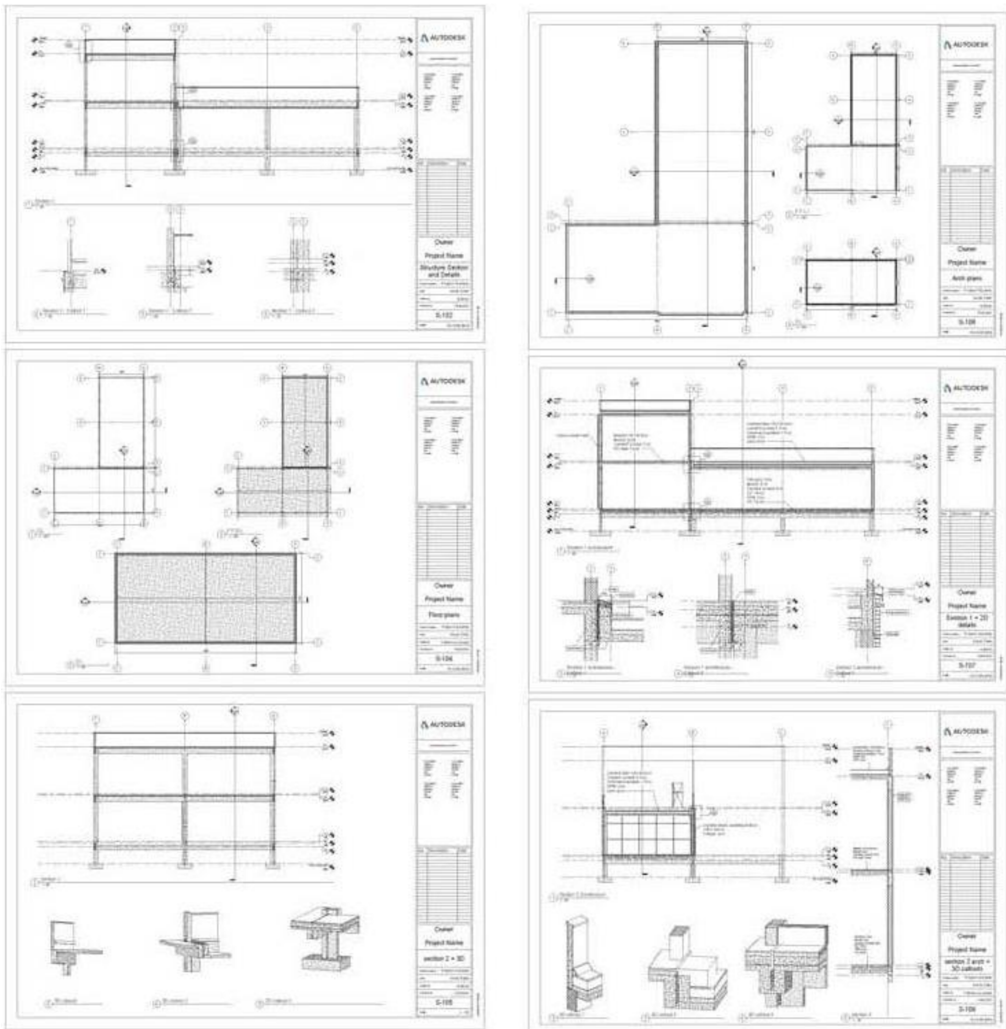


Figure 9.02 Building Components, BIM Assignments Samples Method "*B*"

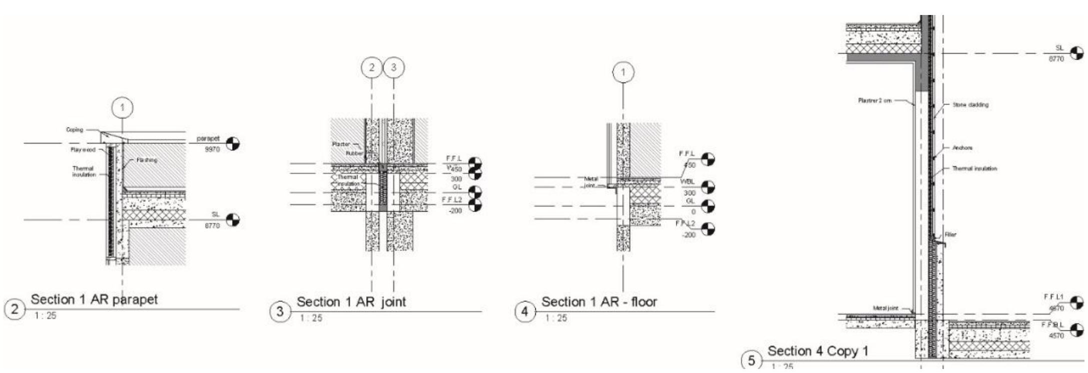


Figure 9.03 Building Components, UAEU, BIM Detailing Samples

10. Discussion of Additional Results: comparison of BIM Introduction based on REVIT at UAEU and AURAK

In order to properly understand the introduction of BIM in different programs and how difficult it is to modify a program which has already been running for years, we decided to compare the UAEU trial with a new program which is still progressing and where most of the professors are willing to include BIM. This inclusion is not an easy task, as the program curriculum was set a long time ago without the inclusion of BIM. AURAK is in the process of obtaining United States (US) National Architectural Accrediting Board (NAAB) accreditation, which makes any changes additionally difficult.

The greatest difference between UAEU and AURAK is the will of the professors. At UAEU of twenty-two professors, four were willing to teach and help with skills acquisition, three were fine with using BIM as long as they didn't have to do exert effort, and fifteen rejected the idea of BIM because they didn't see the benefits, or they were not motivated to improve their skills and change their courses. At AURAK, of six professors and three teaching assistants, three professors and all three teaching assistants are helping the students improve their BIM skills and try to introduce it in the desired courses. Of the remaining three professors, one wants BIM to be implemented but has not improved his skills and relies on the others, and the other two are not interested at all in BIM.

From the data stated at UAEU only 18% of the professors were willing to introduce BIM and only one of the main professors of the core courses. We can state from this data and the research from Barison and Kymmel [5,15], that one of the main problems is that after long time of teaching a course, some professors are very difficult to motivate to improve their skills, change the design of their courses and overall alter their traditional way of working. We can also observe that in a new program it is easier for the professors to introduce new skills as they already are designing the courses from scratch.

Looking at Figure 4.03, we can observe that while at UAEU it was decide in a departmental meeting to introduce BIM based on Revit skills in six core courses, it has been done only in one and in that one we couldn't accomplish the desired level as it was not the first course. We can state based on the surveys done in this research that 90% of the students arrived in the BCC course with no Revit nor BIM skills and concepts. This forced us to modify the BIM lectures from intermediate to basic in order for the students to be able to follow. We could accomplish 70% of the expected results of this course. In the Modeling & Simulation course, the students learned how to use BIM to improve solar analysis, sustainable energy performance analysis, 4D simulation, project management, MEP, HVAC and clash detection.

In the AURAK program the introduction of BIM is done progressively and it is still not complete. During the fall of 2016, BIM skills used were half 2D using CAAD programs and half BIM using Revit; in the fall of 2017 the whole course used BIM skills using Revit either for 2D or 3D, and the information of the project. In Construction II, we changed in the fall of 2016 from a traditional course, to using BIM and adding also site visits to the course in the fall of 2017, in order to improve student understanding. In Building Utilities I the students used BIM tools to calculate and design the HVAC system of a project and finally in the building environment elective course, the students learned how to use BIM to improve solar analysis, sustainable energy performance analysis, 4D simulation, project management and clash detection.

If we analyze the topics covered at both universities they are mainly the same, but at AURAK, as we have more support from the faculty, the students acquired the skills as an accumulative and progressive learning experience, getting to a deeper level of the BIM concepts and skills. We have to state that faculty is the most crucial fact in order to change and develop BIM courses and curriculum. On the other side the students' motivation and satisfaction will provide them the determination to improve their skills and continue increasing their knowledge from a BIM model into a collaborative working environment in the Graduate Project (GP) and their professional work in the AEC industry.

UAEU		Semester	AURAK			
Construction	Electives		Skills course	Construction	Other disciplines	Electives
		3	**BIM skills**			
		4		**Construction II**		
		5		**Construction III**		**Built enviroment**
Building Components		6		**Construction IV**		
		7			**Building Utilities I**	**Parametric design**
	Modeling & Simulation	8			**Specifications and Quantity Surveying**	
	Modeling & Simulation	9				**Parametric design**
	Modeling & Simulation	10				

Table 11.01 3D UAEU vs AURAK _ BIM current program introduction

10.1.1. **Comparative Examples**

Before comparing the work from both universities, we need to understand several issues. The courses which we are going to compare are BCC at UAEU which focus mainly in detailing, and Construction III at AURAK, which covers two extra topics, modular coordination and long span structures.

In the BCC course, the students use the traditional method of class instruction combining lectures, research and AutoCAD drawings; and during the last 5 weeks they learn how to create details in a 3D/2D BIM model using Revit as a tool to develop the details and introduce the information of the local materials they found during their research. In the Construction III course in AURAK, the students use one project to develop a BIM model which combines long span and short span structures, and they develop the project including details, curtain and cladding systems.

It is difficult to compare two courses that are not the same, but this paper identifies the outcome of each course as qualitative data to consider. First, we will introduce a collage of some course assignments of a successful student for both courses, and after we will present the detailing study of each course to check both outcomes.

10.1.1.1. *CC Course at UAEU, Assignments Resume*

This course has three different types of assignments; research about local and innovative materials, AutoCAD detailing, and BIM detailing and data management based on Revit.

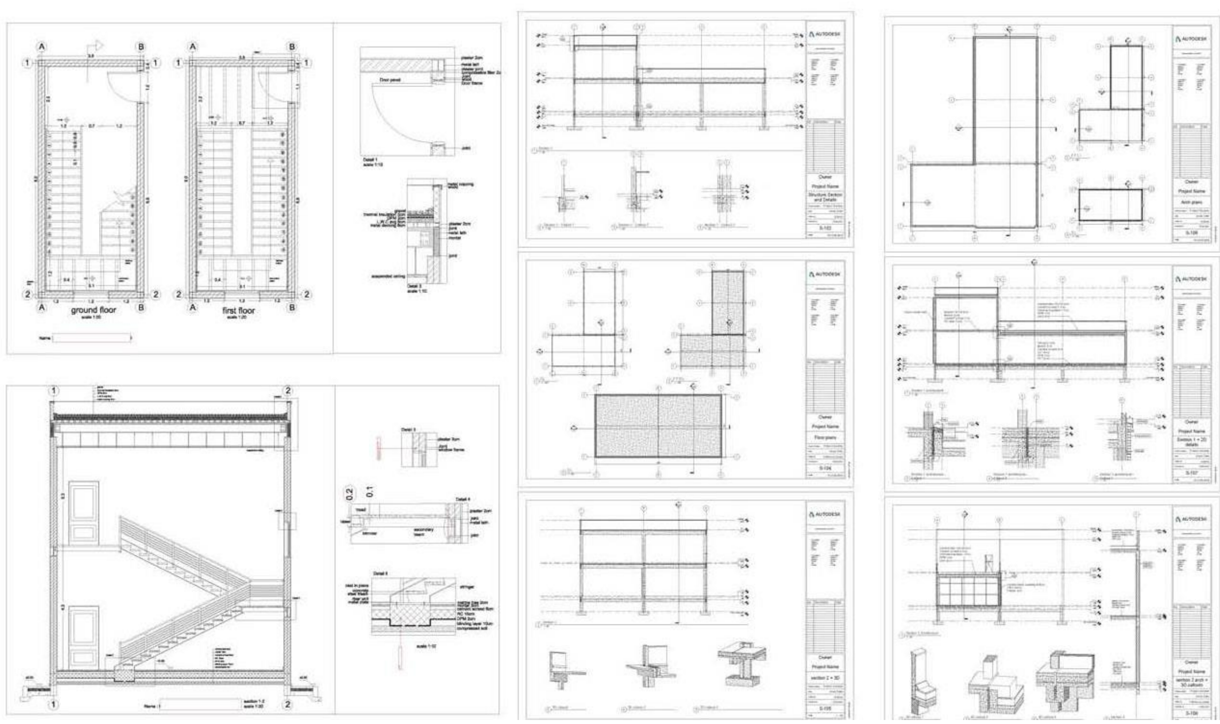


Figure 10.01 Building Components, Assignments Samples

Figure 10.02: Building Components, Assignments Samples.

The first BIM assignment in the BCC course is the structural system of the house used during the course, as shown in Figure 4.11. In the second assignment they have to define three details in 2D and 3D, adding all the information they found in the research assignments, as shown in Figure 10.01.

10.1.1.2. *Construction III course at AURAK, Assignments Resume*

The Construction course is the second semester that is offered, and the first time is done using BIM. In this course there was one site visit Figure 4.10, this is scheduled to be done on more regular basis on the next semesters, and with better note book results. About the BIM assignments, there are five assignments figure 4.11 & 4.14: modular coordination, long span case study, long span application and two final assignments about detailing. All the 2D drawings are done from a 3D BIM model, based on 3D objects which holds materials, physical properties, costs, and much more information from the project.

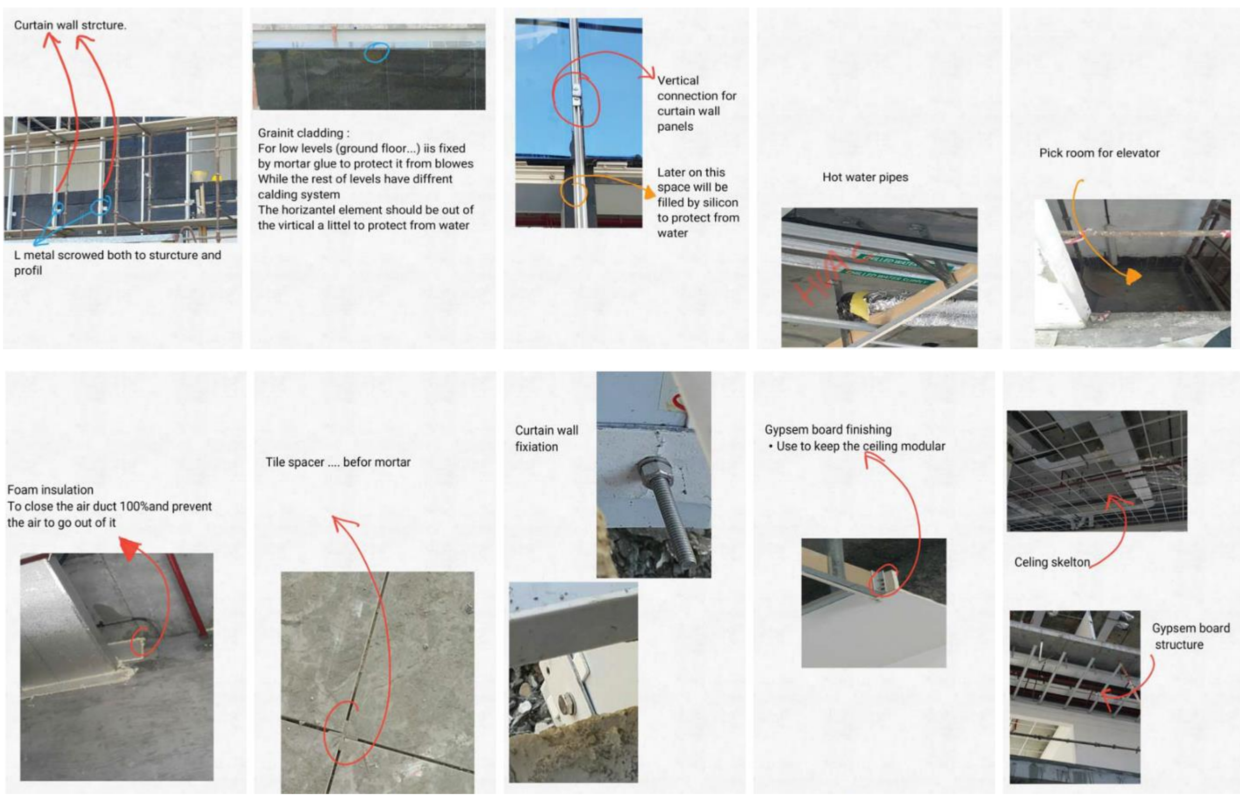


Figure 10.03 Construction III, site visit

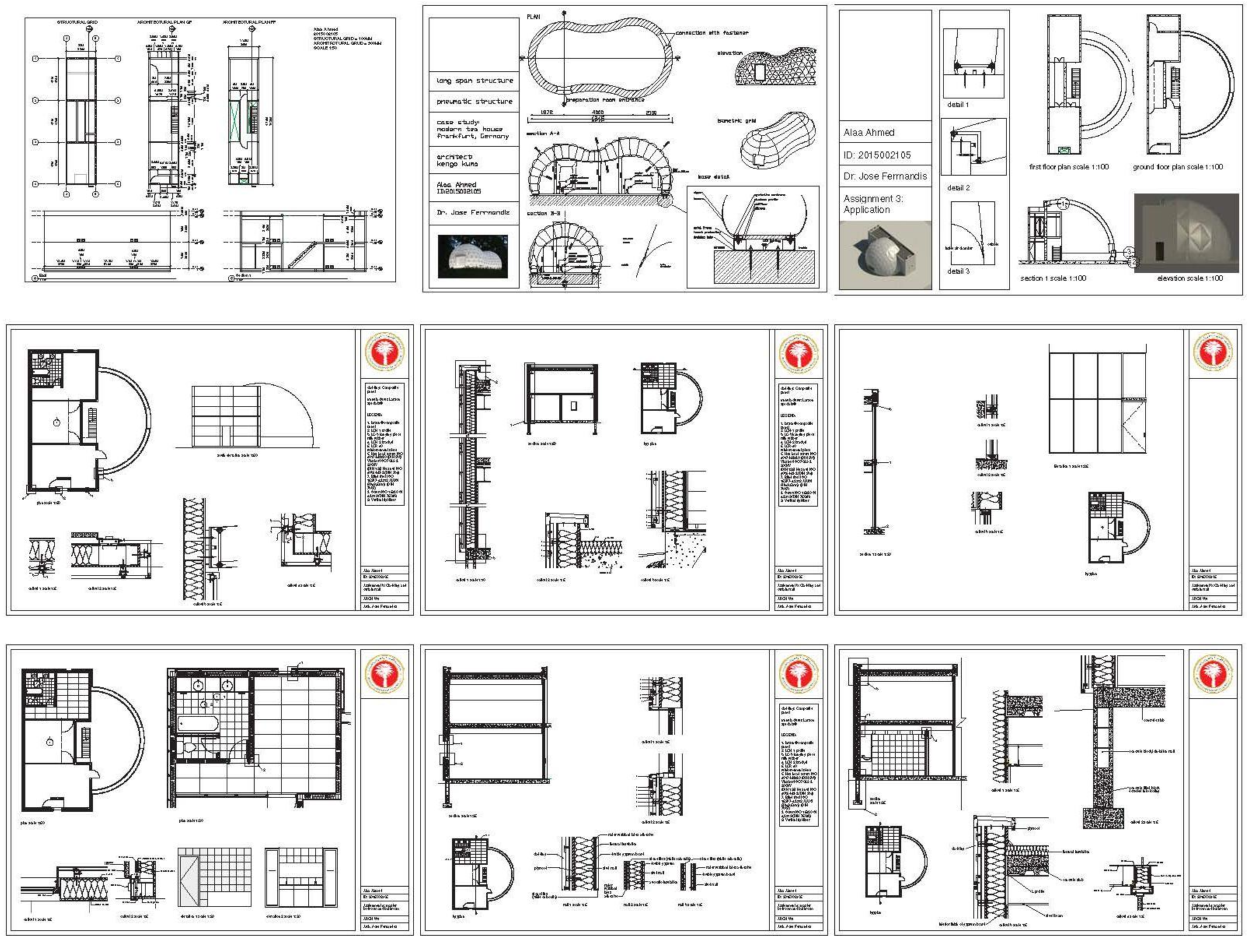


Figure 10.04: Construction III, Assignments examples

10.1.1.3. *Detailing comparison UAEU/AURAK, Assignments*

Here we will provide examples of the current method "*B*" research of this thesis and the first attempt of the future research -- testing a completely re-designed construction course in order to introduce BIM into the curriculum, this latter method will be called "*C*". After checking the samples provided we will discuss the results of both approaches.

UAEU 2D detailing:

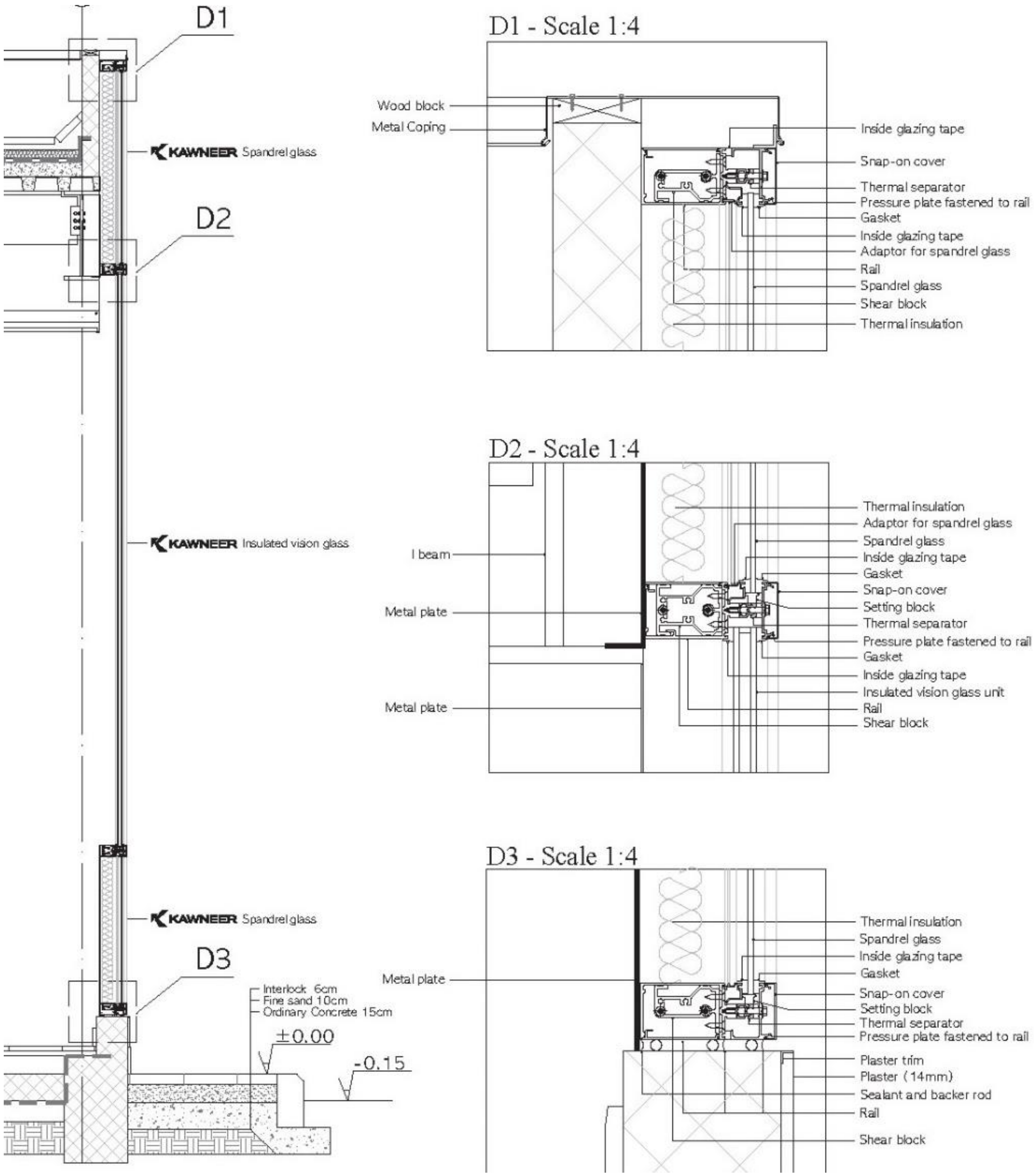


Figure 10.05 Building Components, UAEU, Detailing Samples

UAEU BIM Detailing:

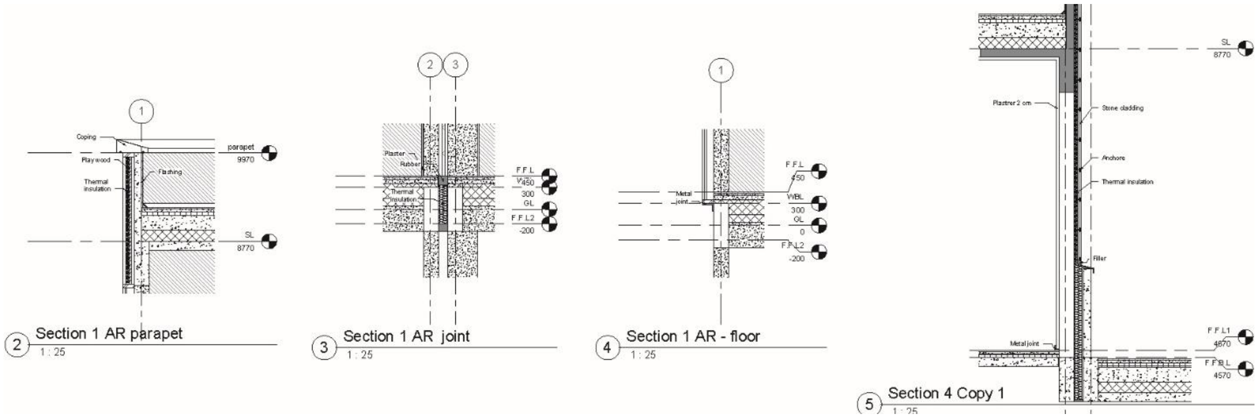


Figure 10.06 Building Components, UAEU, BIM Detailing Samples

AURAK BIM Detailing:

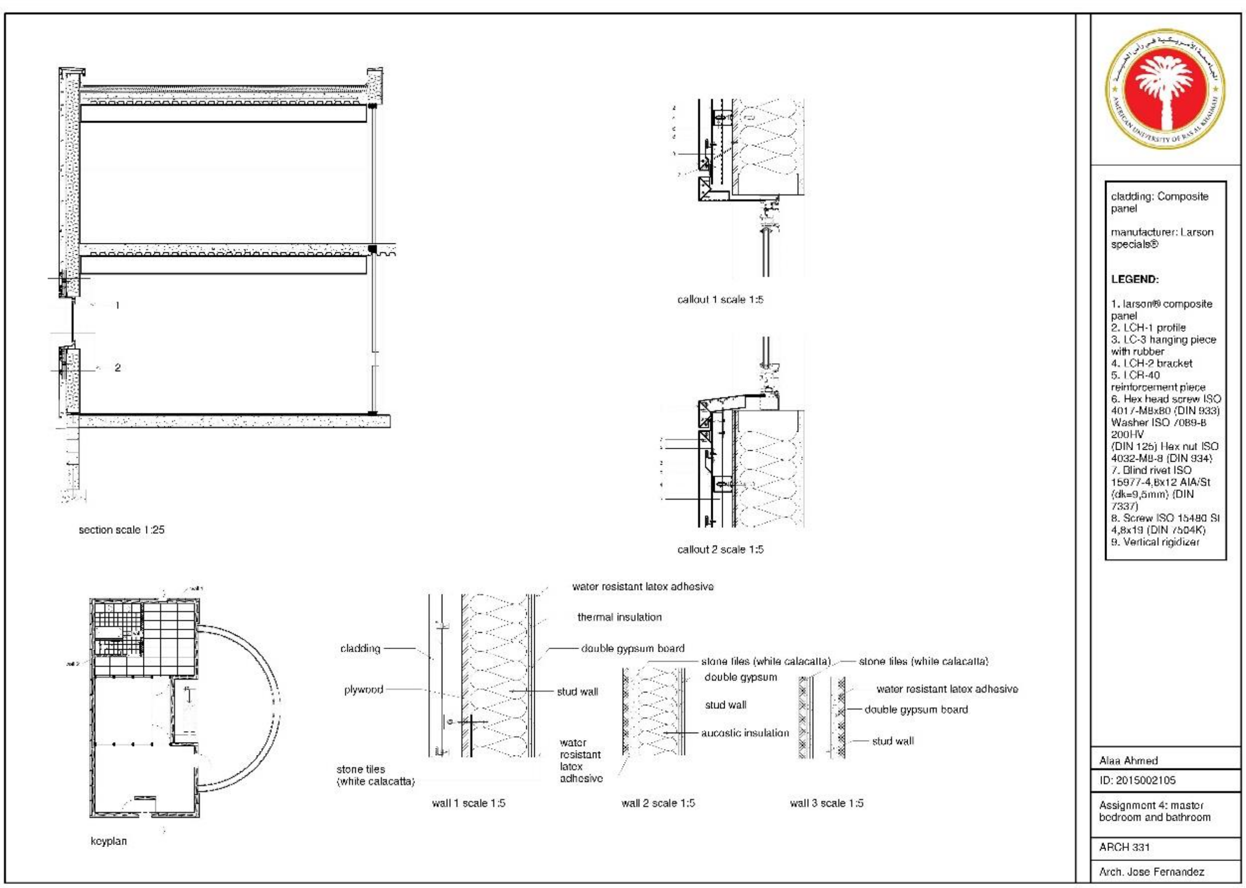


Figure 10.07 Construction III, AURAK, Detailing Samples

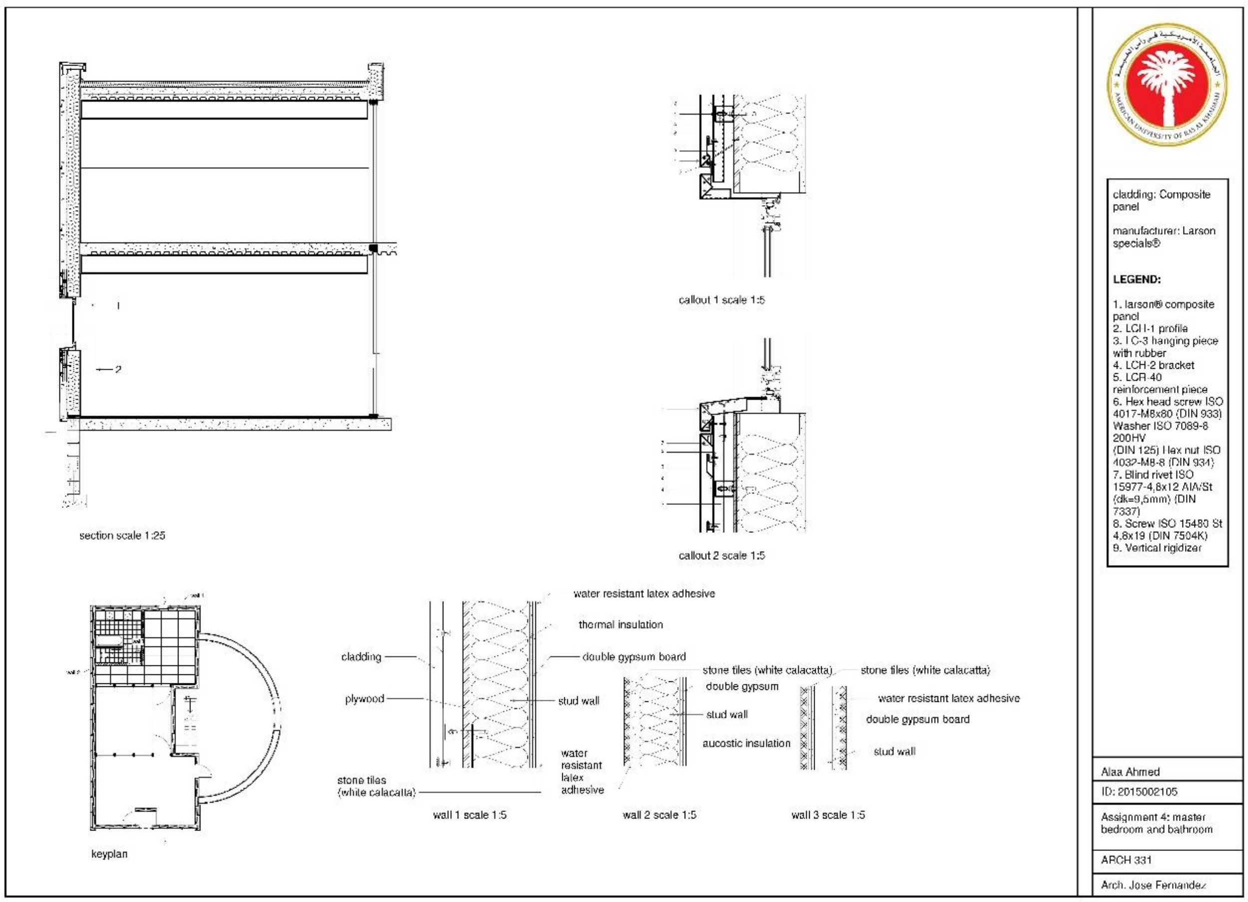


Figure 10.08 Construction III, AURAK, Detailing Samples

We can conclude by observing the samples in Figure 4.12 & 4.14 that the 2D level of detailing is similar for both universities. This means that both traditional and BIM project-based learning produce similar 2D outcomes and similar construction learning outcomes. The problem begins when considering the level of the BIM models presented by the students. In the first scenario, the traditional teaching methodology produces a good level of construction understanding, but the BIM model produced is very basic and could barely be considered BIM model, due to the low amount of information that it holds. In the second scenario, the Project Based Learning using BIM provides the students the same construction capacities while they learn a new working environment methodology, and they create a BIM model which holds most of the information of the project.

This model can produce 2D and 3D views of all the elements and could be used to produce quantity surveying, solar analysis, energy performance analysis, structural analysis and most of the construction, maintenance and demolition processes. This comparison helps us to understand that BIM introduction in the AEC curriculum should be done with re-designing the course, because it produces similar benefits to the students' knowledge as the traditional teaching methodology, while providing a BIM collaborative working environment which our students will need when they reach the job market.

10.1.2. **Comparison of Performance Improvement Data**

After comparing both courses' outcomes, we reach the hypothesis that comparing the students enrolled in the traditional course to those in the BIM learning environment, they will acquire the same construction knowledge, but in the second course adding BIM skills. In order to test this hypothesis we will compare the deviation of student grades in each of the courses evaluating the direct effect of the changes on student performance.

This comparison will follow the same mixed method methodology as explained in chapter 5, and used previously for this thesis study. To create a proper assessment of student performance, we will control several groups of students through each modification of the courses, analyzing their grading evolution. The grades are collected directly from the main instructor of each course, divided into theoretical, practical and final, so we have the same evaluation criteria and approach. Our performance assessment process is based on a continued follow up of the construction course, to evaluate the variance of the performance each time we modify the course. This quantitative data is analyzed together with two types of qualitative data, student work samples and interviews with three random subjects from each group to get feedback about the course.

Mann-Whitney 1947 [286,288,292]. These tests are more accurate for non-normal distribution than the usual P-test and Anova. We have run tests about the students' performance where the grades are measured on scale from 0 to 100 points.

In the BCC course at UAEU we have three different course methodologies to study:

- Traditional methodology;
- BIM approach 1, this course is mainly the traditional one but we divided the lab sessions into half session traditional and half session BIM, each part with its own exercises;
- BIM approach 2, the lab sessions are divided into blocs, the first bloc merging some exercises in order to reduce the total number while keeping the content, and the last 5 sessions are allocated to explain detailing using BIM tools.

In the Construction III course we have two different course methodologies to study:

- Traditional methodology
- BIM PBL learning environment

10.1.3. **BCC Course at UAEU**

The analysis carried out focuses on the student academic performance in the course of "BC" construction 2 which will be deeply explained later in this thesis. At BC course we incorporate BIM into the curriculum through Autodesk products. To do this we studied the variation in student performance in each semester, taking into account the different tools incorporated, the time of their introduction, and other modifications in the methodology of the course. Therefore we are analyzing the global level of the group as it affects the performance of adding Revit to a construction course designed to be carried out with

AutoCAD. The difference is that while AutoCAD is a drawing tool, Revit is a BIM tool that allows you to build a 3D model incorporating information about the project such as physical properties, energy efficiency and cost of materials.

Although it has already been mentioned before, it should be emphasized that there are three different approaches to the BC course that we are studying and comparing.

· Groups 1 and 2 (G1 and G2) experienced the course as they had been during prior years before the implementation of BIM at UAEU, using AutoCAD as a production tool;

· In group 3 (G3) due to the teacher's insistence not to modify the course, it was decided to carry out the same course with the same exercises, adding Revit and other new tools;

· Finally in groups 4, 5 and 6 (G4, G5, and G6) the course was reorganized in such a way that the exercises of the course and the BIM part did not coincide, combining AutoCAD exercises to reduce the number and delaying Revit to the last 5 weeks of the course instead of integrating it, in order to reduce conflicts.

Course	Construction 2 (building components)					
BIM approach	No BIM		Add revit to the existing course	Re-schedule the course	+ Youtube	Professor sick
Professor Lecture	**B**	**B**	**B**	**B**	**B & F**	**F**
Professor lab	**B**	**B**	**B & Jferrandiz**	**B & Jferrandiz**	**B & F & Jferrandiz**	**B & F & Jferrandiz**
Student Group:	G1	G2	G3	G4	G5	G6
Statistic	F 14-15	Sp 14-15	F 15-16	Sp 15-16	F 16-17	Sp 16-17
Nbr. of observations	29.0	29.0	29.0	29.0	29.0	29.0
Nbr. of missing values	17.0	12.0	20.0	12.0	0.0	11.0
Sum of weights	12.0	17.0	9.0	17.0	29.0	18.0
Minimum	54.0	56.0	0.0	32.0	65.0	75.0
Maximum	94.0	97.0	88.0	90.0	92.0	93.0
Freq. of minimum	1.0	1.0	2.0	1.0	1.0	1.0
Freq. of maximum	1.0	1.0	1.0	2.0	2.0	2.0
Range	40.0	41.0	88.0	58.0	27.0	18.0
1st Quartile	63.3	73.0	31.0	65.0	81.0	80.3

Median	73.0	80.0	71.0	80.0	83.0	86.5
3rd Quartile	83.3	89.0	79.0	87.0	86.0	89.6
Sum	885.0	1357.0	467.0	1281.0	2386.5	1534.0
Mean	73.8	79.8	51.9	75.4	82.3	85.2
Variance (n)	156.2	108.7	1106.3	213.9	49.1	26.8
Variance (n-1)	170.4	115.5	1244.6	227.2	50.8	28.4
Standard deviation (n)	12.50	10.43	33.26	14.62	7.01	5.18
Standard deviation (n-1)	13.05	10.75	35.28	15.07	7.13	5.33
Variation coefficient	0.169	0.131	0.641	0.194	0.085	0.061
Skewness (Pearson)	0.162	-0.288	-0.517	-1.449	-0.968	-0.179
Skewness (Fisher)	0.187	-0.317	-0.627	-1.593	-1.021	-0.196
Skewness (Bowley)	0.025	0.125	-0.667	-0.364	0.200	-0.333
Kurtosis (Pearson)	-1.173	-0.367	-1.326	1.935	0.549	-1.086
Kurtosis (Fisher)	-1.130	-0.047	-1.383	3.111	0.896	-1.037
Standard error of the mean	3.768	2.607	11.760	3.656	1.324	1.257
Lower bound on mean (95%)	65.5	74.3	24.8	67.6	79.6	82.6
Upper bound on mean (95%)	82.0	85.3	79.0	83.1	85.0	87.9
Standard error of the variance	72.7	40.8	622.3	80.3	13.6	9.7
Lower bound on variance (95%)	85.5	64.1	567.8	126.0	32.0	16.0
Upper bound on variance (95%)	491.2	267.6	4567.9	526.4	93.0	63.9
Standard error(Skewness (Fisher))	0.637	0.550	0.717	0.550	0.434	0.536
Standard error(Kurtosis (Fisher))	1.232	1.063	1.400	1.063	0.845	1.038
Mean absolute deviation	10.583	8.325	30.568	11.190	4.987	4.586
Median absolute deviation	10.500	9.000	17.000	8.000	2.500	4.750
Geometric mean	72.7	79.1		73.5	82.0	85.1
Geometric standard deviation	1.195	1.150		1.289	1.095	1.065
Harmonic mean	71.6	78.4		70.8	81.6	84.9

Table 10.02 Building Components, Performance Descriptive Analysis

Analyzing the data obtained, there is a very clear first analysis: introducing BIM without modifying anything into a course designed for another ICT is a disaster. This attempt divided the course into two groups, some that failed or left the course (which somewhat held the average) and another group that adapted and received very good grades. This leads us to the fact that it is not a good learning method. The increase in the teaching load increases the productivity of good students, but frustrates the rest leading them to suspend or even surrender and abandon the course halfway.

Regarding the analysis of the second method, student performance has grown in each new semester, presumably due to the maturity of the material and the introduction of new tools such as video tutorials on tools and complicated elements. The G4 data allow us to affirm that the performance of the course without BIM was recovered and G5 and G6 improved performance by 5%. It is very curious that G6 that was the worst performer in the BS course, as it was the one that obtained the best performance in the BC course; this may be due to the change of teacher in the previous section of the practical part of the course, who evaluated the students more strictly. This fact could confirm the theory that the quality of the students had not fallen, but simply the evaluation criteria changed with a new instructor.

p-values:

	BC g1	BC g2	BC g3	BC g4	BC g5	BC g6
BC g1	**1**	0.793	0.866	0.994	0.275	0.173
BC g2	0.793	**1**	0.360	0.987	0.934	0.628
BC g3	0.866	0.360	**1**	0.514	0.082	**0.026**
BC g4	0.994	0.987	0.514	**1**	0.525	0.237
BC g5	0.275	0.934	0.082	0.525	**1**	0.919
BC g6	0.173	0.628	**0.026**	0.237	0.919	1

Table 10.03 Building Systems, Performance Statistical Analysis

As for the statistical analysis Table 2, we observe how the "*p*" value in terms of the homogeneity of the yield is equalized between G1, G2 and G4, reaching values close to 1, which would be 100%; G3 differs from all the others as we observed in the descriptive data due to the separation of the class between students who excelled and those who did not reach the minimum level or even left the course; G5 and G6 are increasingly different from G1 and G2 because they are improving over the performance of the previous groups, even so we can verify that the G2 and G5 are still quite similar although the average of G5 is higher.

10.1.3.1. *Construction III Course at AURAK*

The Architectural Program at AURAK is a new program and the CIII course is only being held for two semesters, the first semester the course was a traditional course of construction with lectures and AutoCAD 2D drawings, while the second semester we introduced a project based learning environment based on BIM and Revit as a tool.

The Architectural Program at AURAK is a new program and the CIII is only being hold for two semesters, the first semester the course was a traditional course of construction by lectures and autocad 2D drawings, while the second semester we introduced a project based learning environment based on BIM and Revit as a tool.

The data analysis as observed in the following table shows that the first line, which corresponds to the traditional teaching methodology, produces more regular outcomes from the students than BIM. As this is the first semester in the university where BIM has been applied, some of the students had some difficulty to acclimate to the new working processes, even though the mean and the statistical analysis provide us a 95% of certainty that both courses have a similar performance. The analysis means that student performance is constant when we added BIM skills and concept knowledge to the construction knowledge.

This encourages us to continue the introduction process. We must understand that designing a course from scratch to introduce BIM will increase the level of student understanding and skills vis-à-vis BIM, and they will not lose any construction knowledge. We will analyze the students' point of view to check if this tool also helps them to understand and comprehend the construction concepts explain during the course.

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
78.9	12	0	12	76.400	92.500	85.167	4.885
68.2	6	1	5	74.200	98.200	85.800	10.644

Mann-Whitney test / Two-tailed test:

U	30
U (standardized)	0.000
Expected value	30.000
Variance (U)	90.000
p-value (Two-tailed)	0.959
alpha	0.05

The p-value is computed using an exact method. Time elapsed: 0s.

Test interpretation:

H0: The difference of location between the samples is equal to 0.

Ha: The difference of location between the samples is different from 0.

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The risk to reject the null hypothesis H0 while it is true is 95.93%.

Table 10.04 Construction III, AURAK, Statistical Analysis

10.1.4. **Interviews**

The interviews were made only for the courses where we introduced BIM. We will separate the results into the different methodologies, in this resume we will group all the different sections and groups of students under the same method. The methodology results were published in the journal of the Universal Access in the Information Society by professors Ferrandiz, Abdulaziz and Peña [42].

10.1.4.1. *UAEU method 1 (1 group, 3 students interviewed)*

- 66% of the students interviewed didn't finish the BIM assignments with the tools required, rather with the tool that they were using for the non-BIM assignments;
- No students interviewed had previous skills with BIM tools;
- All of them wanted to have more BIM skills, but there was not enough time to complete both traditional and BIM assignments at the same time.
- Half of the students pointed out that the BIM tools helped them better understand the construction concepts.

10.1.4.2. *UAEU method 2 (3 groups, 9 students interviewed)*

- 78% of the students interviewed would like to use BIM tools from the beginning of the course;
- 100% of the students felt that the assignments using BIM tools were rushed, and they would have liked to have had more time to develop them;
- 89% of the students pointed out that the BIM tools helped them better understand the construction concepts;
- Only 11% of the students interviewed had previous skills with BIM tools.

10.1.4.3. *AURAK method 3 (1 group, 3 students interviewed)*

- All the students interviewed had some Revit knowledge, but not applied to construction or structures;
- All the students thought that Revit helps in understanding construction elements;
- With each assignment their work speed improved, as they improved their BIM skills;
- All the students asked for YouTube tutorials to be added.

11. Conclusions

The conclusion of this study yields some relevant results in terms of the proper approach to introducing BIM into construction courses. While the data reveal that introducing BIM without modifying the course drops student performance, a slight modification of the lab sessions, dividing them in two blocks, would be enough to maintain the level of student performance. This second method tested in the BCC course in the AE program at UAEU works fine, although the BIM knowledge acquired was less but enough to encourage 78% of the students to continue to work with the BIM tools and develop their skills on their own.

The last method tested in the Architectural program at AURAK shows that if we design a course introducing PBL based on BIM skills, the students will gain further knowledge of BIM while they keep the same level of performance and construction knowledge acquired.

The students from the second and third method pointed out during the interviews that the 3D BIM model helped them to understand the construction concepts explained during the course, which means that it is not only a tool needed by the AEC industry, but also a help for understanding construction concepts in academia.

This experiment tested whether within a 95% probability the performance of the students would not drop if we use methods B from the UAEU or C studied at AURAK to introduce BIM in an intermediate course of construction with students who have almost no previous BIM skills or exposure. While we recommend the third methodology, due to the problems detected by Barison and Kymmel 5,15, it is understandable that universities with a large number of professors and students will likely use the second methodology, which is easier to develop and introduce with a consensus from all concerned parties.

11.1. Hypothesis 1; Objective A:

Regarding the difficulties involved in introducing BIM into the curriculum, these are clearly analyzed in chapters 3.1.2, 3.1.3 and 4.2. It is noted that BIM, as a "*disruptive technology,"* [33] by its very nature demands a complete change in the thought processes behind building design and construction in order to achieve the full potential and possibilities of this new technology. Institutions should offer training for faculty and emphasize the importance of all faculty acquiring BIM skills; but they must also address the need to change how courses are constructed – traditionally separated courses will not allow for the comprehensive collaborative experience that BIM requires in the AEC industrial process.

The studies conducted by Kymmel in 2007 and Barison in 2012 [5] gave a clear outline of difficulties involved in adopting BIM that were confirmed in our own research, including

- Methodology – no framework for how to introduce BIM, fewer documented experiences or collaborative practice in how to teach BIM concepts and/or skills;
- Curricula – no comprehensive plan that would facilitate the adoption of BIM across the range of areas of expertise and their integration; how to encourage and accommodate creativity;

- Instruction – doubt among faculty members as to the effectiveness of BIM; reluctance to change an established, proven curriculum and go through skills training;
- Logistics – lack of physical resources to teach BIM, such as computers, software, etc.; how to align student schedules to allow for BIM introduction across several disciplines;

11.2. **Hypothesis 1; Objective B:**

The different problems to achieving BIM introduction that were encountered in this research are discussed in chapters 4.1, 4.2 and 4.3. As a summary of the relevant data collected, we will explain the different situations that occurred while trying to introduce BIM into the AE program, which provides more data that confirm Kymmel's and Barison's studies.

UAEU University offered a certification course in Revit and Navisworks for faculty; however out of 25 faculty only half attended the entire course and obtained a certification, and another half only attended one or two sessions. After the training, only four faculty members used the knowledge they gained in their classes; one professor in the design courses, which meant that only those students in his section were able to submit projects using Revit and develop BIM skills while the other sections did not; and three professors in the construction courses, where there were varying levels among the faculty of acceptance of BIM and willingness to modify courses – from direct refusal to acceptance without course modification to acceptance with some course modification.

This confirms what was discovered in the literature review, namely that people in general are averse to change, and the training and motivation of faculty is critical to the successful introduction of ICTs in academia; [182] without faculty skills, knowledge and cooperation, the adoption of BIM into university curricula will not be possible. The resistance on the part of the faculty, through a lack of knowledge, skills, and/or motivation, as well as the lack of a clear methodology for the introduction of BIM and appropriate academic content, are problems that this thesis seeks to address by being an initial step towards a formal framework for the introduction of BIM and new ICTs in the curriculum of AEC.

Following this brief conclusion will be the findings for each hypothesis and objective after the completion of a deep data mining study at UAEU.

11.3. **Hypothesis 1; Objective C:**

As has been stated, it is very difficult to solve some of the problems. When discussing how to introduce BIM in the AEC curriculum, several of the references from the literature review are correct in stating that the key to solving the problems is the motivation and engagement of both students and faculty. However in some cases where the program is very well stablished, the number of faculty is large, or they are not on keen on the digital aspect of the AEC industry, it is better not to create a totally inclusive BIM course, but rather choose one of these two partial solutions:

- create short workshops throughout the entire program to create the BIM base of knowledge, students will then have the opportunity to use it by themselves;

- create a BIM master program for those who are really interested in exploring this new collaborative working environment.

11.4. Hypothesis 2; Objective D:

In summary of the discussion about the students' evaluation, this study tested two different approaches to introduce BIM based on Revit into the AE program at UAEU in the female section. The male section is excluded from this study, because they have two separate campuses and the number of students was too few from the male campus to create a valid sample. As a background, all the students are from Arab countries, and the majority UAE citizens. They had medium/high skill levels on AutoCAD, but little-to-no knowledge of BIM, Revit or any other BIM tool.

11.4.1. Performance

This study proved that method "*A*", which introduces Revit skills without redesigning the course, causes a drop in student performance which can split the course into two groups: those students who can cope with the extra load at the same time they are learning new skills do outstanding work which correlates to a high level of performance; and those who can't fail or drop the course.

On the other hand method "*B*", re-designing the course and providing the students with new and better skills, allows the students to progressively improve their performance semester after semester, while improving the introduction of BIM and correcting minor inconsistencies between the subject and the skills.

We have also verified the direct relationship between the results of the course where we introduce BIM and the subsequent course, even though the use of the new skills is not mandatory in the ABS course. We verified that when students have a lower performance in first course where BIM is introduced, they also earn lower grades in the following course; with the correct introduction of the ICT the grades increase not only in that course but in the following ones as well.

11.4.2. Motivation and Satisfaction

The satisfaction of the students towards the tool introduced is directly related to their performance. We can observe how G3 (during the BCC course) and G4 (which added those students from G3 who failed the BCC course) had low satisfaction towards the tool, similar to those who do not know anything about these new skills; however when the tool is properly introduced the satisfaction increases from one semester to the next as the course is being improved and refined.

If we analyze the subsequent courses of students who do not have the skills and are not thought to be able to use the tool properly, their satisfaction decreases a bit but is still high. This analysis uses G4 and G5 students as they were the same students, and we have all the data available for the BC and ABS courses.

For the motivation analysis we must differentiate between their motivation towards improving their grades and their motivation about their studies and career overall. The analysis of the motivation towards the grades is directly related to the integration of BIM skills into the course. With method A the students have a very low expectation that their new skills will improve their performance, while the groups using method B are better motivated. The results of this section are not as comprehensive as we would like, as the BIM skills are introduced as a workshop and not really integrated into the course, although the assignments are related.

The analysis of the motivation towards their studies and career shows they are related and have a deviation of 5%. The analysis of these sections are not as clearly correlated with the integration of the skills into the course as in the previous analysis. Focusing on the quality and engagement of the BIM skills part of the course will give the students confidence and ability to understand the benefits of these new skills.

The analysis of the continuity of the skills into the future is related to two factors -- their motivation towards the tools as a means to succeed in their studies and career, and their proficiency with the tools. With these two factors we can understand how G2, with a high motivation but no skills, has very low value towards continuity, lower than G3 which had poor motivation but some skills and knowledge. Finally the other groups with high motivation *and* knowledge about the tool have the intention to continue using it, which is one of the main goals with this introduction as it is a must for them to be properly integrated in the AEC industry, which is moving forward with this technology.

		Performance	Satisfaction	Mot. Grades	Mot. Degree	Mot. Career	Revit cont	Mot. ICT initial
G2	ABS	70.75	3.11	3.86	3.50	3.86	2.86	
G3	BC	51.89	3.25	3.00	2.75	3.25	3.13	4.25
	ABS	66.40	3.79	3.83	3.50	3.50	4.17	
G4	BC	75.35	3.83	3.38	4.21	4.33	4.23	3.62
	ABS	73.86	3.09	3.50	3.88	4.00	4.00	
G5	BC	82.29	3.90	3.88	4.08	3.85	4.19	3.90
	ABS	80.30	3.73	3.23	3.54	3.62	4.62	
G6	BC	85.22	4.05	3.63	4.25	4.13	4.31	4.00

Table 9.26 Resume data analysis.

The G3 students had a better initial motivation towards ICTs for architecture, but a flawed methodology brought down all the results for performance, satisfaction, motivation and continuity during the BCC course; the same was true for the following G4 group at the BCC and ABS, which included the students who failed from G3. When we analyze the rest of the groups which used method B to introduce BIM skills, all results were raised.

11.4.3. **Interviews**

Based on student opinions about the courses already analyzed, the main problem they faced in method A was the lack of assignment coordination and the simultaneity of using two different tools, which they didn't master and therefore couldn't produce similar outputs. This caused half of the class to abandon the new skills and deliver all the assignments with the other tool as well as they were able, with little overall success. With method B there were no major problems, but the students felt that the BIM assignments were rushed, and they also felt that it would have been more convenient to begin with BIM as they produced the whole model, rather than just with the detail.

On the positive side, both groups felt that BIM skills based on Revit help them to deliver their projects better and faster, and recognized that it will be useful in their futures. All students but one were willing to continue their learning process in these skills, and they look forward to further training.

From the course point of view, both courses are designed for AutoCAD and Revit is not properly integrated. In method A the professors tried but it was impossible for both courses to advance in parallel. The lack of previous skills with Revit and the different timing of both tools made this trial impossible for the students to follow. In Method B the course was delivered and then a workshop was conducted separately where the students produced a project with 2D/3D details which gather information, but it was not really a BIM course. It worked for them to begin and get motivated but not to master, and it was almost completely separate from the proper course.

11.4.4. **Relevance and cross relation of the data**

Analyzing the whole data discussion as only one element, we can observe that method A, the introduction of BIM without modifying the course, decreased the motivation, satisfaction and performance of the students. The second methodology, method B, had the opposite effect, improving all the data. The data, as has already been discussed, can be misleading because of the modifications of G3 during the ABS course and G4 during the BC and ABS courses.

When we look at to the next course (ABS) which is not BIM-introduced or BIM-friendly, method B improved the performance, satisfaction and continuity of Revit, but decreased the motivation due to the lack of a BIM-friendly work environment.

		Performance	Satisfaction	Mot. Grades	Mot. Degree	Mot. Career	Revit cont	Mot. ICT initial
G 2	ABS	70.75	3.11	3.86	3.50	3.86	2.86	
G 3	BC	51.89	3.25	3.00	2.75	3.25	3.13	4.25
	ABS	66.40	3.79	3.83	3.50	3.50	4.17	
G 4	BC	75.35	3.83	3.38	4.21	4.33	4.23	3.62
	ABS	73.86	3.09	3.50	3.88	4.00	4.00	
G 5	BC	82.29	3.90	3.88	4.08	3.85	4.19	3.90
	ABS	80.30	3.73	3.23	3.54	3.62	4.62	
G 6	BC	85.22	4.05	3.63	4.25	4.13	4.31	4.00

Table 9.26 Resume data analysis.

We can conclude that method B is an easier approach with fewer impacts on the established curriculum; it provides the students some BIM concepts, skills, improved satisfaction, motivation and the will to continue using BIM. This can be a valid approach for large institutions, where the difficulties in modifying the curriculum and the resistance of the faculty will make it difficult or impossible to create a quick jump from the traditional to the BIM working environment.

As we can glean from the interviews, the students would like a deeper BIM/Revit environment, introducing BIM from early stages, changing the way the architectural process is defined in academia; they would prefer using a collaborative and more industrial approach during their learning stage, trying to emulate the current industrial situation. However this will not always be possible as discussed in chapter 4.2. This study further reflects that method B has a greater impact on the students and encourages them to improve their skills at a master or specialized workshops to train themselves in the area of expertise they would like to continue in as professionals; it has a low impact in the curriculum and the faculty which makes it more suitable and easier as a broad methodology to introduce BIM based on Revit.

11.5. Hypothesis 2; Objective E:

After a careful review of the literature, and experiences during our study and the analyzation of the data about student motivation, satisfaction and performance, the following good and bad practices were determined:

11.5.1. **Good Practices**

Create short tutorials for the skills, which will allow the students to improve them without sacrificing the entire class period.

Re-design the course assignments to include the creation of the model and not only the plans, or provide the model which they then have to detail. As BIM is a model-based technology which is not thought to deliver isolated plans or details, they can be made as families.

To align the level of the course with the level of skills required, if the BIM course is not dedicated to computer tools, the course should be balanced between knowledge and skills. A proper design is the one that balances the knowledge, skills and assignments to produce a constant and consistent improvement of student performance and result, as a result of the continuous development and evolution of the course.

11.5.2. **Bad Practices**

Adding a new ICT to a course without understanding the challenge that this technology will be for the students.

Adding a new ICT without knowing the previous skill and knowledge level of the students.

Not re-designing the course assignments to fit the new tools.

Do not use more than one tool which can deliver similar output at the same time, as the students can get confused.

Adding BIM skills without modifying the course is an extra load, and too much load divides the students into two groups – those who can handle that load and those who can't. The course should be remodeled in order to allocate proper space and timing for the skills and its assignments.

11.6. **Hypothesis 2; Objective F:**

From the two different approaches studied at UAEU to introduce BIM in the construction courses at a public, renowned and large university, the correct one should be method B. The courses should be re-designed in order to improve student motivation, satisfaction and performance.

Future works should also be kept under consideration, where a first stage comparison will be conducted between the UAEU approaches (methods A and B) and a new method C approach which is a new program for BIM introduction currently under study at the American University of Ras al-Khaimah (AURAK). The results obtained in this study will be compared to the ones we collect at AURAK in order to broaden our scope and create a more relevant study.

In a perfect scenario BIM would be introduced in several courses, with a faculty that really believes that BIM is changing the present and future of curricula and the AEC industry overall. However the truth is that most professors are against changes for different reasons -- lack of interest, motivation and knowledge, laziness or simply they feel that ICT skills can be learned anytime. The reality is that the first skills you learn while studying become like your mother tongue – it has a formative impact on your development and way of thinking. Old architects will always use sketching and physical models, new architects will combine these tools with 3D and 2D CAAD tools, and following generations will continue this path and use BIM tools as part of the design process.

Anyone reading this thesis who wants to introduce BIM in the curriculum should realize that one of the most difficult obstacles to properly introduce a new ICT is going to be the faculty. While some of the faculty may be truly interested in how ICTs can improve student motivation, satisfaction and performance, and take it as a challenge and an opportunity to improve their courses, most of the faculty will consider it as a time consuming problem and they will be reluctant to change their teaching methodology, lectures, exercise and outcomes of the course.

In order to minimize these problems, this research tested two low impact methodologies to introduce BIM with minimal changes in the course, and method B has proved a good low impact method to introduce BIM skills based on Revit, while the Method A generated more problems than solutions, as concluded in this summary:

- **Using Method A** (introducing BIM in the intermediate course of construction without re-designing the course) to introduce BIM into the AEC curriculum is proven not valid, because although we succeeded in our intentions to use BIM based on Revit as a method to improve student motivation and satisfaction in the use of Revit, student performance dropped drastically, as discussed in chapter 7.
- **Using Method B** (introducing BIM at the intermediate course of construction as a five-week workshop) to introduce BIM into the AEC curriculum is proven valid, because it did not modify the course outcome, and improved both motivation and satisfaction. What this means is that the students will continue developing their skills beyond the course in order to get ready for the job market.

11.7. **Hypothesis 3; Objective G:**

During this study we exceeded our expectations, attending three international conferences attended and publishing in two journals.

11.7.1. **Conferences**

Ferrandiz J, Del Ama gonzalo F, Fonseca D, Galal K. "*BIM implementation at the Construction courses in the Architectural Engineering in the United Arab Emirates university*"; BIM Academic Symposium 2018; Orlando, FL; March 27-28; 2018.

Ferrandiz J, Fonseca D, Banawi A. "*Mixed Method Assessment for BIM implementation in the AEC curriculum*" Human Computer Interaction Conference 2016, Toronto, Canada; July 17-22 2016.

Ferrandiz J "*BIM implementation at the building systems course at the United Arab Emirates University*"; BIM Academic Symposium 2016; Orlando, FL; April 4-5; 2016.

11.7.2. **High Impact Journals Related to the Thesis**

Under Review Ferrandiz J, Del Ama gonzalo F, Sanchez-Sepulveda M, Fonseca D. "*Introducing a new ICT tool in an active learning environment course: performance consequences depending the introduction design.*" The International Journal of Engineering Education; 2018

Invited Paper Ferrandiz J, Banawi A, Peña E. "*Evaluating the benefits of introducing "BIM" based on Revit in construction courses, without changing the course schedule*" Universal Access in the Information Society Journal; 2017.

11.8. **Hypothesis 3; Objective H:**

A very specific research group is developing two studies, one about the introduction of BIM in academia which matches 100% the scope of this research, and other about the introduction and development of BIM in the AEC industry. We also succeeded in being awarded a grant to be able to continue this research over time, which will provide two student research assistants each of them for six months.

11.8.1. **International Scientific Associations Related to This Study**

In thanks for the presentation given at the conferences related to this Thesis, Jose Ferrandiz received an invitation to become a member of Academic Interoperability Coalition Research Group (AiC), where there is ongoing research on the implementation of BIM in the US in the AEC Industry, presented and led by Wei Wu, Mcuen, Issa and Smith[293,294].

11.8.2. Grants Related to This Study or for Further Related Studies

We have submitted two grant applications, the first has been approved and the second is currently under review:

Seed Grant from the American University of Ras Al-Khaimah. The Seed Grant Funding Program supports new areas of research. Proposed projects must clearly and convincingly demonstrate a new research direction. Seed Grant Funding under this program is considered a valuable opportunity to successfully compete for external funds to support the project in the long term. Awards are given to proposals that have high potential for external funding or publication in reputed journals, have significant scientific and/or scholarly merit, represent a new direction for the principle investigator, and build or strengthen cross-disciplinary research partnerships.

Seed Grant from the Al Qasimi Foundation. The Al Qasimi Foundation's Seed Grants provide modest start-up funding to projects that address an education, public health, urban planning/development or closely-related public policy issue relevant to Ras al-Khaimah and the UAE. The Foundation seeks to provide opportunities for applied research or pilot initiatives that will have a positive effect on the Ras al-Khaimah community, encourage interdisciplinary thinking and solutions to public policy problems, foster high-quality research and development projects, and promote collaboration among individuals, businesses, academic institutions, and other government and non-government entities locally and globally.

11.9. Hypothesis 3; Objective I:

In order to continue our research we have succeeded in our last objective and have been afforded two major opportunities:

Expanded our own research over 14 different universities beginning fall 2018, thanks to the collaboration of the professors from the AIC research group; also collaborated to create within the AIC research group the "*BIM Body of Knowledge*" (BOK) definitions.

We also joined another a research project with Dr Wei Wu, Assistant Professor at Fresno State University and head of the research "*BIM Course Redesign using the BIM learning outcomes from the BIM Body of Knowledge*," which is very close match to ours and the results of which will complement our own.

12.Future Works

There are three main future lines of work which have already been started:

- The continuation of our study which is currently under process at the American University of Ras Al-Khaimah as comprehensively explained deeply in chapter 10; it will be expanded to other universities as stated below.
- The new collaborative research project "*BIM Course Redesign using the BIM learning outcomes from the BIM Body of Knowledge*" with Dr Wei Wu as the head of the project.
- The improvement of the BIM introduction guide the first sketch of which we introduced in chapter 12.2; it is still in the early stages as we need to collect more data from both studies.

12.1. Improvement of learning Analytics data mining

The study completed in this thesis is one of the first data mining studies in the field of architectural academic learning analytics, focused on introducing BIM in AEC programs. The intention is for this study to be expanded to several of the universities from the AIC research group and both of the Spanish universities where the author studied; this expansion will increase not only the amount of data but also the spectrum of our data as it includes different countries and programs within the AEC industry. The target universities for the initial expansion are:

- University of Oklahoma, US, Architecture and Construction Science
- Fresno State University, US, Construction Management
- University of Salford, UK, Built Environment
- John Brown University, US, Construction Management
- Dublin Institute of Technology, Ireland, Surveying and Construction Management
- University of Texas at Austin, US, Architectural and Environmental Engineering
- École nationale supérieure d'architecture de Toulouse (Université fédérale de Toulouse Midi-Pyrénées), France, Architecture
- Universidad Politécnica de Cataluña, Spain, Architecture and Construction Engineering
- LaSalle Barcelona (Universidad Ramon Llull), Spain, Architecture and Construction Engineering.

12.2. BIM Course Redesign Using BIM Learning Outcomes from BIM Body of Knowledge

The Re-design will consist of four phases, Each of them will have as part of the methodology one Fact Sheet form, I provide the first stage form developed by Dr Wei Wu, Fresno State University:

[Title of your BIM Course]

[Name(s)]

[Institution]

BIM Course Name & Description:
Redesign Case Study Abstract: [3-4 sentences]
Keywords/Tags:
Instructional Delivery: [In-class, Hybrid, Online, etc.]
Pedagogical Approaches: [Flipped, Team-based learning, project-based learning, Peer Instruction, Virtual Labs, gaming and simulation, etc.]
Class Size:

About the BIM Course Redesign
Stage 1 Due Apr. 13, 2018

Background on the Redesign

Why Redesign Your Course?

- **Course Characteristics:** What type of characteristics are you looking to change in the redesign?
- **The Learning Problem:** You may want to identify a particular learning problem that your students face or difficulty in teaching a particular concept that is hard for students to visualize. You may want to get students more actively engaged in learning the skills in the classroom. You may want to address enrollment and look for creative ways to teach larger class sizes.
- **Overarching goals of redesign -** implementation of the AiC BIM BOK and the partnership with your Industry Advisory Board (IAB) to identify prioritized BIM competency you'd like to cultivate in your program/course.

Course History/Background

- Describe how this course maps into the selection of courses the students take before and after this particular course in your department or program.
- How do prerequisites impact this course and how does course completion affect the next set of courses?
- What is the department's historical context for student success in these courses? What programs or majors are associated with it? How long has it been offered?

High Demand / Low Success Issues

- Describe the high demand/low success issues which are affecting the course you are redesigning?

(Submit a copy of your syllabus from pre-designed course)

Figure 12.01 Fact Sheet form, first stage of the BIM Re-design Course study lead by Wei Wu

12.3. Creating a BIM Program/Introducing BIM into the AEC Curriculum

Based on the literature review, our expertise and – primarily -- the two research studies in which we are participating for introducing, re-designing and evaluating the introduction of BIM in academia, we proposed a first plan to develop a guide to introduce BIM. This guide is not meant to be an instructional manual of what the universities should do, but a guidance for them to understand their own singularity and try to achieve the best fit for their programs and their available/possible resources, including faculty, labs, tools, budget, students and of course motivation. This path can be divided into three main ideas:

- Understand the program focus, where BIM can improve your program scope and which level of knowledge and skills students will achieve.
- Define a clear strategy to introduce BIM which can fit the faculty and student motivation and skills; sometimes the strategy should be introduce through minor changes every semester and other times through sudden, major changes.
- Re-design the courses to match the strategy developed as one single experience in different stages, so that the knowledge of the course and BIM increase gradually, in order to build up the skills and knowledge to fit your vision.

This new project is articulated into steps to be very clear and comprehensive, with each step requiring a new decision and analysis to be able to have a common agreement where all the parts are engaged and motivated. It was discussed in the thesis that motivation is one of the main criteria needed in order to succeed and cannot be achieved without a consensus, even when this consensus is to avoid the introduction of these new skills in part of the curriculum, in order to achieve other goals.

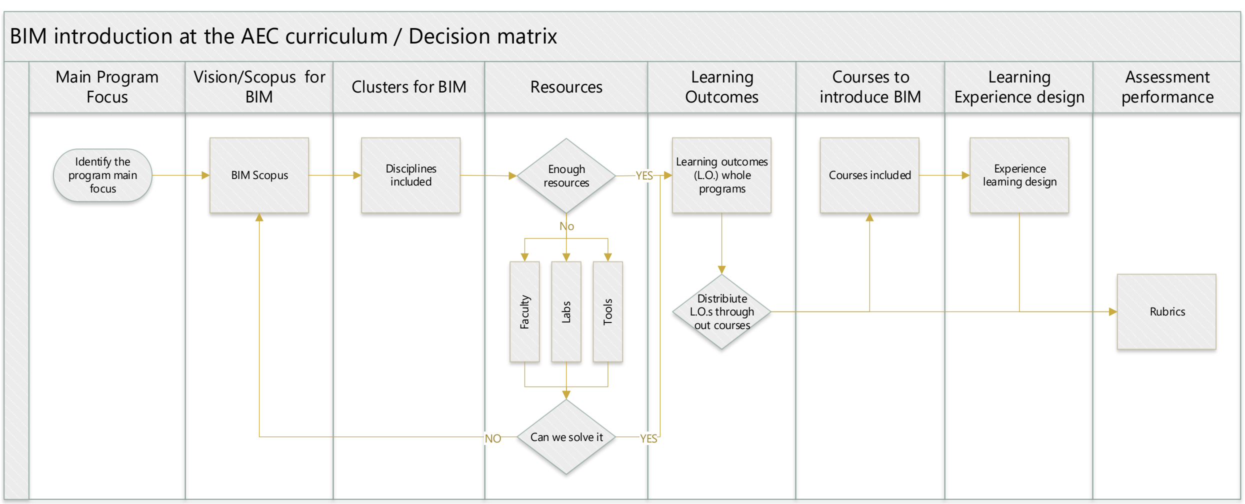


Table 12.01 Building Components, Students' Mot. for their careers Statistical Analysis

In order to explain the actual process which needs further development, we will use as an example, the Architectural Curriculum from LaSalle 2002 which we know deeply. All the assumptions which we will make for the example are just our point of view of the curriculum during the years 1999-2010 when we were related to the program, and may not match the current picture or other points of view. These assumptions should be done by a committee which integrates the direction of the college, the program and as many faculty as possible.

12.3.1. **Main Program Focus**

The beginning element is the need of understanding the program priorities. BIM is a powerful new working environment, with a very broad spectrum that is used for business, design, risk management, construction development, maintenance, collaboration between the different stakeholders and almost anything related to the data of a project.

Therefore the first step is to understand the major direction of the program. Looking at La Salle Barcelona from 1999-2010 the architectural bachelor degree program had **two main foci,** one in the area of **design** and the other one in the **building sciences**; this program looked for architects who have very strong design skills and the capabilities to develop all its components.

12.3.2. **Vision/Scope for BIM**

After understanding the main focus of the program, you should decide which path you will take to introduce BIM for the curriculum. In our example we have two main focus design and building sciences, which can lead to several different approaches:

- Pure design development (model creation and documentation drawings only);
- Parametric design development;
- Sustainable design development (use of the model to analyze and conduct simulations);
- Building science application (creation and calculation of EMP, Hvac and structures);
- Collaboration between different disciplines.

With only these two foci there are lot of options to develop as well as many others not stated. It is crucial to have a consensus of the vision and scope, and the different phases for implementation, before continuing.

Keeping with the example, it is possible that there will be a fight between three options -- those who will think that it is a lot of effort for a new ICT; design professors who will want to opt for the parametric design option; and the rest of the faculty which would like to produce building science application or collaboration.

If all the faculty have good skills and everyone is on board it could all be applied; but while the design professors will like to study parametric design opportunities, some of them won’t be able to keep current and that will make the scenario difficult but still possible if they are motivated and compromised.

After analysis and discussion, the conclusion is that the best approach for the program is to introduce BIM basic digital design skills as computer courses, and introduce BIM later into the building science part, to allow students to learn the skills they need it progressively and discover the possibilities of the BIM analysis through project development.

12.3.2.1. *Grade of BIM Design Information Quality*

Based on the research of Benard[295], we can easily understand the quality of the BIM model information based on eight defined criteria:

- Relevance: the procedure to establish information flow on the project; evaluated by whether the receiver could identify and specify information requirements for conducting tasks, whether a continuous information flow could be established, and whether the sender could understand the receiver's information requirements and act according to them.
- Consistency: the review and coordination procedure performed during and after the design phase.
- Correctness: the established procedure for correcting incorrect design information.
- Precision: the level of design information detail; this is evaluated by opposing the available and expected levels of detail.
- Availability: the "digital distance" to design information; digital distance combines physical distance and the device used to access it. A paper drawing archive at the construction office is inferior to information available digitally in the work situation or contained on a mobile device.
- Distribution: the procedure to distribute design information to relevant receivers.
- Flexibility: the design information medium (such as paper documents, digital documents, BIM models).
- Amount of information: the negative effect (unmanageability) of information media quantity on design information quality.

While the scale remains the same over time, the definition of the individual observable phenomena is adjusted regularly to suit the current practice. Technology and practice evolve. Technology that is a most-innovative practice today will become a best practice tomorrow and will be a traditional practice next week. In this way, measurement is corrected for progress in practice development, and the development of the organization is measured relative to the rest of the industries' practice.

Criterion	Traditional	Typical	Advanced	Best	Most innovative
Relevance	Contractor's informational needs are not identified; design information is sent at the end of each phase; sender is not able to fulfill specific informational needs.	Contractor's informational needs are not identified; design information is sent continuously; sender is not able to fulfill specific informational needs.	Contractor's informational needs are identified; design information is sent at the end of each phase; sender is able to fulfill specific informational needs.	Contractor's informational needs are identified; design information is sent continuously; sender is not able to fulfill specific informational needs.	Contractor's informational needs are identified; design information is sent continuously; sender is able to fulfill specific informational needs.
Consistency	Only coordinates, grids and naming conventions are shared.	Requirements are coordinated in a collaborative process.	Geometry is coordinated using software.	Building code requirements are coordinated using software.	All functional and behavioral requirements are coordinated using software.
Correctness	Design team is not available to provide correct information. (>4 weeks)	Request for information proccess must be followed (1-4 weeks)	Correct information is achieved by informal process. (5-7 days)	Correct information is achieved by fast-track process. (3-4 days)	Design team quickly provides correct information. (1-2 days)
Precision	Dimensions are sufficient for scope.	Level of detail is sufficient for scope.	Specifications are unambiguous.	BIM objects reflect production parts.	BIM objects reflect actual products
Availability	Paper documents at the office.	Digital docu-ments at the of-fice.	Digital docu-ments in a note-book.	Digital docu-ments at the place of produc-tion.	Digital docu-ments on a mo-bile device.
Distribution	Broadcast (information push).	Receiver chosen manually (information push).	Receiver chosen by role (information push).	Receiver subscription (information pull).	As specified by information requirements (information pull).
Flexibility	Documents.	Editable documents.	Geometric 3D models.	Building information models.	BIM according to information requirements.
Amount of information media	Documents.	Digital documents (not versioned).	Digital documents (versioned).	Multiple 3-D models and specifications.	Integrated 3-D models and specifications.

Table 12.02, by Berard[296]: criteria to assess design information quality according to level of practice.

12.3.3. **Clusters**

The second part of the BIM introduction will begin analyzing the BIM scope and the curriculum, to select those clusters which will be included in the process and those which should be avoided, and it will be the students who decide if they make use of the tools or not.

In the current example, as BIM was introduced at the digital architecture and building science development areas, we will use the clusters of computer tools, MEP, HVAC and sustainability.

12.3.3.1. *Skills to Develop:*

After the target is understood, and where BIM will be introduced is determined, we have to select the BIM skills we want our students to master; for this purpose we will use the skills definitions from the BIM Body of Knowledge [23,294,297,298], to be designated as Student Learning Outcomes (SLOs). These definitions are one of the results of a project[288] we joined in 2015, guided and developed by the AIC which is a vehicle for academics around the world to discuss and communicate their concerns about the BIM introduction.

This project is still in process, and we will use its achievements as a data to define the BIM SLOs to introduce in our curriculum. The AIC identified in their BIM BOK four main areas of work and 57 skills at a construction BIM multidisciplinary work:

1. Plan the BIM introduction (27 skills/LSO): Organizational mission statement, BXP: Process mapping, BXP: Information exchange, BXP: Goals BXP: BIM usage, BXP: Procurement strategy, ISO 15686-10: Life cycle functional performance, Infrastructure planning, Quality assurance effort, Business process mapping, Employer information requirements, Benchmarking practices, Security policy, Risk management, Facility management needs, Enterprise architecture, Life cycle assessment, Corporate/organizational learning, Organizational training of others, Professional development, Internal standards across the organization, Development guides, Building performance targets, Commissioning plan, Staffing projects, Budget (VDC/BIM), Software selection & upgrade strategy.
2. Coordinate the BIM introduction (6 skills/LSO): Technical support for interoperability, Model coordination, Pre-construction issue resolution, Software version coordination, Provide training, Understand the roles of all phases of the life cycle.
3. Manage the BIM data (21 skills/LSO): Model quality control, Manage BXP, Refine BXP, Performance measurement, Model validation, Standards compliance checking, Buy in room stakeholders throughout the organization, Contract language, Manage workforce, Project controls - budgeting /cost, Project controls - scheduling /time, Project lifecycle data collection - feedback loop, Leadership - team building, Contract administration, Change management, Project administration, Manage information exchange, Pre-construction issue resolution, Evaluate metrics, Protecting IP of digital assets, Professional ethics

4. Produce the BIM model/data (13 skills/LSO): Rendering for marketing, Individual effort, Understand just your own model, Ability to build a model, Aggregate model Software usage, Solving problems and gaining knowledge, Estimating Site logistics, List of BIM uses, Knowledge of scripting, Knowledge of programming, Technical writing

For further description of each one of these skills, the main source BIM BOK[288] should be referred to in order to be ethical and updated with the latest published results from the study. It is very important to properly select the skills to develop and their level of achievement, which will lead to the next step.

Continuing with the example we decided to introduce eight different skills in the architectural program in three different working areas:

1. Coordinate the BIM introduction (2 skills/LSO):
   a. Model coordination; as we will use BIM to introduce the different disciplines from the building sciences, we need to coordinate all the different models/stakeholders (students). These skills will be introduced in the process of the digital architectural cluster and the knowledge will be developed in the different discipline courses.
   b. Roles of all phases of the life cycle; it is important in our curriculum, and currently in the architectural industry in Spain, to understand the different phases of the project and how BIM relates to them as nowadays there are more renovations and rehabilitation than new construction works. It will be introduced in the sustainability cluster to understand the process, the management of the materials and the data during the different phases of the project.

2. Manage the BIM data (1 skills/LSO):
   a. Performance measurement; it is very important to be able to extract data from the model. This skill will be introduced in the process of the digital architectural cluster and the knowledge developed in the different discipline courses.

3. Produce the BIM model/data (4 skills/LSO):
   a. Individual effort; it will be studied at the introduction of each discipline.
   b. Individual models; how to understand just your own model, it will also be studied at the introduction of each discipline.
   c. Ability to build a model; each discipline will introduce its own different components, and how they should be introduced in the model.
   d. Solving problems and gaining knowledge; data analysis and problem solving at each building science discipline, mainly at the sustainability cluster, analyzing the materials, energy performance, shading devices and pv panels.

12.3.4. **Courses to Introduce BIM**

It is very important once the skills that we want to apply are known, to study deeply the curriculum and identify which courses are the best fit for each skill and at each level. It is also a must to establish prerequisites for the correct introduction of BIM, to assure that the students have the minimum qualifications required to begin the learning process.

Without going into too much depth, in the current example the university can decide the main ICT tool to be introduced at the computer tools course and then spread into the different disciplines. It is the author's recommendation to begin at the last part of each discipline an initial course to identify all the elements explained previously and how these can be introduced in the model; in the second course students can then develop an entire system in the project; and in the third course they can use the model to produce analysis and data, and improve the system and its performance.

12.3.5. **Resources**

There are three main resources to be considered when applying BIM: faculty and student skills and motivation, computer lab requirements, and ICT tools.

12.3.5.1. *Faculty/Student Skills and Motivation*

This is one of the most crucial points for a successful introduction of BIM. If all the faculty are motivated and willing to join the process, then it is only a matter of time to get a good outcome. If there are some weak points these can affect the students' base of knowledge for the next courses, creating a problem that will negatively impact the possibility of a smooth learning experience.

Once the faculty is engaged and motivated the university should provide qualified training for all the faculty, so they all can understand the process and help the students in their specific areas of expertise, as generally most of the current faculty will not have the requisite skills or knowledge.

In our example, the biggest problem regarding faculty motivation was at the design part, which we decided to avoid, and the full professors who would not learn the new software programs. There should be a strategy to develop and inspire motivation and introduce BIM to these faculty without undue effort from their side; otherwise they will directly reject the idea as happened in this experience and is explained in chapter 4.3 of this thesis.

The students' motivation towards IT and BIM as tested here is almost assured. They need only be provided good materials and progressive knowledge and they will easily become enthusiastic as was shown in this study.

12.3.5.2. *Lab Equipment*

The most of the architectural BIM software require high performance computers with i7 processors, 16 GB RAM and dedicated graphic cards, which the university should provide in a digital lab as not all students will have individual access.

A server may also be needed in order to be able to create multi-disciplinary real experiences, if not using a cloud BIM system.

12.3.5.3. *Tools Availability for Students*

Tools availability will depend on the programs used. If it is decided to use the Autodesk package on cloud or desktop (they are currently different tools the connectivity of which is currently under development, as reported in the last AIC meeting) the students can have a free three-year license for most of their programs and tools.

For other tools the university will have to negotiate with the companies. In general most of them agree to provide free licenses, but only for the digital lab and faculty laptops and not for student personal computers which they cannot control.

This issue, and the fact that Autodesk products are the most used all over the world, constitute the main factor why most universities use Autodesk products for their BIM experiences.

12.3.6. **Learning Experience Design**

The learning experience design has to be developed for each course individually, and it will depend on the skills and the level of each course, and achievement goals. This thesis describes and provide data from three different approaches which can be applied. However each group of faculty constructing their own course should develop their own. This chapter is currently under research, and it will be developed further as well as all guidelines, which are just the first draft of the project.

12.3.7. **Assessment Performance**

It is recommended to use the assessment performance developed for this thesis as a BIM design assessment procedure, but each university may apply their own criteria or relevant accreditation board requirements.

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14. Appendix 1. Former Courses of Construction: Construction cluster at the UAEU

The focus of the AE program at the UAEU is Construction/Construction Management, what makes the construction cluster one of the main focus in the program. After the Department decided to introduce BIM into the program, it was decided to introduce it using Revit software. This introduction will take place in two different clusters: Design cluster to improve their creativity and skills towards architecture representation; and the construction cluster to improve their construction drawings and detailing skills.

The author of this thesis is in charge of supporting the professors of the construction courses to introduce Revit and improve the students' experience. At this chapter we will have an overlook of the three courses of construction, their lectures, assignments, and finally the experiment and the reasons to introduce Revit in Building components and its method of implementation.

All the lectures and assignments samples provided at this chapter are a resume of the real samples, in order to allow the reader understand the construction courses that are delivered at the AE program in the UAEU. The introduction of this new ICT into the Building Components course, the data obtained, the modifications into the course and the exercises samples will be properly describe and illustrate at the chapter six.

14.1. Building Systems

This is the first course of construction at the AE program in the UAEU. The main instructor is of this course is Dr. Mahmoud Haggag. At this course the students will be introduced to the Building Construction Systems. This course will provide the students with a solid base in building construction principles, concepts, systems and criteria.

The Building Construction Systems course focuses on fundamental principles, concepts and problem solving approaches associated with the construction of simple buildings. The course aims to make students understand fundamental construction materials and methods widely applied in the building construction industry. Applicable building codes and standards are presented. The course introduces students to common building materials and their properties, and construction processes ranging from site planning to construction. Construction technology, systems, methods and techniques are selected with emphasis on local applications and practice. Simple structural systems, construction methods, and building components are covered, including foundations, structural components, wall systems, and floor and roof systems.

The course materials are delivered through a series of lectures coupled with group discussions, readings, hands-on practice assignments, and on-line blackboard access for course documents and information.

14.1.1. Course Learning Objectives:

- To understand basic building construction terminology, building standards, and building codes.

- To enhance knowledge of building systems and materials, including structural systems, wall systems, and floor and roof systems.
- To understand the different building components both technically and structurally.
- To enable students to undertake professional drafting skills and principles of working drawing process.

14.1.2. Course Measurable Outcomes*

By the end of this course, students should be able to:

- An ability to recognize building codes, standards and construction terminology [C and K]
- An ability to comprehend and describe the necessary foundation of knowledge to understand building construction and structure systems [C and E]
- An ability to propose, analyze and evaluate alternative solutions to technical problems of building materials, construction methods and structure systems [C, E and K]
- An ability to express graphically and technically building materials, components, structural systems, and construction methods [E and K]

* Capital letters in brackets refer to the AE Program Educational Objectives

14.1.3. Course Outline

Week	Topic/Subject
Week 1	Orientation & Course Overview
Week 2	Understanding Buildings & Load Distribution, Construction Terminology, Standards, and Codes
Week 3	Buildings Materials & Principles of Working Drawing Process
Week 4	Short Span Structural Systems: Bearing Wall System
Week 5	Short Span Structural Systems: Skelton System
Week 6	Foundation Systems
Week 7	Floor Systems
Week 8	Midterm Exam (Date to be Confirmed)
Week 9	Roof Systems
Week 10	Wall Systems
Week 11	Openings and Wall Components
Week 12	Moisture and Thermal Protection
Week 13	Long-span Structural Systems
Week 14	Vertical Circulation
Week 15	Concrete Stair Cases

Week 16	General Revision
Week 19	**Final Exam**

Table 4.1: Course outline Lectures and Assignments Fall 2014/Spring 2014

14.1.4. Student Performance Assessment and Grading Criteria

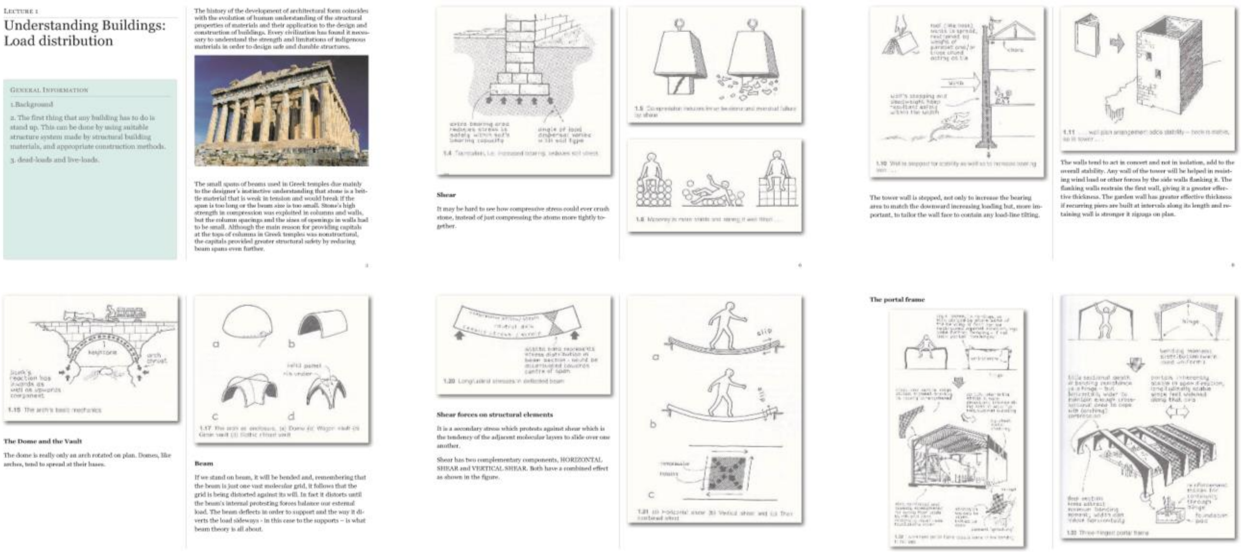
Throughout this course, the students will be gaining knowledge and competencies that will be evaluated using different assessment techniques. This course allocates 40% of the final grade to the students' performance in the lab sessions, and 60% for exams and class participation with the following percentages applied: Class Participation 10%; Mid-Term Exam 20%; Final Exam: 30%.

14.1.4.1. *Grading criteria*

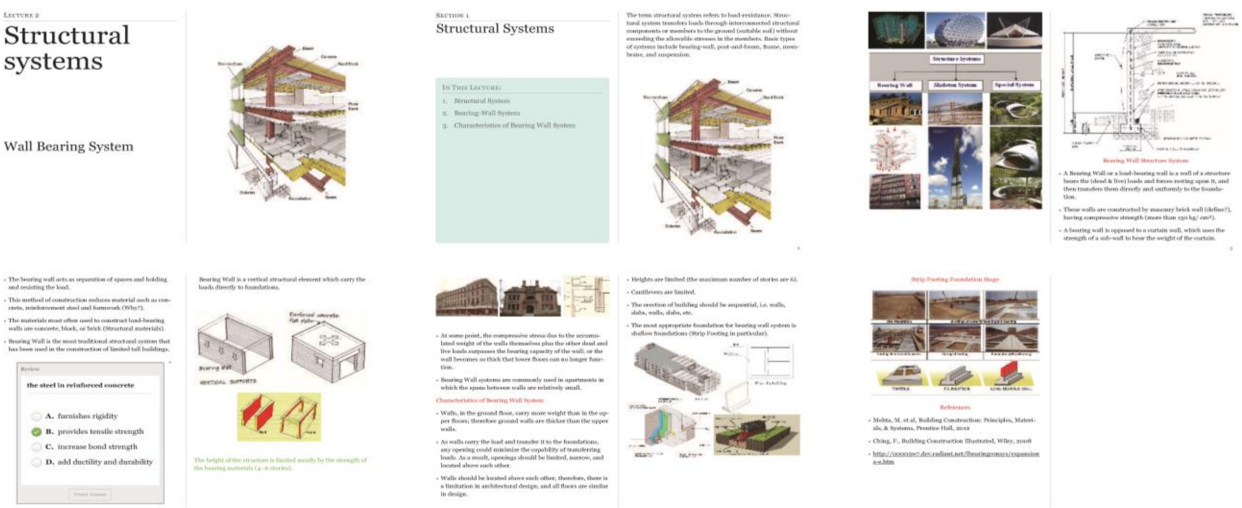
- Understanding of the construction problem; the design of a solution based on the literature review, case studies and problem analysis.
- Application of criteria to select the appropriate construction systems; the integration of both these systems and its components to the project.
- Proper integration and application of the Building Standards and Building Codes
- Pre-calculus of structural elements
- Capacity to produce quality and well defined Building Construction Drawings.

14.1.5. **Lecture Samples**

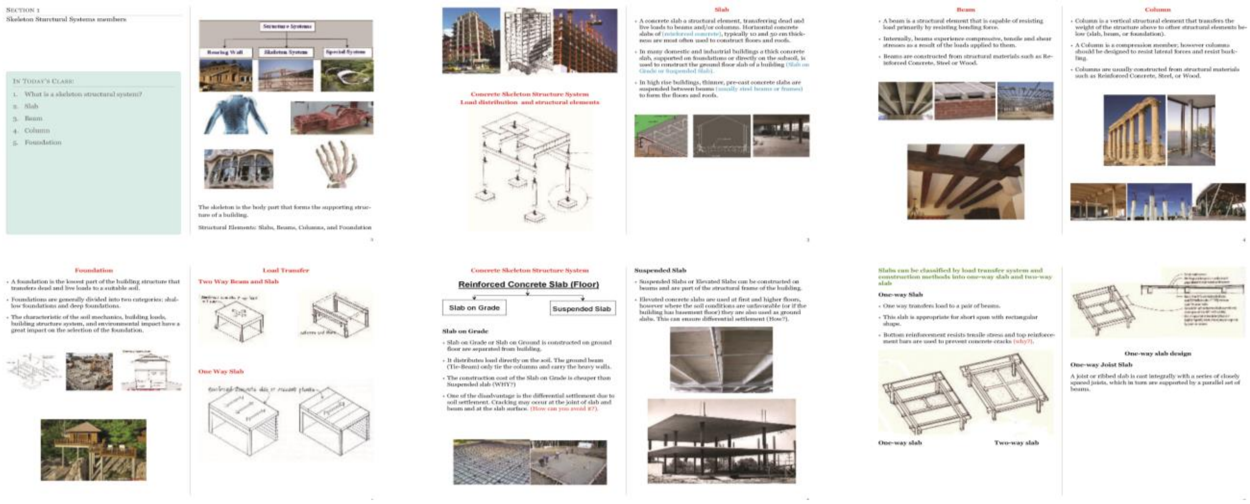
14.1.5.1. *Lecture 1: Introduction to Building Construction Systems*



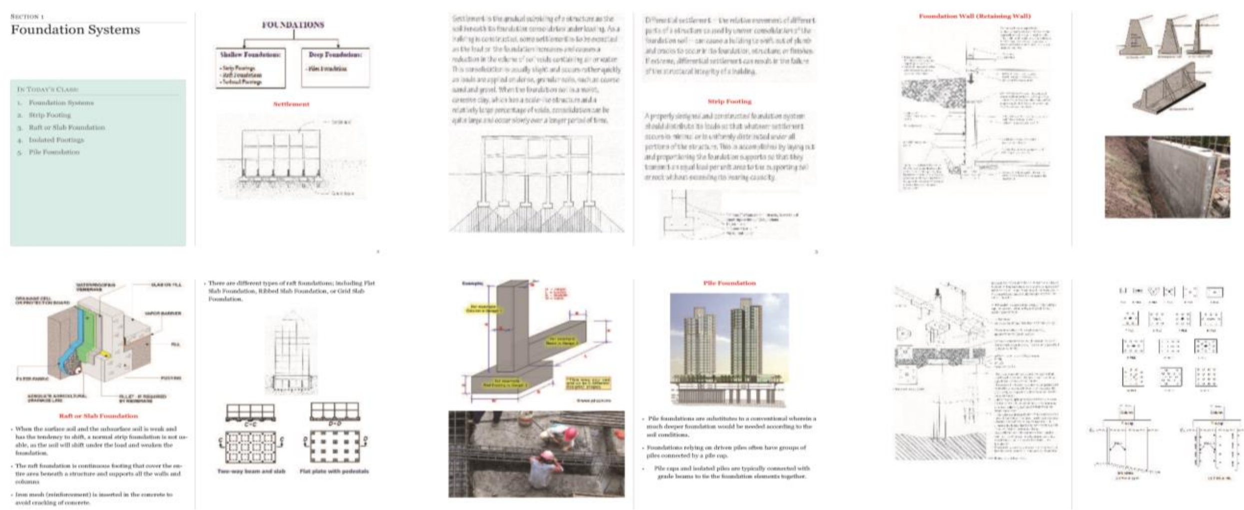
14.1.5.2. *Lecture 2: Structural Systems, Bearing Walls*



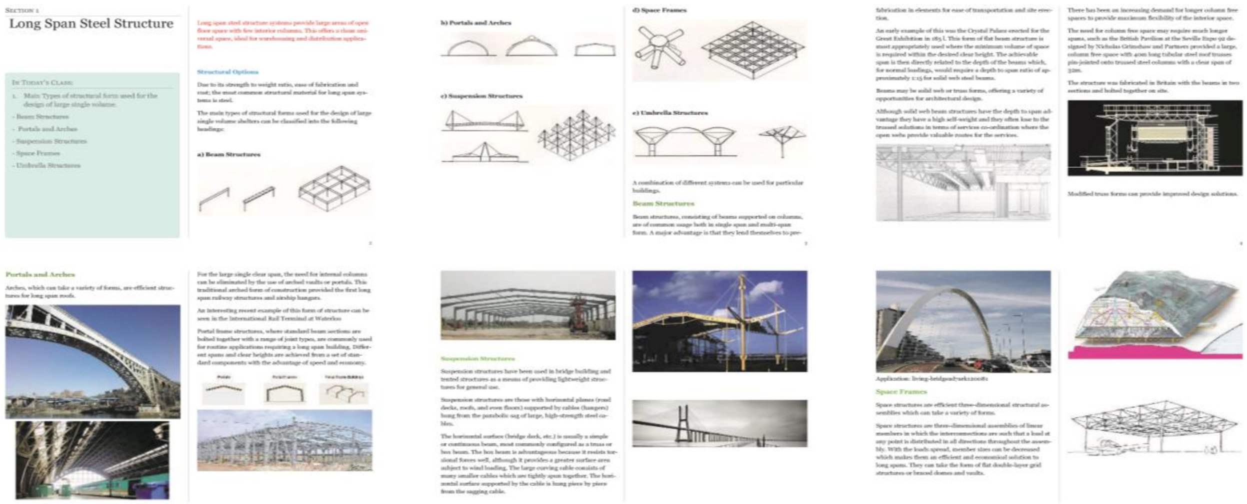
14.1.5.3. *Lecture 3: Structural Systems, Skeleton Systems*



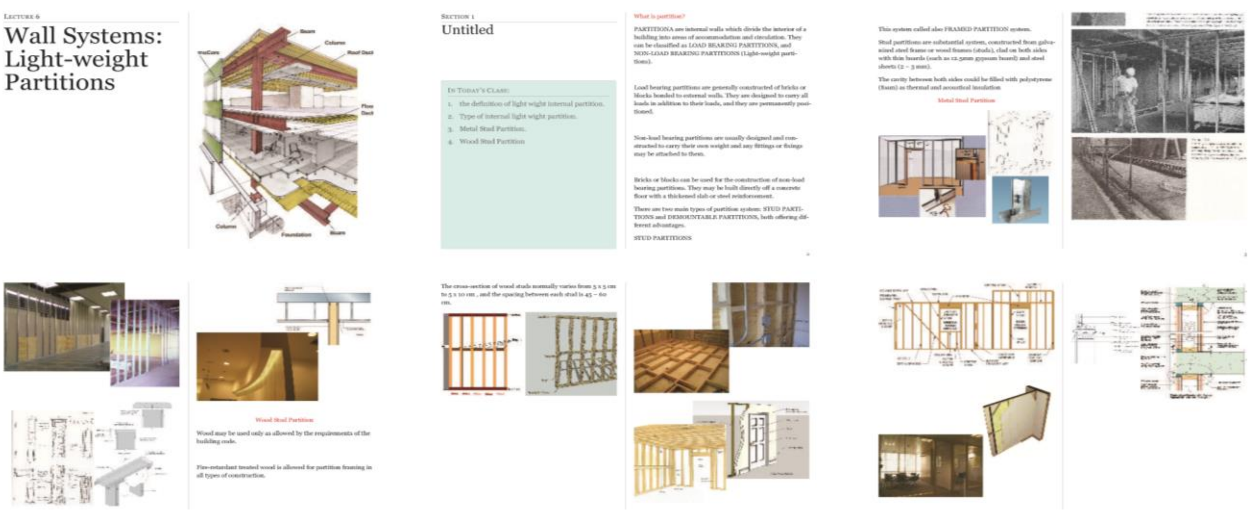
14.1.5.4. *Lecture 4: Foundation Systems*



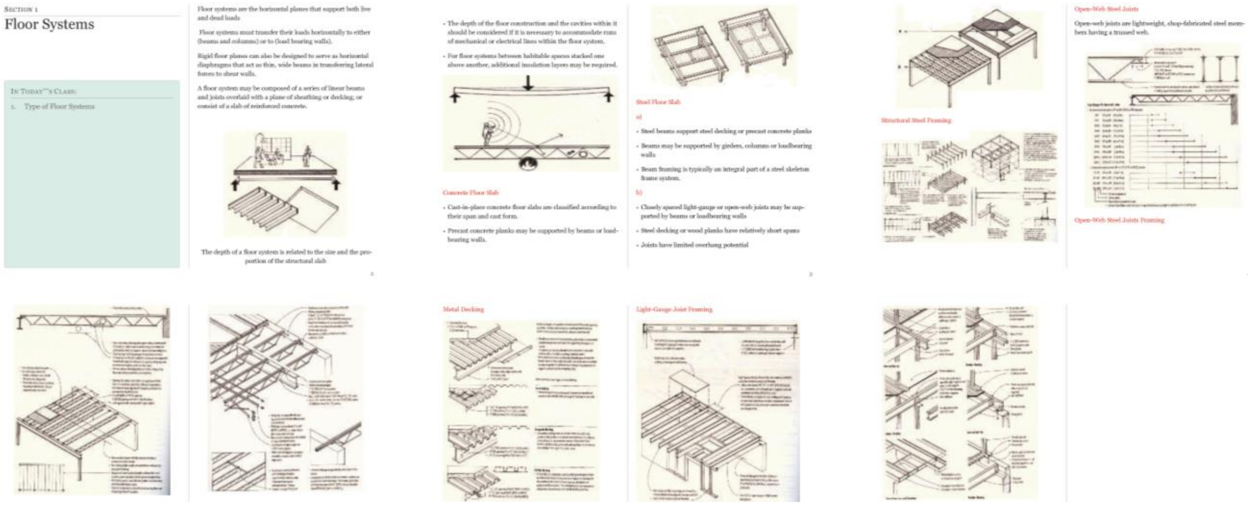
14.1.5.5. *Lecture 5: Long Span Structure*



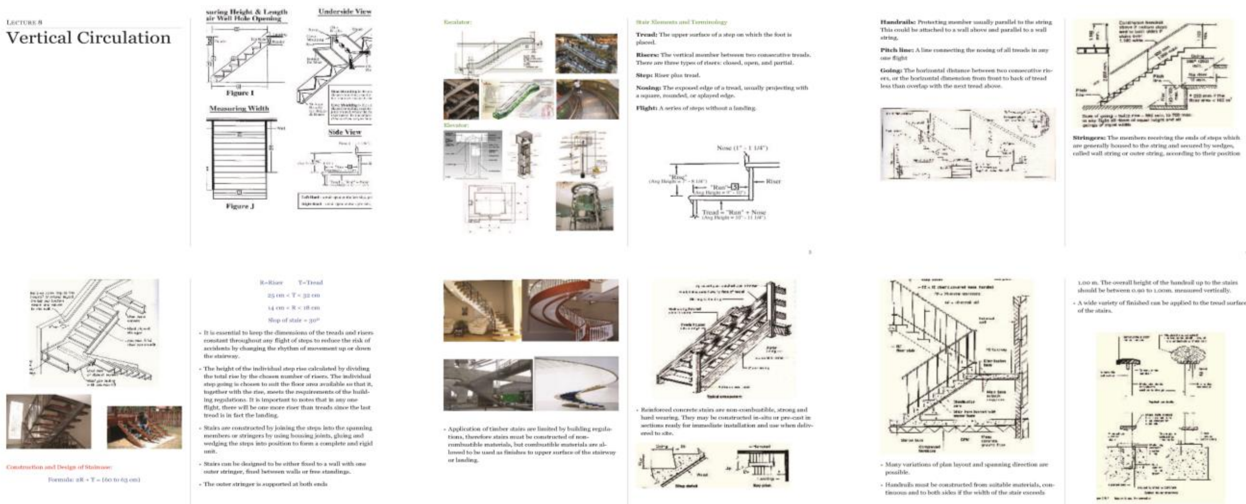
14.1.5.6. *Lecture 6: Light Wall Partitions*



14.1.5.7. *Lecture 7: Floor Systems*

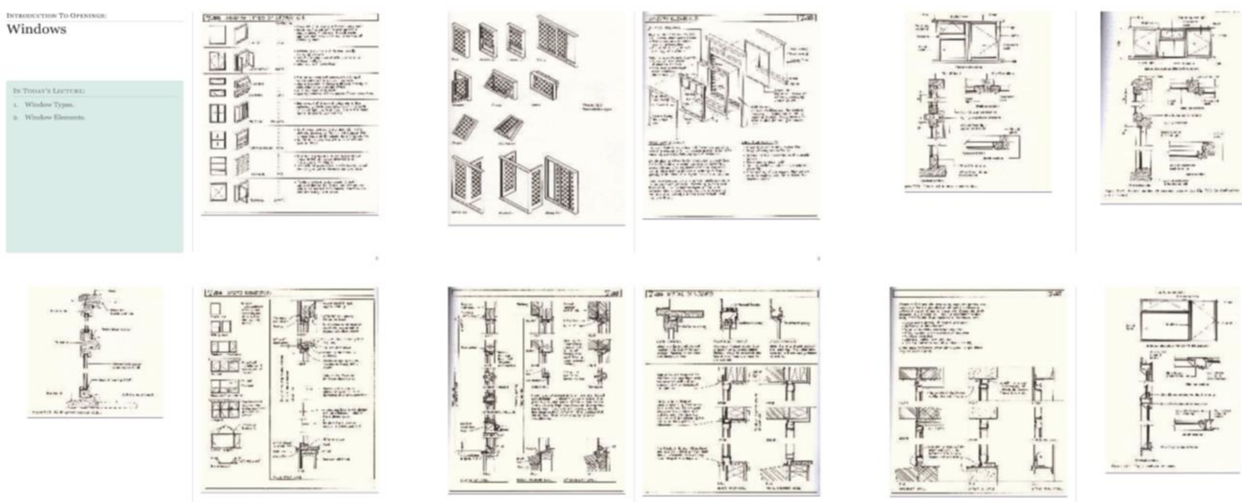


14.1.5.8. *Lecture 8: Vertical Circulation*



14.1.5.9. *Lecture 9: Openings, Doors*

14.1.5.10. *Lecture 10: Openings, Windows*



14.1.6. **Assignment Samples**

14.1.6.1. *Assignment 1*

ARCH 315	**Building Construction Systems**	**UAEU** College of Engineering Architectural Engineering Department
Assignment # 1	**Load Bearing Structure System**	
Duration	**One week**	

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	**ABET Program Outcomes**
1- To learn how to express graphically and technically building construction assemblies drawings	*K- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

B) Grading Criteria

1) Understanding	2) Standards and building codes	3) Building structure system and its components	4) Calculations	5) Construction drawings	Total grade
Clear understanding of building construction problem	Application of Building Standards and Codes.	Integration of structure system, construction methods, and building components	Basic calculations of structural components	Technical and graphical expression of building materials, structural system, and construction methods.	
/0	/0	/0	/0	/10	/10

C) Assignment

Description:
The attached sketches represent plan, section, and elevation of a small house with the following specifications:

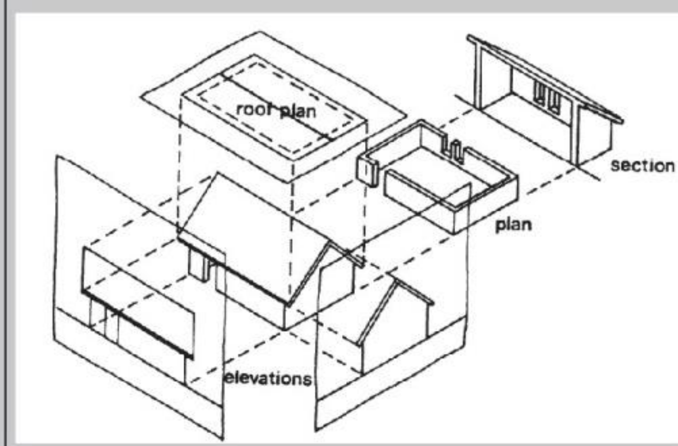
- **Walls: masonry brick walls with 20 cm thickness.**
- **Slab: reinforced concrete with 10 cm thickness.**
- **The width is 3 m, and length is 4 m.**
- **The clear heights are 3.2 (the highest point and 2.4 (the lowest point).**

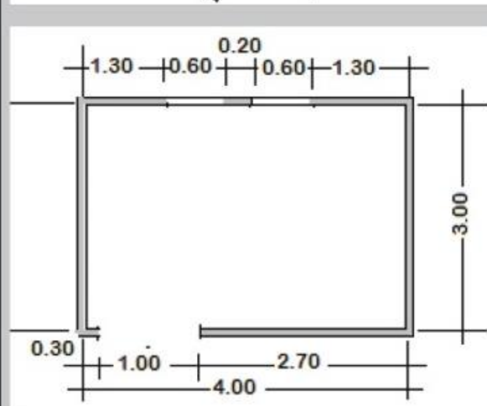
Requirements:
It is required to draw:

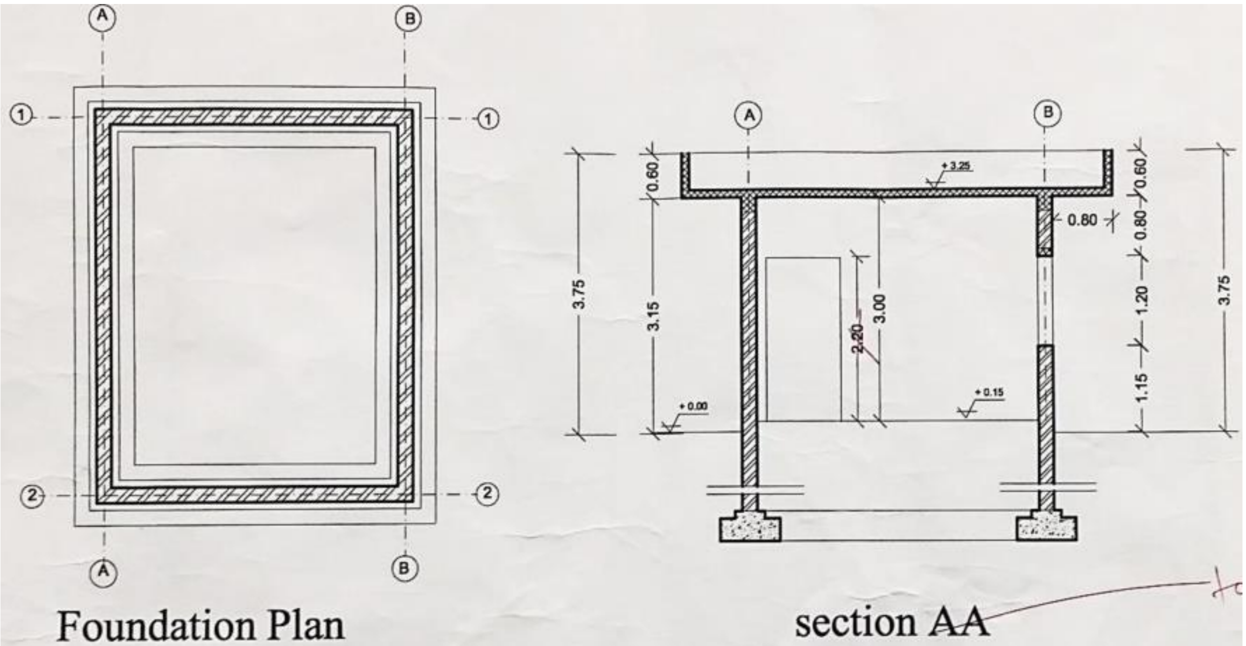
- **Floor Plan (1:20), showing building materials, levels, and dimensions**
- **Building Section A-A (1:20), showing wall components**

Notes:

- **Students should suggest any required information or dimensions that are not shown in the sketches.**
- **Students should submit a hard copy of an AutoCAD file, using A3 sheet.**







14.1.6.2. *Assignment 2*

ARCH 315 **Building Construction Systems** **Assignment # 2** **Load Bearing Structure System** **Duration** **One week**	UAEU College of Engineering Architectural Engineering Department

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1- An ability to recognize building codes, standards and construction terminology *[C and K]* 2- An ability to comprehend and describe the necessary foundation of knowledge to understand building construction and structure systems *[C and E]* 3- An ability to express graphically and technically building materials, components, structural systems, and construction methods *[E and K]*	*C- An ability to design and evaluate building engineering systems, components, or processes to meet desired needs* *E- An ability to identify, formulate, and solve engineering problems* *K- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

B) Grading Criteria

1) Understanding	2) Standards and building codes	3) Building structure system and its components	4) Calculations	5) Construction drawings	Total grade
Clear understanding of building construction problem 1/0	Application of Building Standards and Codes. 1/0	Integration of structure system, construction methods, and building components 5/0	Basic calculations of structural components 1/0	Technical and graphical expression of building materials, structural system, and construction methods. 2/10	/10

C) Assignment

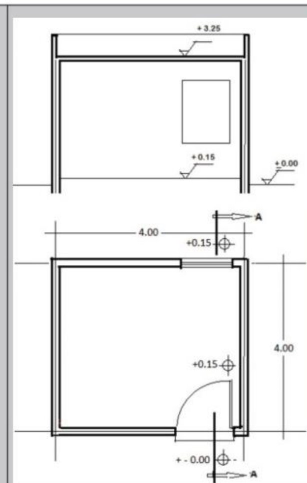
Description:
The following sketches are diagrammatical plan and section of a small building. The structure system is load-bearing wall. All walls are masonry bricks with 20 cm thickness. The slab is constructed from reinforced concrete with 10 cm thickness.

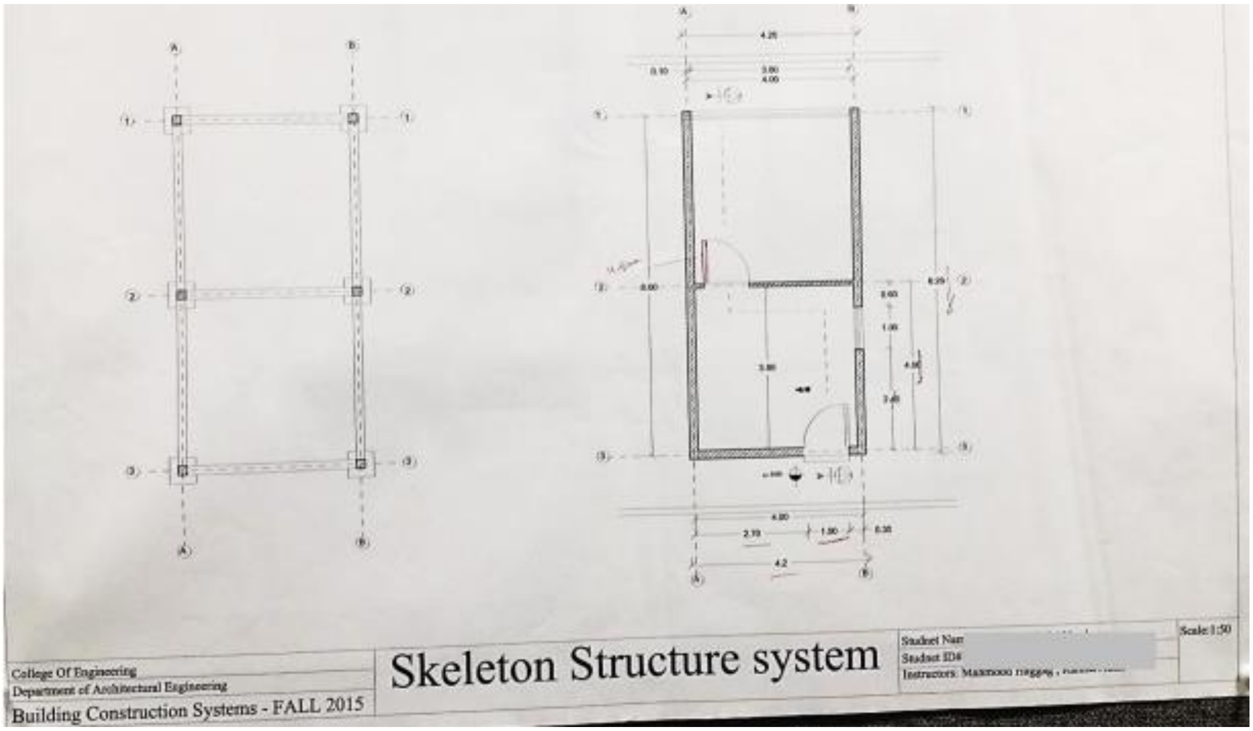
It is required to draw a building section A-A (scale 1:20), showing wall components including foundation, , window sill, window head (lintel), parapet, dimensions, and levels.

Requirements:
It is required to draw:
- **Building Section A-A (1:20), showing wall components including window sill, window head (lintel), foundation, parapet, dimensions, and levels.**
- **Floor Plan (1:20), showing building materials, levels, and dimensions**
- **Foundation Plan (1:20)**

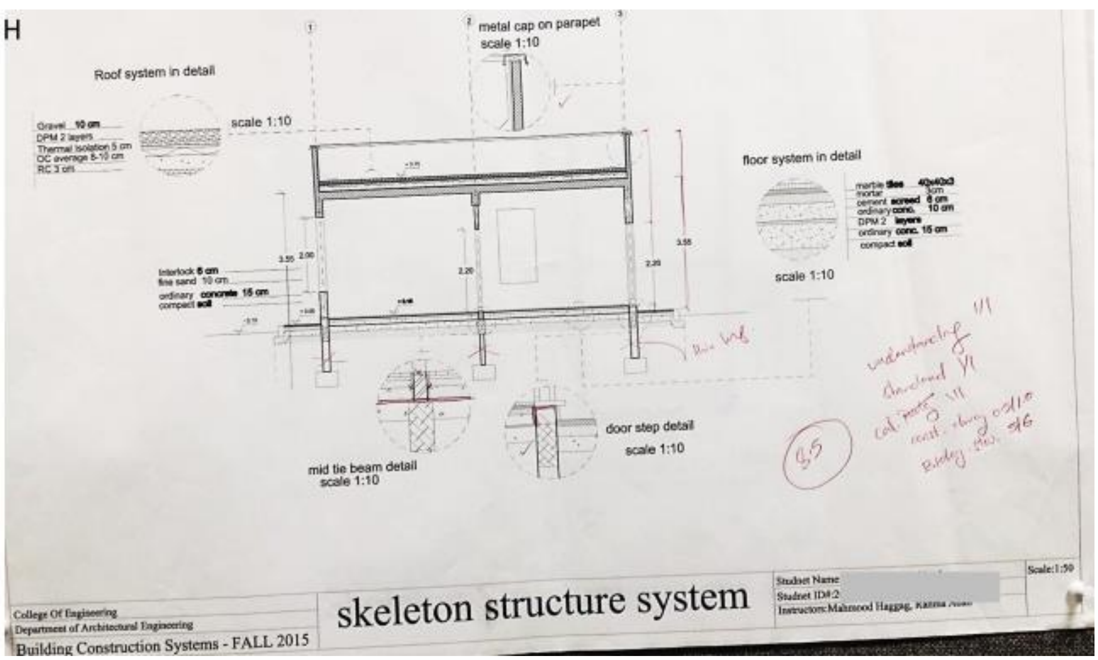
Notes:

- **Students should suggest any required information or dimensions that are not shown in the sketches.**
- **Students should submit both digital and hard copy, using A3 size sheets.**




Skeleton Structure system
College Of Engineering
Department of Architectural Engineering
Building Construction Systems - FALL 2015
Scale:1:50

Sec. 51 - H


Roof system in detail
scale 1:10
metal cap on parapet
scale 1:10
floor system in detail
scale 1:10
door step detail
scale 1:10
mid tie beam detail
scale 1:10
skeleton structure system
College Of Engineering
Department of Architectural Engineering
Building Construction Systems - FALL 2015
Scale:1:50

14.1.6.3. *Assignment 3*

ARCH 315	**Building Construction Systems**	**UAEU** College of Engineering Architectural Engineering Department
Assignment # 3	**Skeleton Structure System**	
Duration	**One week**	

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives

1- An ability to recognize building codes, standards and construction terminology *[C and K]*
2- An ability to comprehend and describe the necessary foundation of knowledge to understand building construction and structure systems *[C and E]*
3- An ability to express graphically and technically building materials, components, structural systems, and construction methods *[E and K]*

ABET Program Outcomes

C- An ability to design and evaluate building engineering systems, components, or processes to meet desired needs
E- An ability to identify, formulate, and solve engineering problems
K- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

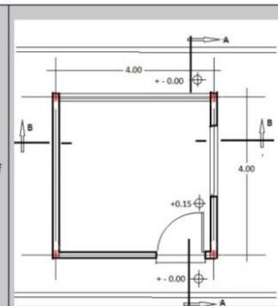
B) Grading Criteria

1) Understanding	2) Standards and building codes	3) Building structure system and its components	4) Calculations	5) Construction drawings	Total grade
Clear understanding of building construction problem 1/0	Application of Building Standards and Codes. 1/0	Integration of structure system, construction methods, and building components 6/0	Basic calculations of structural components 1/0	Technical and graphical expression of building materials, structural system, and construction methods. 1/10	/10

C) Assignment

Description:

The following sketch represents a diagrammatical plan of a small building. The structure system is a concrete skeleton (post and beam structure system). The size of each column is 20X20 cm. with isolated footing foundation. All walls are masonry bricks with thickness of 20 cm. The thickness of the slab is 12 cm. Floor levels are shown in the diagram and the clear height is 3 m.

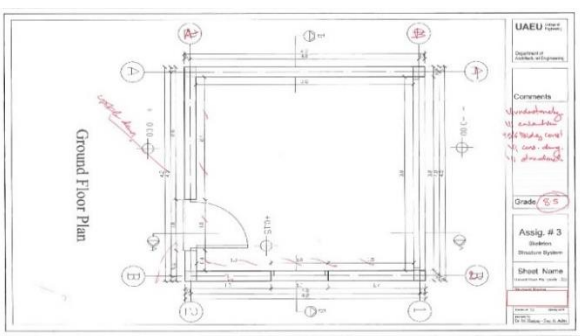


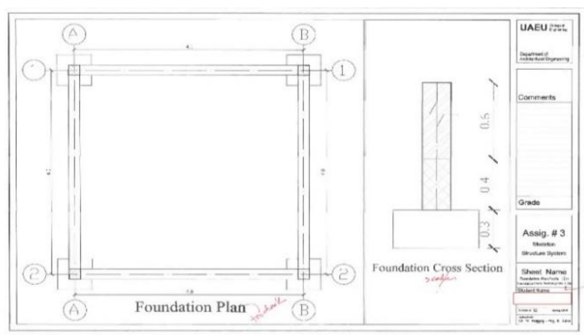
Requirements:

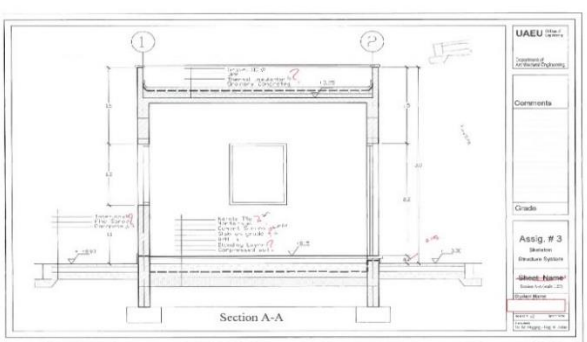
It is required to draw the following:
1- Floor Plan (scale 1:20), showing structure system, wall components, openings, dimensions, and levels.
2- Foundation plan (scale 1:20)
3- Building sections A-A and B-B (scale 1:20), showing wall components, slab, floors, parapet, dimensions, and levels.

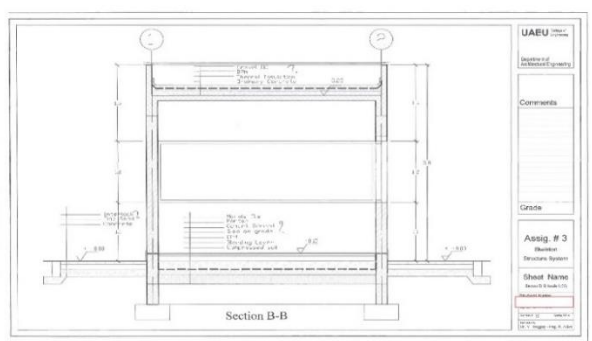
Notes:

- Students should suggest any required information or dimensions that are not shown in the sketches.









14.1.6.4. *Assignment 4*

ARCH 315 Assignment # 4 Duration	Building Construction Systems Skeleton Structure with Steel Roof System two week	UAEU College of Engineering Architectural Engineering Department

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1- An ability to recognize building codes, standards and construction terminology *[C and K]* 2- An ability to comprehend and describe the necessary foundation of knowledge to understand building construction and structure systems *[C and E]* 3- An ability to express graphically and technically building materials, components, structural systems, and construction methods *[E and K]*	*C- An ability to design and evaluate building engineering systems, components, or processes to meet desired needs* *E- An ability to identify, formulate, and solve engineering problems* *K- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

B) Grading Criteria

1) Understanding	2) Standards and building codes	3) Building structure system and its components	4) Calculations	5) Construction drawings	Total grade
Clear understanding of building construction problem 1/0	Application of Building Standards and Codes. 1/0	Integration of structure system, construction methods, and building components 5/0	Basic calculations of structural components 1/0	Technical and graphical expression of building materials, structural system, and construction methods. 2/10	/10

C) Assignment

Description:

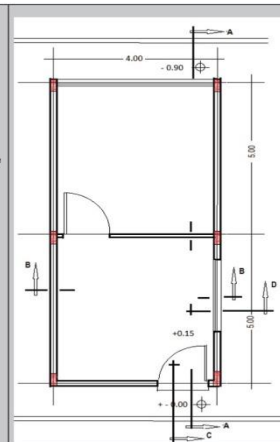
The following sketch represents a diagrammatical plan of a small building. The structure system is a concrete skeleton with open-web steel joists and metal decking. The size of each column is 20X40 cm. Foundation is isolated footings. All walls are masonry bricks with thickness of 20 cm for the external walls, and 10 cm for the internal wall. The clear height is 3 m. Floor levels are shown in the diagram.

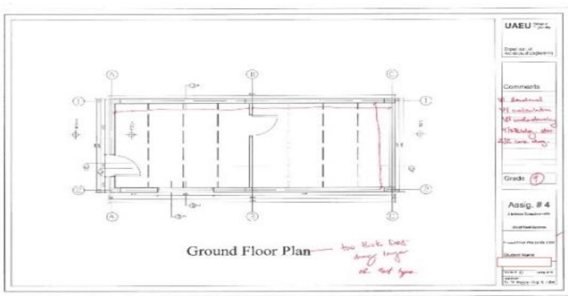
Requirements:

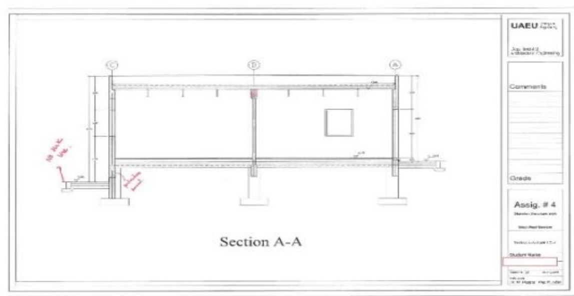
It is required to draw the following:
1- Floor Plan (scale 1:50), showing structure system, wall components, openings, dimensions, and levels.
2- Building sections A-A and B-B (scale 1:50), showing wall components, slab, floors, DPM, parapet, dimensions, and levels.
3- Detailed wall sections C and D (scale 1:10)

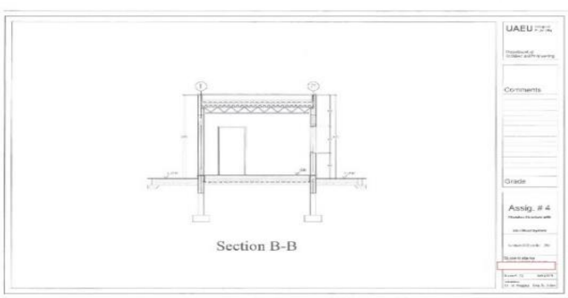
Notes:

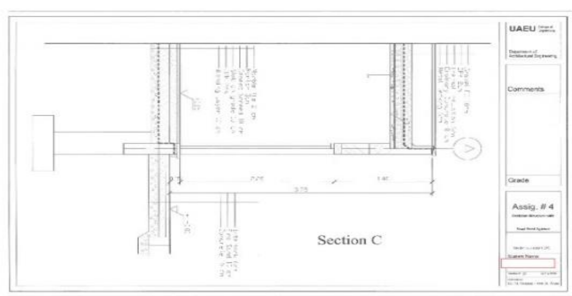
- Students should suggest any required information or dimensions that are not shown in the sketches.











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14.1.6.5. *Assignment 5*

ARCH 315 Assignment # 5 Duration	Building Construction Systems Wall systems – Metal Stud Partition one weeks	UAEU College of Engineering Architectural Engineering Department

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1- An ability to recognize building codes, standards and construction terminology *[C and K]* 2- An ability to comprehend and describe the necessary foundation of knowledge to understand building construction and structure systems *[C and E]* 3- An ability to express graphically and technically building materials, components, structural systems, and construction methods *[E and K]*	*C- An ability to design and evaluate building engineering systems, components, or processes to meet desired needs* *E- An ability to identify, formulate, and solve engineering problems* *K- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

B) Grading Criteria

1) Understanding	2) Standards and building codes	3) construction systems and Their components	4) Calculations	5) Construction drawings	Total grade
Clear understanding of building construction problem 1/0	Application of Building Standards and Codes. 1/0	Integration of structure system, construction methods, and building components 5/0	Basic calculations of structural components 1/0	Technical and graphical expression of building materials, structural system, and construction methods. 2/10	/10

C) Assignment

Description:
The following drawings are diagrammatical plan and section of part of an open office floor (typical floor). The externals wall are masonry brick wall with a thickness of 20 cm., the internal walls are metal stud partitions covered with gypsum board with 12 mm thickness. The structure system is concrete skeleton with a concrete flat plate (20 cm thickness). All columns are 20X40 cm. The clear height is 3 m.

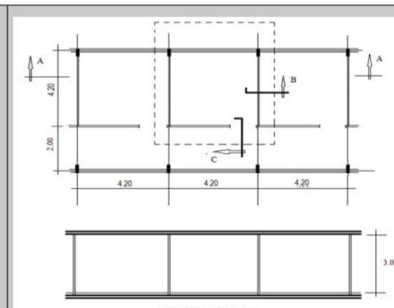
IT IS REQUIRED TO DRAW THE FOLLOWING:

- Floor plans (1:20) for one of the office room (shown in the dashed square).
- Wall sections (B) and (C) 1:20
- Different details for the connections (1:10)

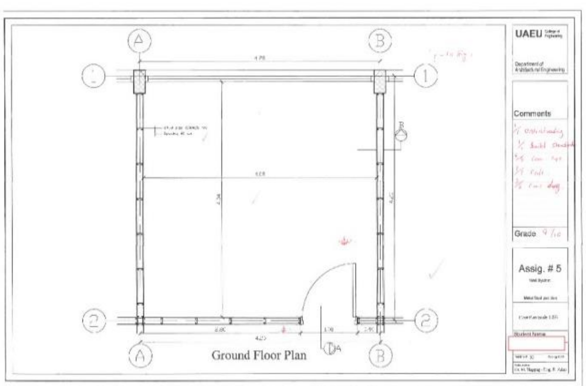
All information and dimensions should be shown in the drawings.

Notes:

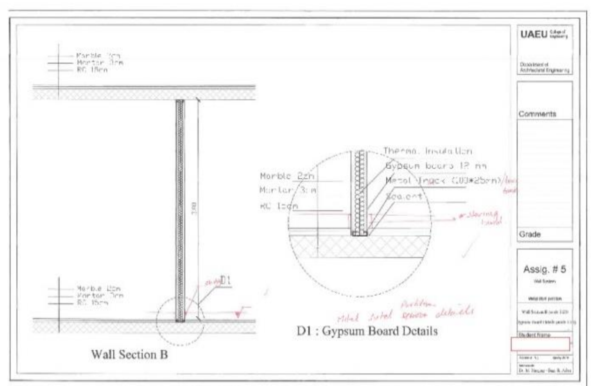
Students should suggest any required information or dimensions that are not shown in the sketches.



Typical floor - Section A-A

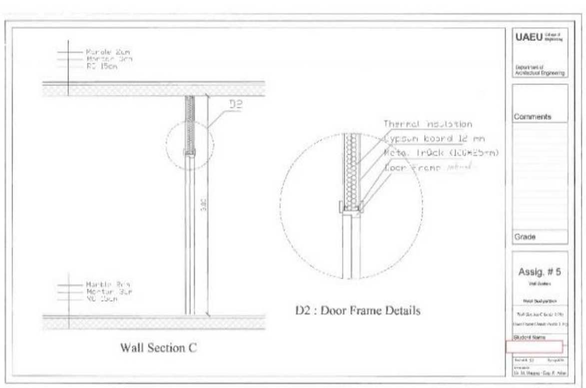


Ground Floor Plan



Wall Section B

D1 : Gypsum Board Details



Wall Section C

D2 : Door Frame Details

14.1.6.6. *Term Project*

Individual Term Project	ARCH 315 Building Construction Systems Duration: 4 weeks	UAEU College of Engineering Architectural Engineering Department

A) Assignment Objectives and Related Program Outcomes

Project Objectives	ABET Program Outcomes
1- To recognize building codes and standards ***[C and K]*** 2- To select appropriate building materials, structure system and construction methods ***[C, E and k]*** 3- To select among alternative, and assemble roof, floor and wall systems and their components ***[C, E and K]*** 4- To design a concrete staircase ***[C, and E]*** 5- To express graphically building materials, components and construction methods ***[E and K]***	*C- An ability to design and evaluate building engineering systems, components, or processes to meet desired needs* *E- An ability to identify, formulate, and solve engineering problems* *K- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

B) Grading Criteria

1) Understanding	2) Standards and building codes	3) Construction systems and Their components	4) Calculations	5) Construction drawings	Total grade
Problem definition	Application of Building Codes, and Standards	Integration of structure system, construction methods, and building components	Basic calculations for selected building components including staircase, stud wall, and metal roofing system	Developing a clear set of construction drawings.	
10%	10%	50%	10%	20%	100%

C) Project Information, Constraints and Deliverables

Description:
The following drawings are diagrammatical plans of one bed room attached house located in Al-Ain city.

Engineering problem:
Develop appropriate roof, floor and wall Systems and design a suitable concrete staircase for a small attached house.

Technical Constraints:

Relevant building codes and standards – building stability, thermal performance – sound performance – recycling materials

Deliverables:

Individual presentation showing selection of appropriate construction systems and materials in light of the given technical constraints

Construction drawings: floor plans, building sections, wall sections and construction details

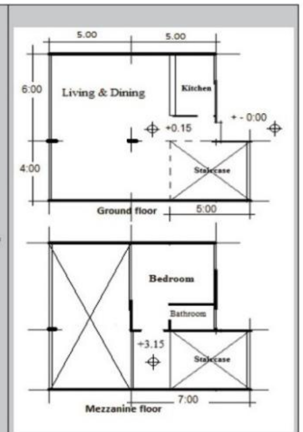
IT IS REQUIRED TO DRAW THE FOLLOWING:

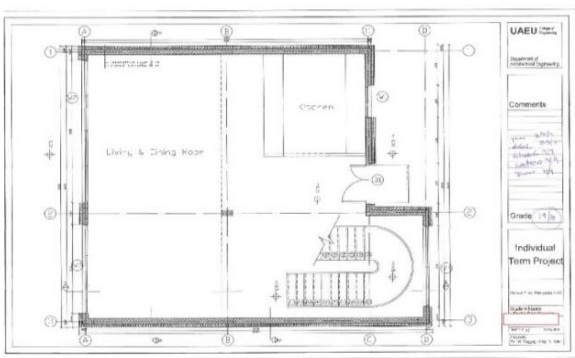
- **Ground and mezzanine floor plans (1:50)**
- **2 perpendicular building sections (1:50)**
- **2 wall Sections**
- **Construction details of a concrete staircase, internal partition, roofing system and internal door**

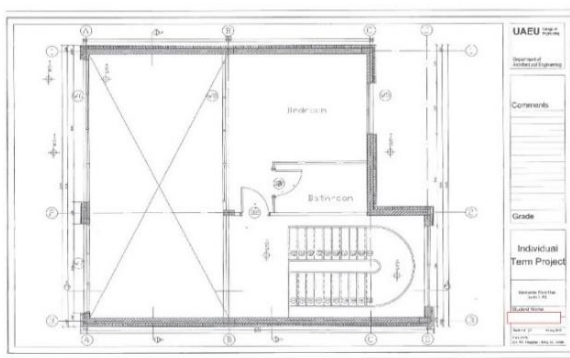
All information and dimensions should be shown on the drawings.

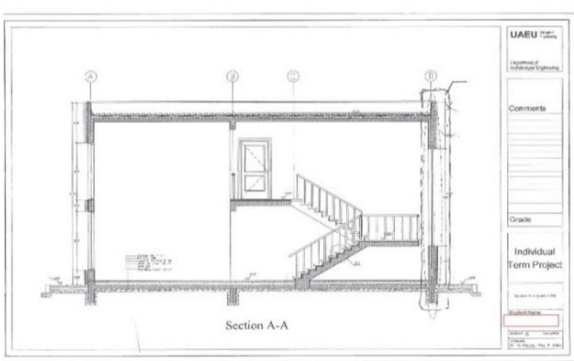
Important Notes:

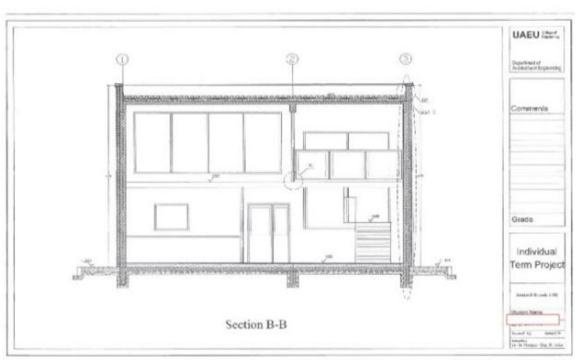
1- Students should select the most suitable structure system, construction methods, and sustainable building materials.
2- Students should suggest any required information or dimensions that are not given











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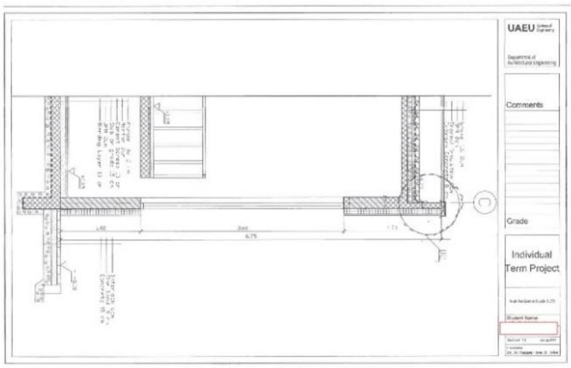
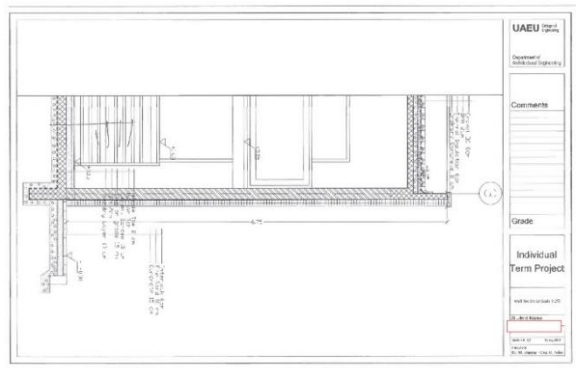

UAEU
Comments
Grade
Individual
Term Project


UAEU
Comments
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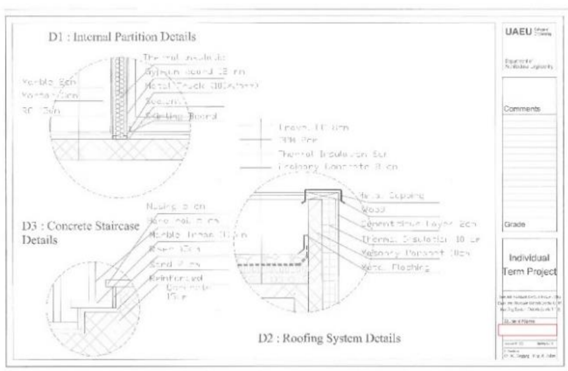
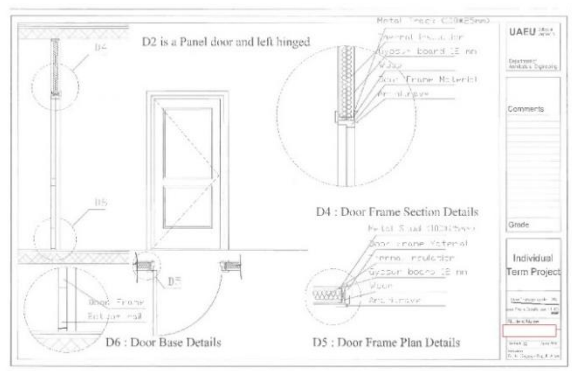
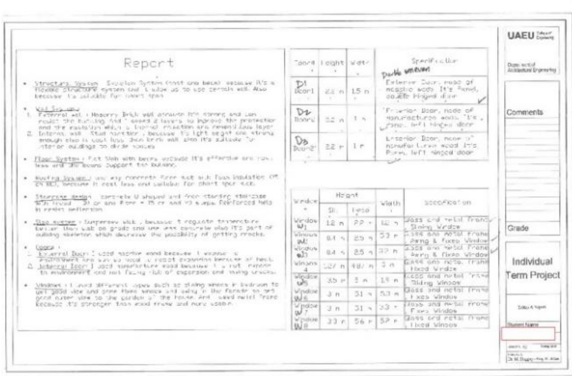
Term Project


D1 : Internal Partition Details
D3 : Concrete Staircase
Details
D2 : Roofing System Details
UAEU
Comments
Grade
Individual
Term Project


D2 is a Panel door and left hinged
D4 : Door Frame Section Details
D6 : Door Base Details
D5 : Door Frame Plan Details
UAEU
Comments
Grade
Individual
Term Project


Report
UAEU
Comments
Grade
Individual
Term Project

14.2. Building Components

The Building Construction Components (BCC) Course is the intermediate Building Construction Course in the AE program at UAEU. At this stage the students learn the building construction components properties, specifications and application methodologies in order to be able to create their own details for their projects. During the BCC course we introduce the students to different types of floor systems, interior and exterior wall systems, false ceilings, building joints, vertical circulation, and openings.

This course is primarily oriented around lectures, in-class discussion, on-line e-learning and hands-on activities during practical hours. The course is organized around a series of interrelated instructional topics. A significant portion of the course material is technical information that requires frequent class discussions and small group interactions. Development of the students' ability to work in teams is an important element of this course. Students are required to come to class on time, take notes during classroom lectures and discussions, analyze assigned readings, and work in class during practical hours [Table 6].

The course has four main elements: lectures where each subject is introduced by the professor, research about products available in the region and innovations, in-class discussion about the lecture and research findings, and finally using sketching and AutoCAD, each of the students is required to develop their own details for their project, using one of the products available in the market.

Attendance & Conduct

Perfect and punctual attendance is expected. UAEU attendance and conduct policies are fully implemented.

Course Learning Objectives:

- To strengthen the student's vocabulary of both internal and external treatment and finishes of the building; by enabling him or her to choose appropriate finishing materials, techniques, and construction methods for spaces; according to type and function.
- To acquire knowledge of vertical circulation elements needed for technically efficient buildings.
- To acquire knowledge of openings and their construction components.
- To understand basic construction terminologies and building codes.
- To utilize the student's knowledge of building materials, building components and openings into construction process.

Course Measurable Outcomes

- Knowledge of basic internal and external finishes, vertical circulation elements and openings needed for technically efficient buildings (C) [MQ, FQ, AQ, AR].
- Ability to understand building joints and services needed for technically efficient building construction (E) [AQ, AR].
- Ability to draw accurate details to allow authenticity in developing building design schemes (E) [MQ, FQ, AQ].

Student Performance Assessment and Grading Criteria

Throughout this course, students gain knowledge and competencies that will be evaluated using different assessment techniques. This course devotes 50% of the final grade to the student's performance throughout the semester. The other 50% is devoted for exams. The following grading percentages were applied:

- Assignments and presentations: 40%
- Class Participation: 10%
- Mid-Term Exam: 20%
- Final Exam: 30%

The following are the main assignment grading criteria:

- Understanding; well-defined problem and clear design intent based on literature review, establishment of needs, and case study analysis.
- Application: Selection and integration of an appropriate construction system, its components, and relevant construction methods.
- Standards and Building Codes: Application of Building Standards and Building Codes.
- Calculation: Relevant to the selected construction system/components.
- Building Construction Drawings: Technical and graphical expression of building materials, structural system(s), and construction methods.

14.2.1. Course Outline

Week Number	Session Topics	
	1st Session	*2nd Session*
Week 1	Introduction to the BCC Course	**Lecture 1:**
Week 2	**Assignment 1:** Group Research for Plastering & Paint	**Lecture 2:** Internal Finishes: Floorings
Week 3	**Assignment 2:** Individual CAD drawing for Internal Finishing	**Lecture 3:** Internal Finishes: light weight partitions
Week 4	**Assignment 3:** Group Research for Demountable Partitions	**Lecture 4:** Internal Finishes: Suspended Ceilings
Week 5	**Assignment 4:** Individual CAD drawing for Demountable Partitions	**Lecture 5:** External Finishes: Plastering + Cladding
Week 6	**Assignment 5:** Group Research in Cladding Systems	**Lecture 6:** External Finishes: Metal & Glass Curtain walls
Week 7	**Assignment 6:** Individual CAD drawing for Cladding and C	**Quiz 1:** Internal and External Finishing
Week 8	General Revision & Open Questions Session	**Mid-Term Exam**
Week 9	Mid-term Revision	**Lecture 7:**
Week 10	**Class Activity:** Individual CAD drawing for Building Expansion	**Lecture 8:** Openings: Doors and Windows Components
Week 11	Field Trip	**Class Activity:** Discussion (Field Trip)
Week 12	**Assignment 7:** Group Research in Doors & Windows Components	**Lecture 9:** Service Components: Ducting, Floor Trench, Floor
Week 13	**Assignment 8:** Individual CAD drawing for Doors and Windows	**Quiz 2:** Openings
Week 14	**Assignment 9:** Group Research about Steel Staircase	**Lecture 10:** Vertical Circulation: Steel Staircase
Week 15	**Assignment 10:**	**Lecture 11:**
Week 16	General Revision	Open Questions Session
Final Exam [date/time as announced]		

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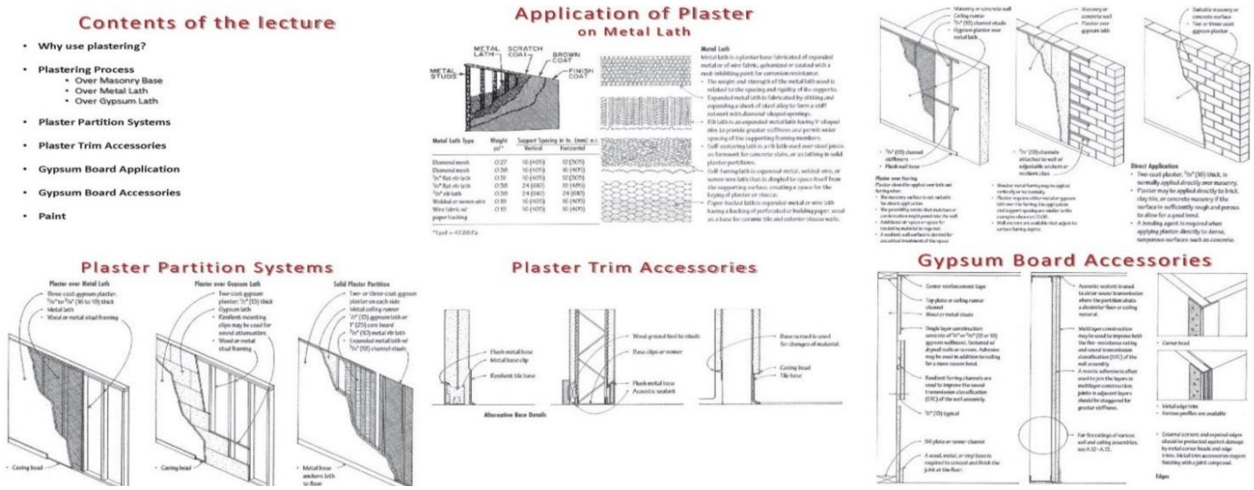
14.2.2. **Lecture Samples:**

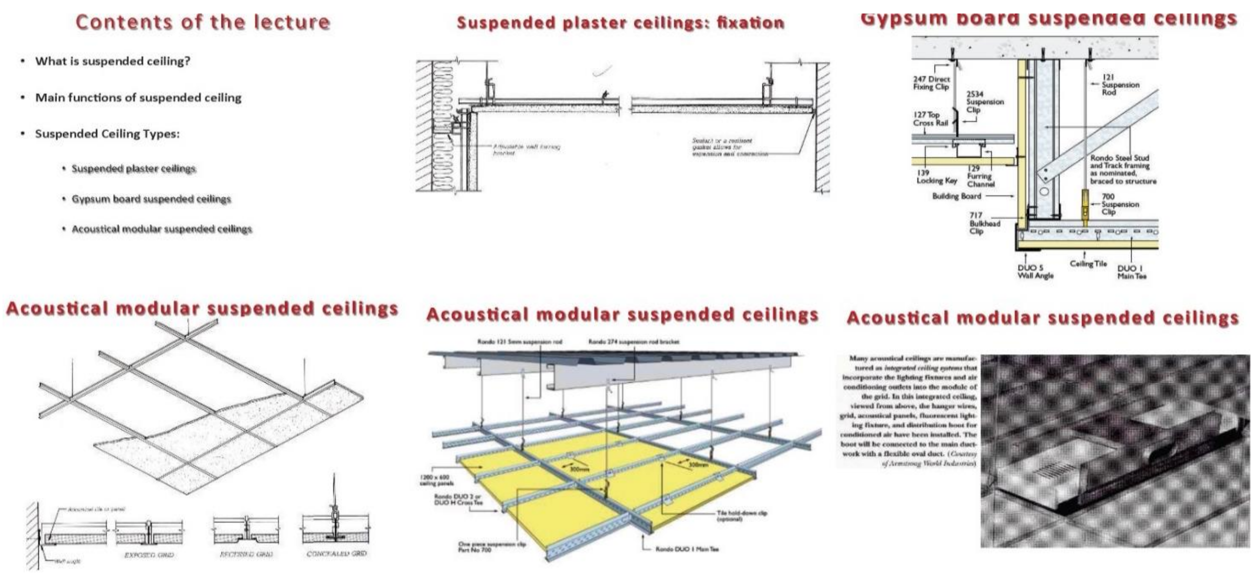
14.2.2.1. *Lecture 1: Internal Finishes: Plastering & Paint*



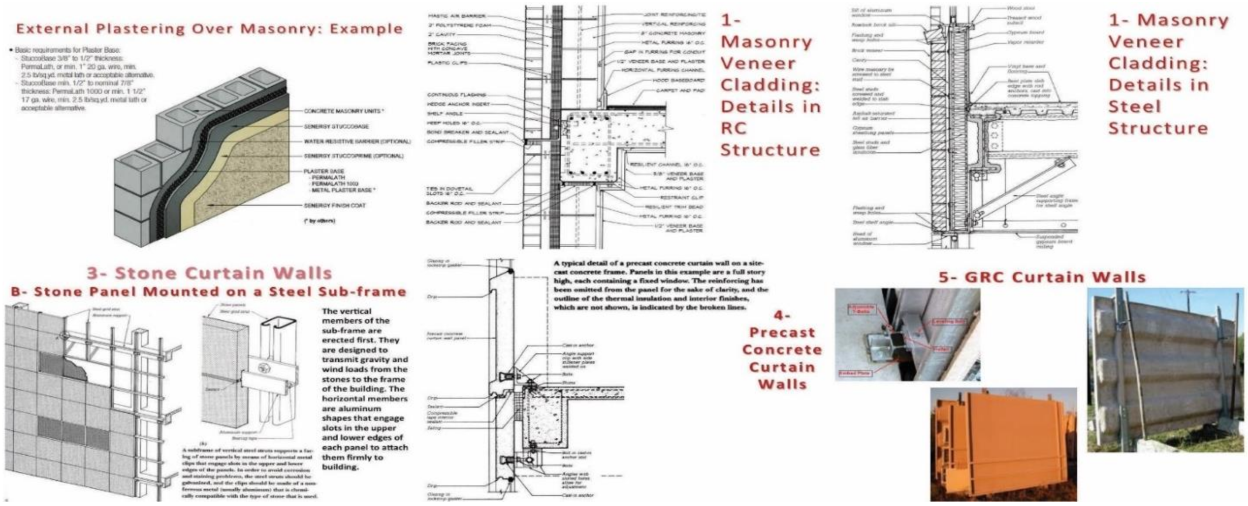
14.2.2.2. *Lecture 2 Internal Finishes: Floorings*

14.2.2.3. *Lecture 3: Light Weight Partitions*

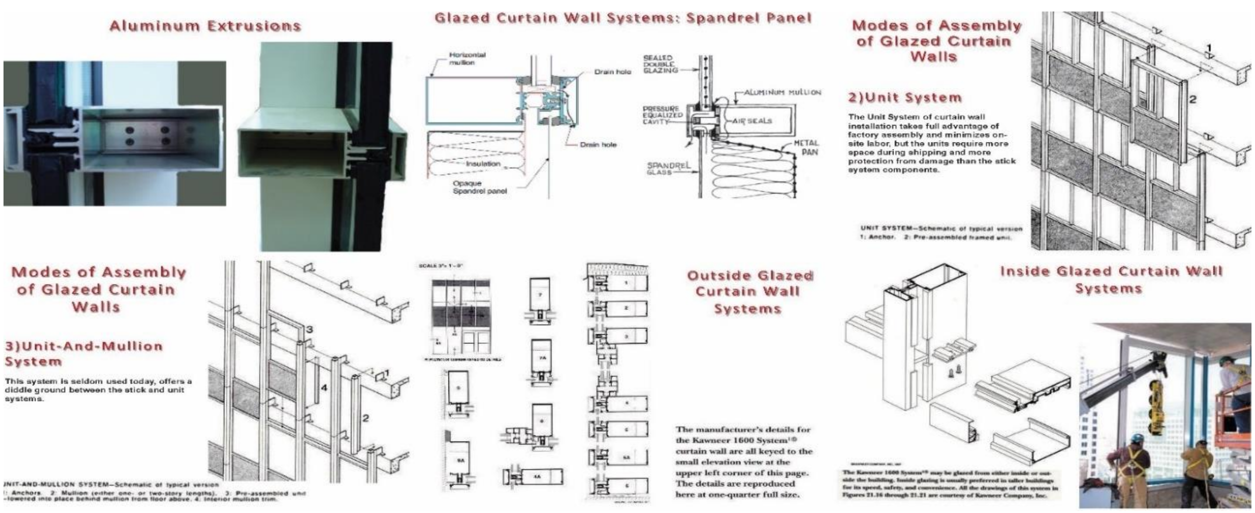
14.2.2.4. *Lecture 4: Suspended Ceiling*



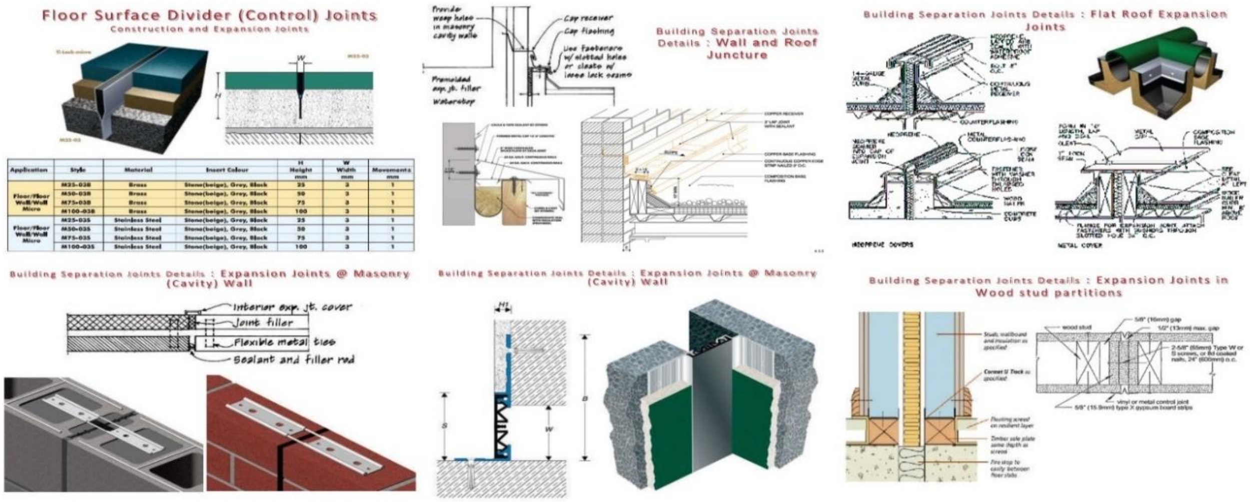
14.2.2.5. *Lecture 5: Cladding Systems*



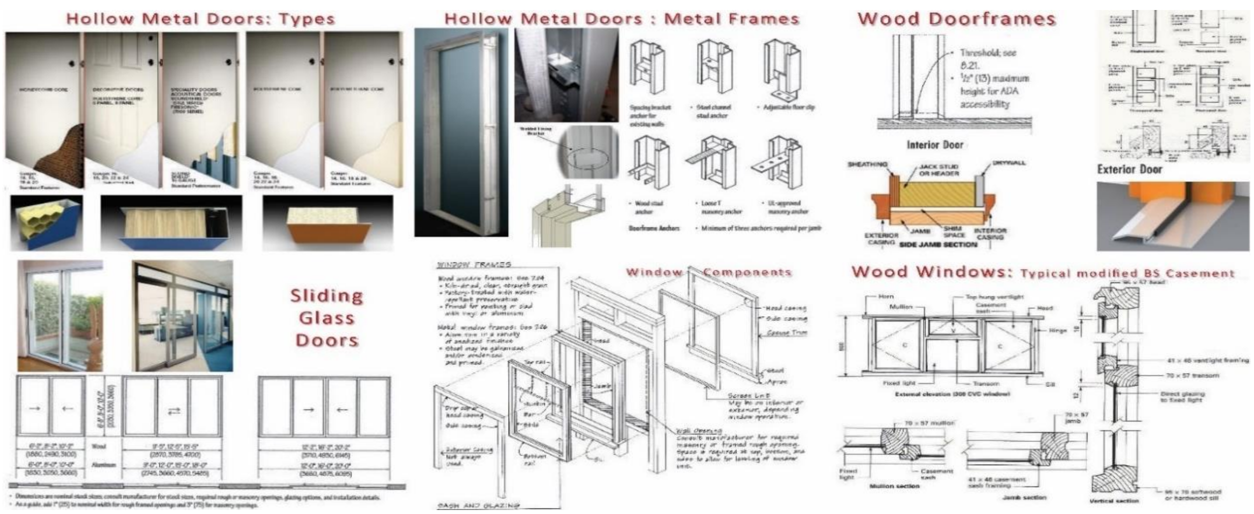
14.2.2.6. *Lecture 6: Curtain Walls*



14.2.2.7. *Lecture 7: Building Joints*



14.2.2.8. *Lecture 8: Windows and Doors*



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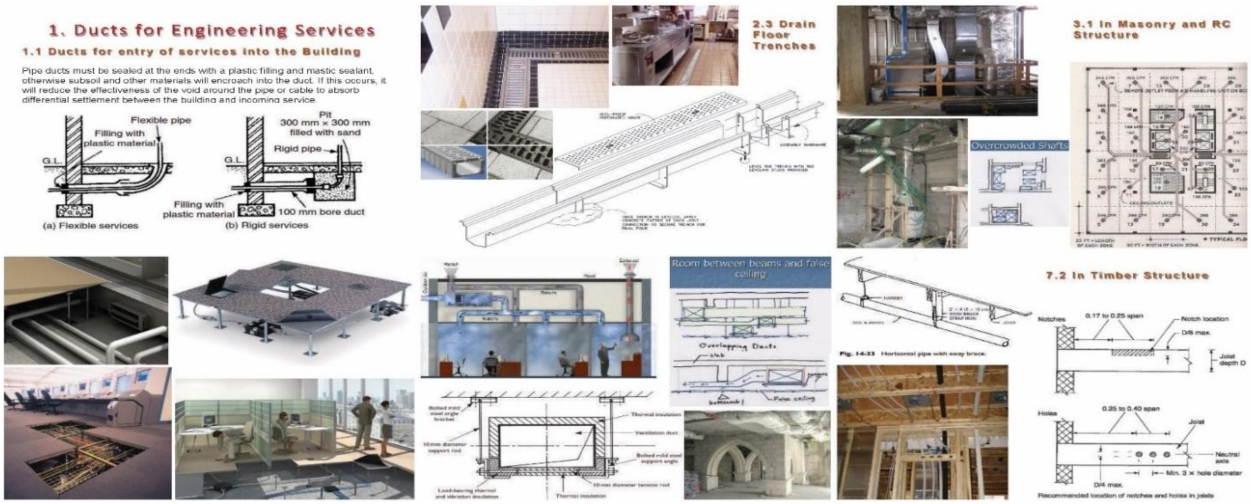
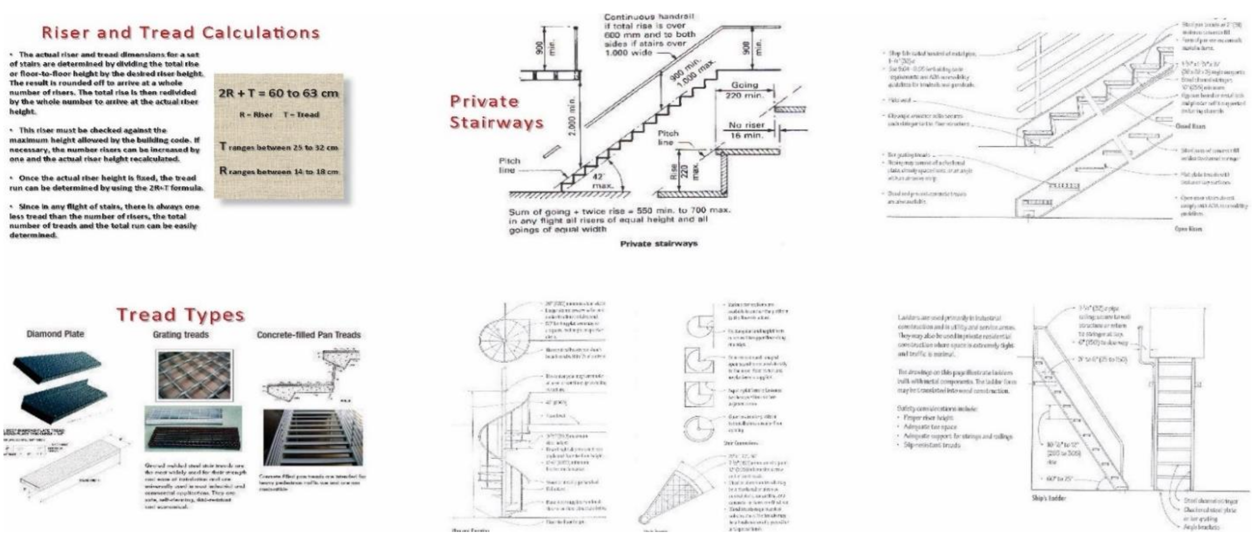
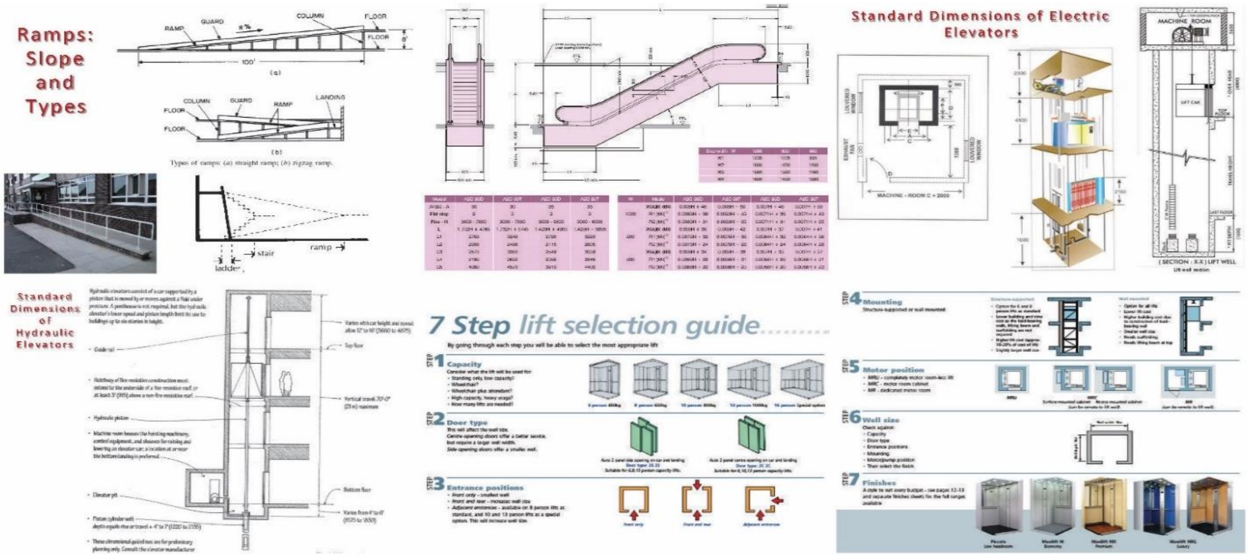
14.2.2.9. *Lecture 9: Building Services*



14.2.2.10. *Lecture 10: Steel Stair*



14.2.2.11. *Lecture 11: Ramp, Elevators and Escalators*



14.2.3. **Assignment Samples:**

Assignment 1 – Research in Plastering & Painting

- Each Person is required to prepare, present and submit via Blackboard [Tools-Messages] and mail a PowerPoint presentation of maximum 10 slides for ONLY one the following issues as assigned in the class:

1- Select one type of gypsum boards produced by a company and present its specs and installation techniques.
2- Present metal/pvc accessories for plastering.
3- Present metal/pvc accessories for gypsum boards.
4- Present new painting materials and techniques.

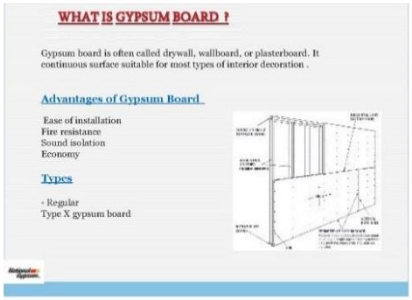
- Each of the students will have to make 5 cards.

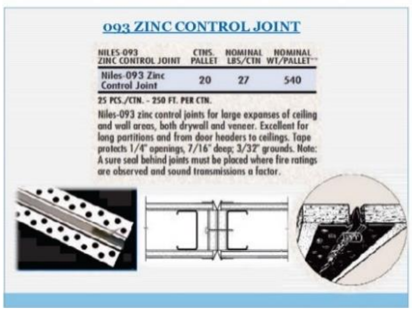
1- card with 3 accessories

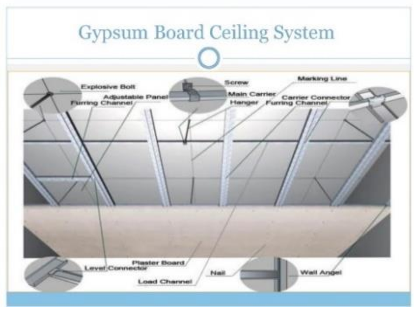
Notes:

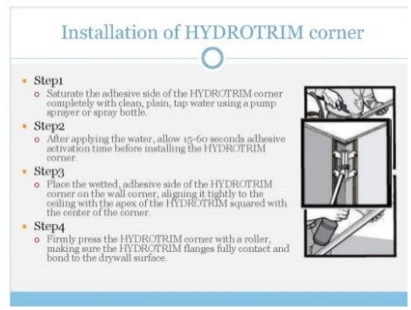
- Each research should include sufficient information about the materials, types, dimensions and installation methods.
- The data presented should reflect state-of-the-art products and techniques supported by sufficient technical information and references list.

- Each member of the research teams is going to present a part of the research.
- Students are to refrain from copying from lectures.









Assignment 2. Plaster & Floorings

For each student:

A) Draw 2 partial sections (Scale 1:20) in an external wall for one floor building showing the following internal finishing for flooring and walls:

In the first section:

- Timber flooring of a type selected by the students and Cement Plastering & Paint (with metal/PVC accessories).

In the second section:

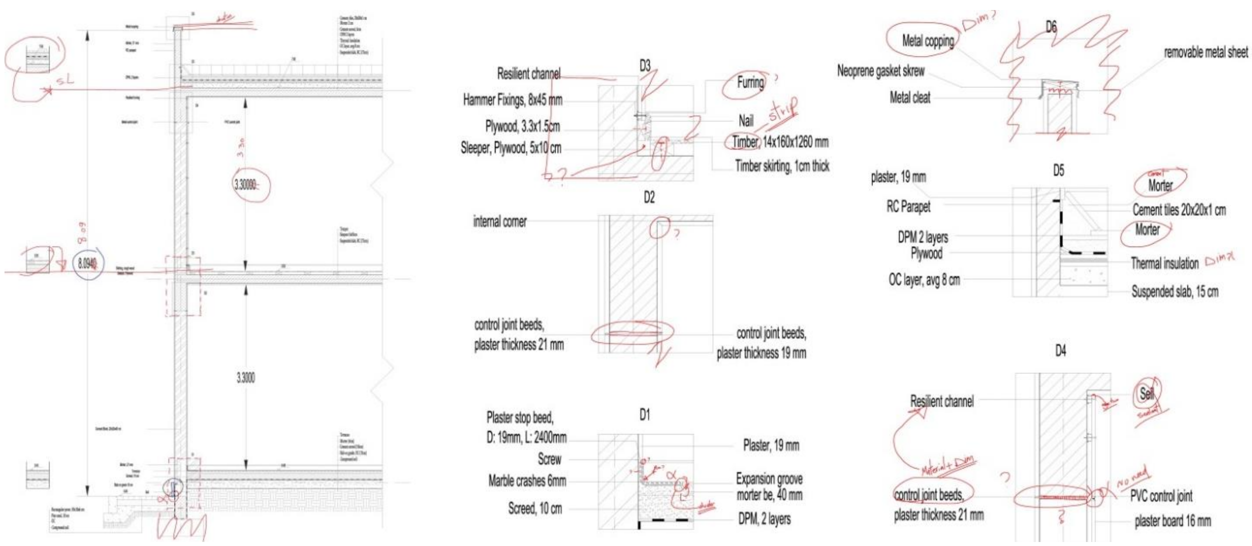
- Tiled flooring of a type selected by the students and Gypsum board & Paint (with metal/PVC accessories).

B) Draw the details (Scale 1:5) for the connections between the wall and both the floor and the roof (including the metal coping) for these two sections.

Notes:

- The clear height is 3.40 m.
- The internal floor level is 0.60 m.
- Assume any undetermined materials/dimensions.
- Attach A4 sheets showing the sources of the specs of all used materials.
- All dimensions and materials should be well illustrated on the drawings.
- The assignment is to be submitted via Blackboard – Tools (Course Message attachment) and in a hardcopy of A2 format.

The samples are an average student's work, corrected by the professor by iPad.



Assignment 3 – Research in Demountable Partitions

Each group is required to prepare, present and submit via Blackboard [Tools-Course Messages] a PowerPoint presentation of 10 to 15 slides for the following issues as assigned in the class:

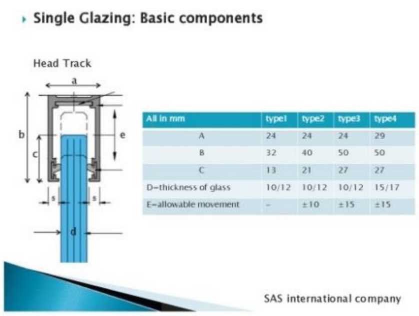
1- Demountable partitions
- Wood
- Frameless Glass
- Aluminum

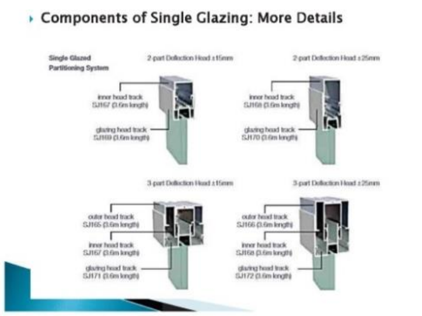
- Gypsum board

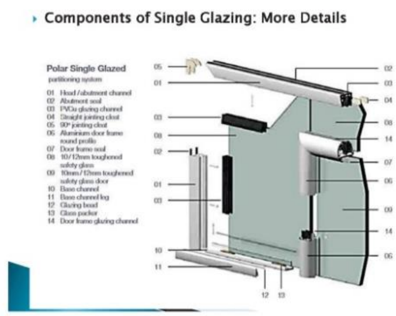
<u>Notes:</u>

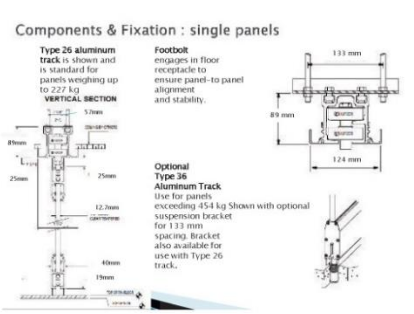
- Each research should include sufficient information about the materials, types, dimensions and installation methods.
- The data presented should reflect state-of-the-art products and techniques supported by sufficient technical information AND NOT TO BE TAKEN FROM THE LECTURE MATERIALS.
- Each member of the research teams should present equal part of the research.

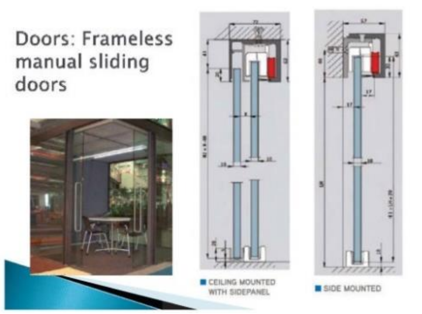
The research example of the assignment is only 6 images from the whole presentation.

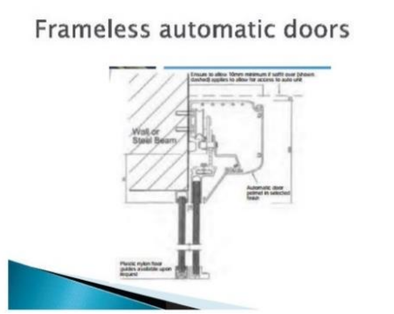










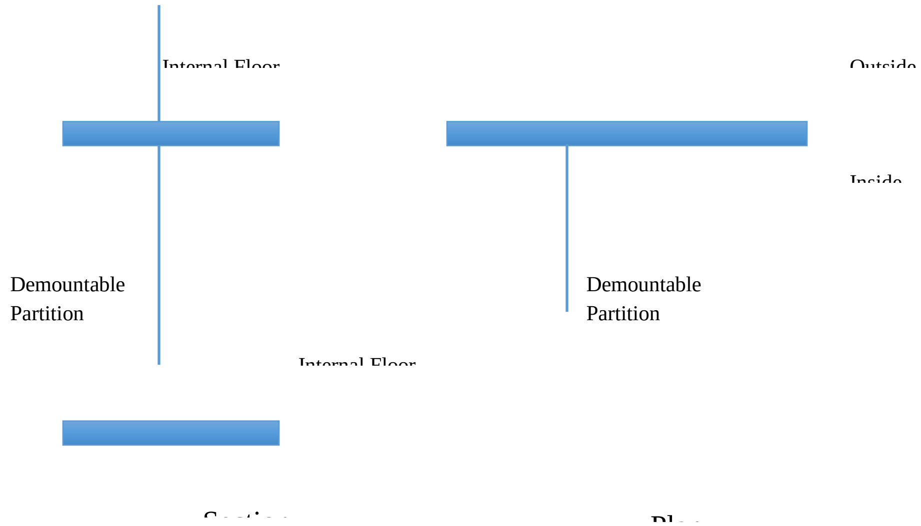


Assignment 4 – Demountable Partitions and Suspended Ceilings

<u>For each student:</u>

A) Draw a plan and a section (Scale 1/20) as illustrated below into a *typical* floor of RC skeleton office building. The internal finishing materials are as follows:

Demountable partition of a type selected by the student, plasterboard-finished insulated CMU, plasterboard suspended ceiling and terrazzo flooring (with all the required metal/pvc accessories).



B) Draw the details (Scale 1:5) for the connections between this internal demountable partition and:

- The terrazzo-finished RC typical floor (from the section).

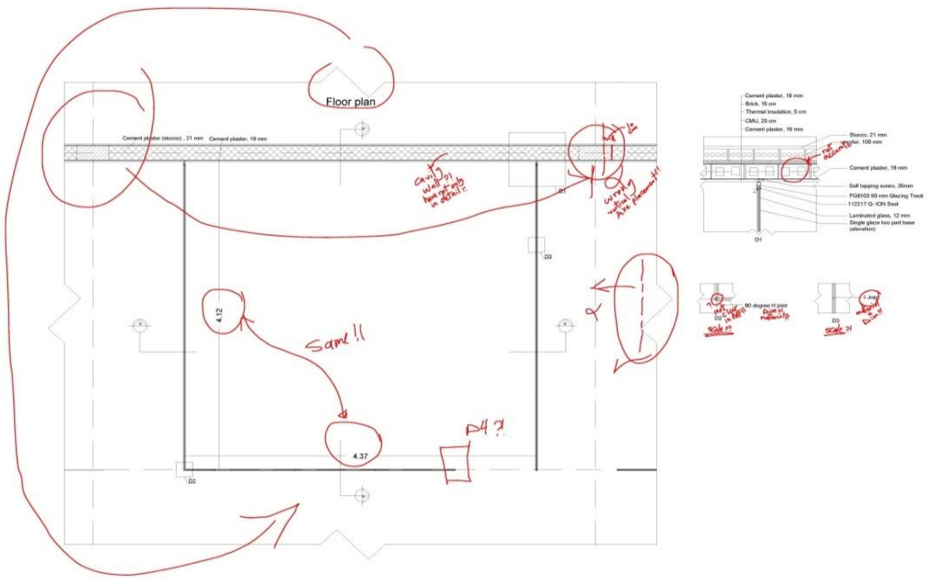
- The plasterboard suspended ceiling (from the section).

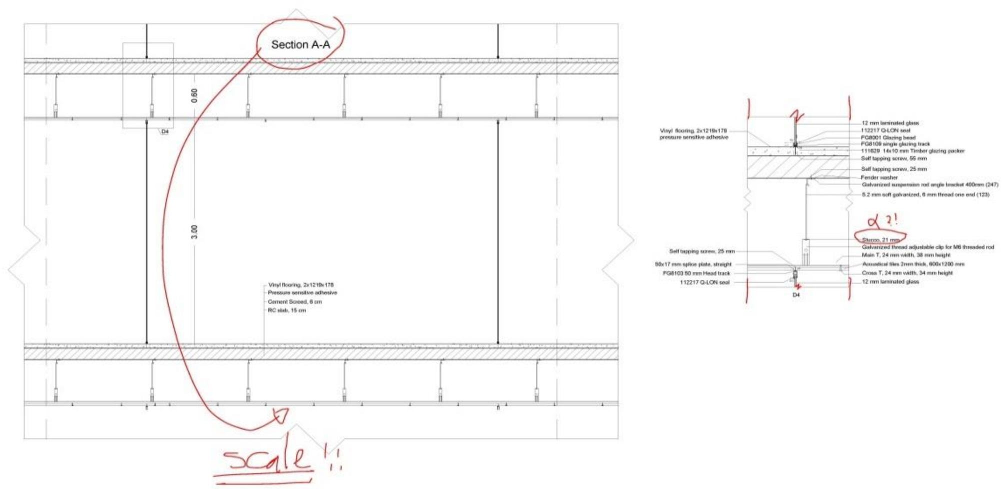
- The external plasterboard-finished [from inside] insulated CMU wall (in the plan).

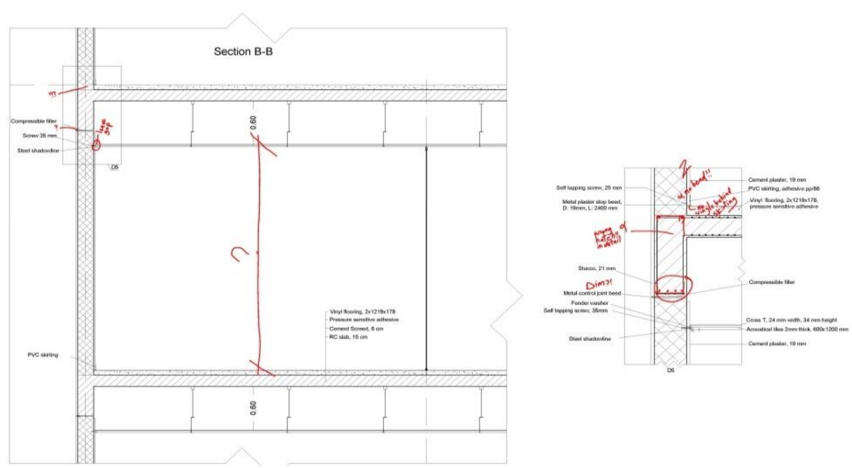
<u>Notes:</u>

- The clear height of the floor is 3.40 m.
- Assume any needed/not mentioned materials and dimensions.
- All dimensions and materials should be illustrated clearly on the drawings.
- Conduct research to obtain any needed dimensions and materials.
- ***Submit with the hardcopy of the assignment A4 print out showing the references of the used materials selected through your research.***
- The assignment is to be submitted via Blackboard (Message attachment) and in a hardcopy of A2 format.

The samples are an average student's work, corrected by the professor by iPad.


Floor plan
same !!
scale !!


Section A-A
scale !!


Section B-B

Assignment 5 – Research in Cladding Systems

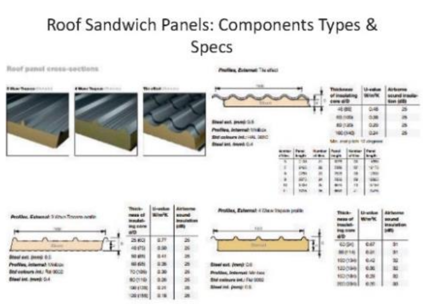
- Each group is required to prepare, present and submit via Blackboard [Tools- Course Messages] a PowerPoint presentation of about 10-15 slides for ONLY one the following issues as assigned in the class:

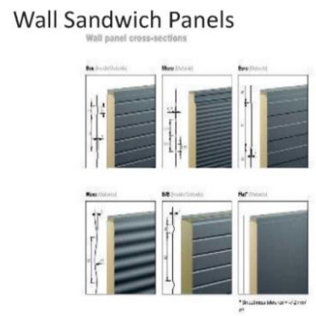
1- Stone cladding system, components and installation.
2- Hollow Metal Panels cladding system, components and installation.
3- Sandwich Panels cladding system, components and installation.
4- GRC cladding system, components and installation.

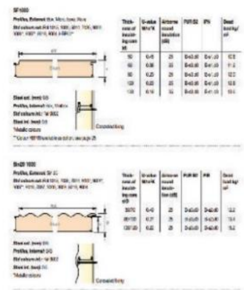
Notes:

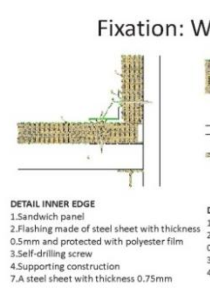
- Each research should include sufficient information about the materials, types, dimensions and installation methods.
- The data presented should reflect state-of-the-art products and techniques supported by sufficient technical information and references list.
- Each member of the research teams is going to present a part of the research.
- Students are to refrain from copying from lectures.

The research example, of the assignment is only 6 images from the whole presentation.









Assignment 6– Cladding and Curtain Walls

A) For a two storey RC skeleton office building, draw a section and two plans (Scale 1/20) for the external wall which is composed of a stone cladding in the first floor and glass and metal curtain wall in the ground floor showing the followings:

In the ground floor: Plastering suspended ceiling and vinyl flooring (with metal/pvc accessories).

In the 1st floor: Acoustic modular suspended ceiling and ceramic flooring (with metal/pvc accessories).

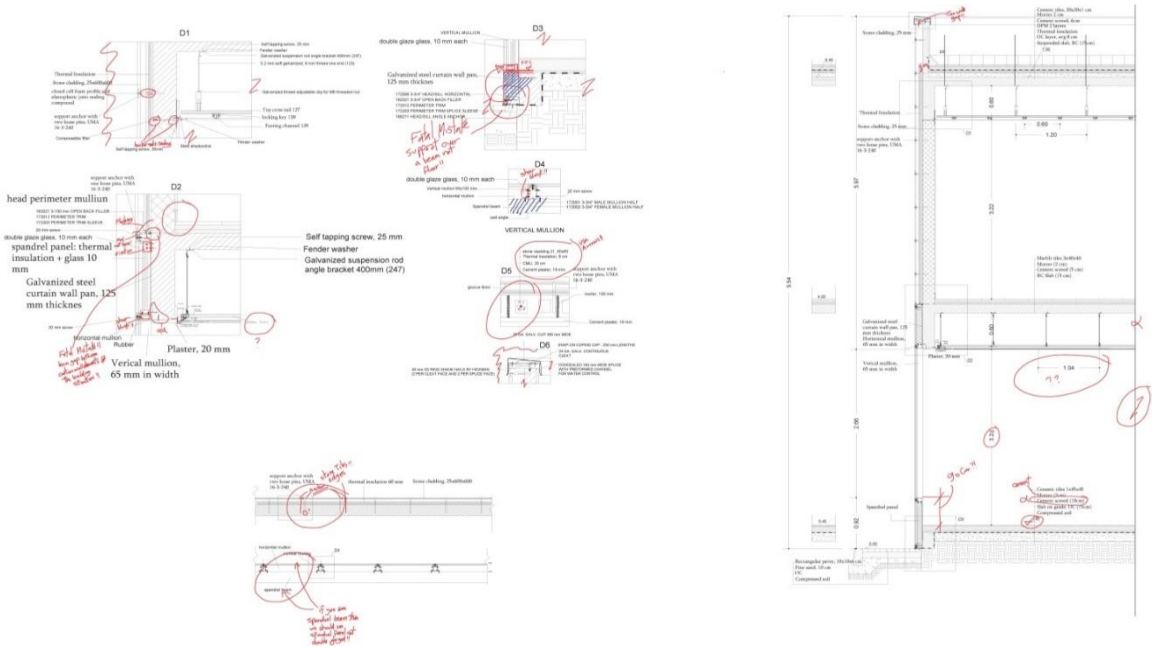
In the roof: Cement tiles, metal coping and other roof finishing materials.

B) Draw the details (Scale 1:5) in both plans and section: for the connections between the wall and both the floor and the roof in each floor showing the fixation methods of the cladding and curtain wall systems.

Notes:

- The clear height of the floor is 3.00 m.
- Assume any needed/not mentioned materials and dimensions.
- All dimensions and materials should be illustrated clearly on the drawings.
- Duration of the assignment is one week.
- Conduct research to obtain any needed dimensions and materials.
- ***Submit with the hardcopy of the assignment A4 print out showing the references of the used materials selected through your research.***
- The assignment is to be submitted via Blackboard (Course Messages attachment) and in a hardcopy of A2/A1 format.

The samples are an average student's work, corrected by the professor by iPad.



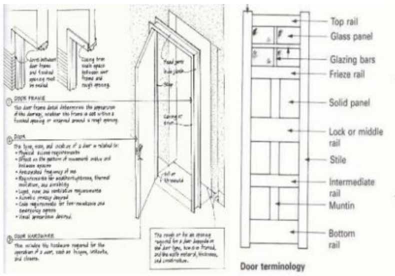
Assignment 7 – Research In Doors & Windows Components

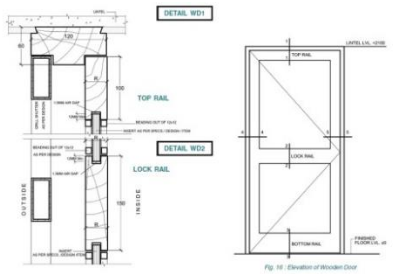
- Each group is required to prepare, present and submit via Blackboard [Tools-Course Messages] a PowerPoint presentation of max. 10 slides for ONLY one the following issues as assigned in the class:

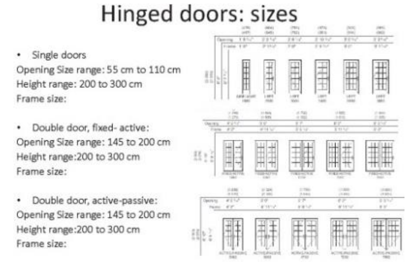
2- Components of Metal Doors and Windows
3- Components of Wood Doors and Windows
4- Components of PVC Doors and Windows
5- Components of Aluminum Doors and Windows

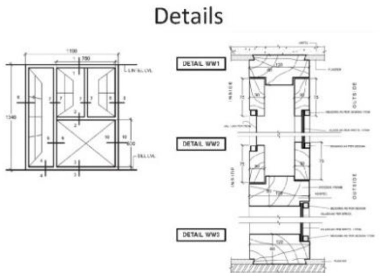
Notes:

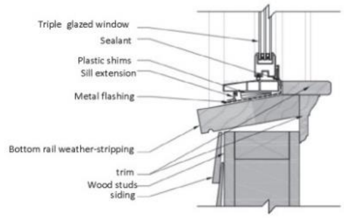
- Each research should include sufficient information about the materials, types, dimensions and installation methods.
- The data presented should reflect state-of-the-art products and techniques supported by sufficient technical information.
- Each member of the research teams is going to present a part of the research.
- Students are to refrain from copying research materials from lectures.

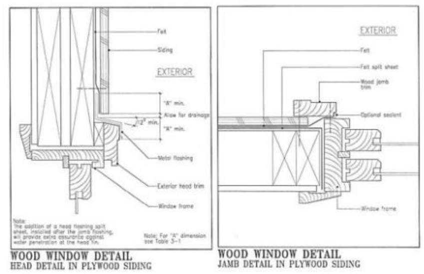












Assignment 8 – Doors and Windows

The shown drawing is a part of one floor office building plan. The office space is divided into small rooms (4.5 x 4.5 m clear) using masonry partitions.

For each student, it is required to draw:

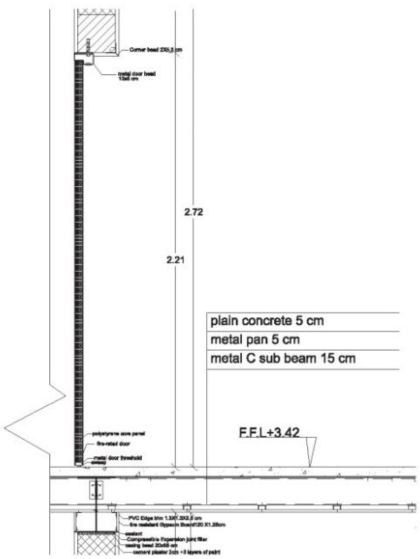
1- **Only part of this plan** (scale 1:20) as shown inside the dashed rectangle showing the masonry partitions, the external cavity wall, the window and the door.
2- **A section A-A** (scale 1:20) **passing through the window and the door** and showing the suspended ceiling, partitions, and floor.
3- **Details** (scale 1:5) **in the plan** showing fixation methods of the frames of both the window and the door with the external wall and internal partitions.

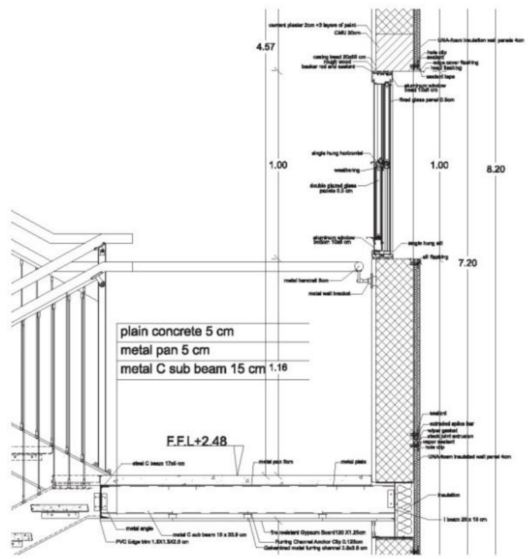
The Door is Paneled (Rail & Stile) Wood and the Window is PVC or Aluminum.

Notes:

- The clear height of the floor is 3.40 m.
- Assume any needed/not mentioned materials and dimensions.
- All dimensions and materials should be illustrated clearly on the drawings.
- Conduct research to obtain any needed dimensions and materials.

- ***Submit with the hardcopy of the assignment A4 print out showing the references of the used materials selected through your research.***
- The assignment is to be submitted via Blackboard (Course Message attachment) and in a hardcopy of A2 format.



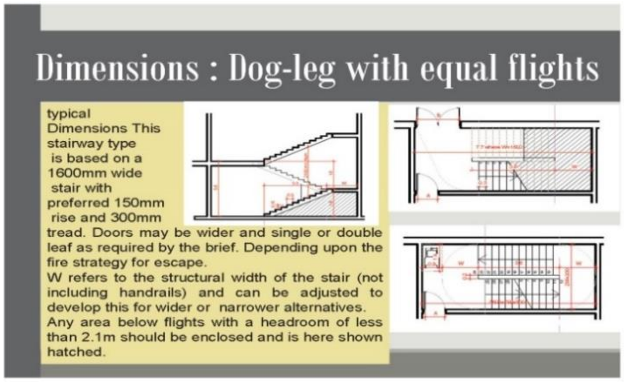


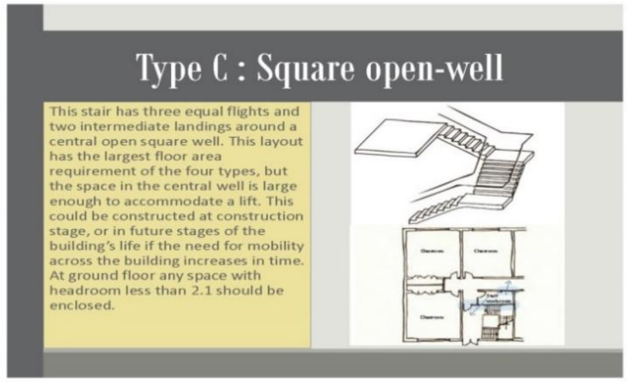
Assignment 9 – Research about Steel Staircase

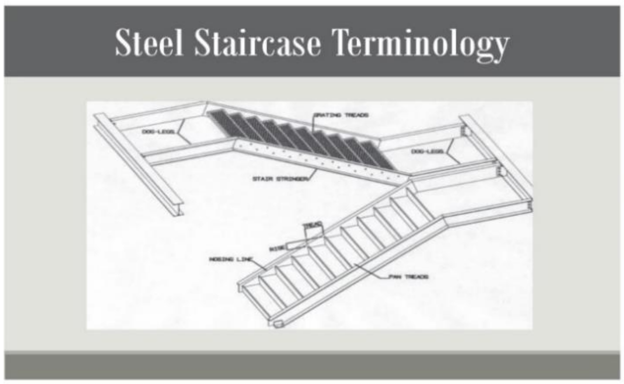
Each group is asked to undertake research about a specific type of steel staircase (as determined in the class):

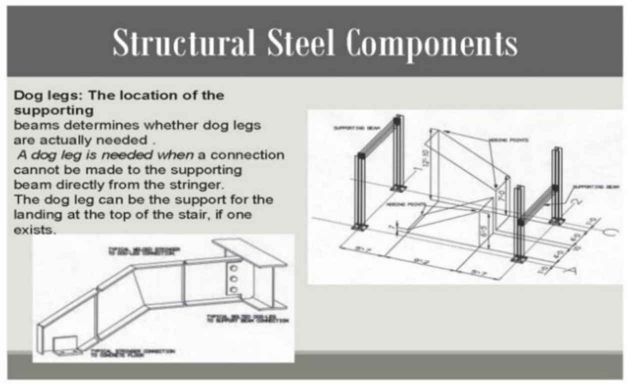
Notes:

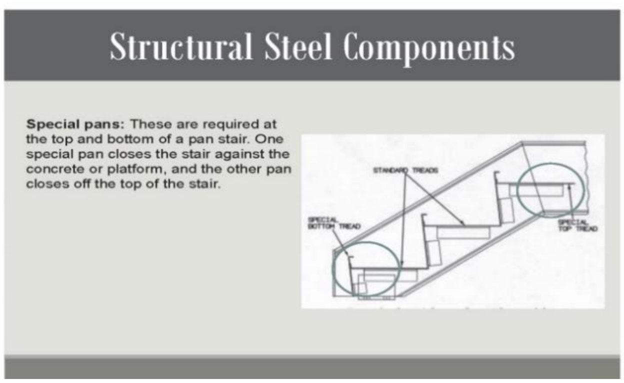
- Each group is expected to prepare a PowerPoint presentation that does not exceed 10 slides.
- The data presented should reflect state-of-the-art products and solutions supported by sufficient technical information.
- Each member of the research teams is going to present part of the research.
- Students are to refrain from copying from lectures.
- The research is to be submitted via Blackboard.

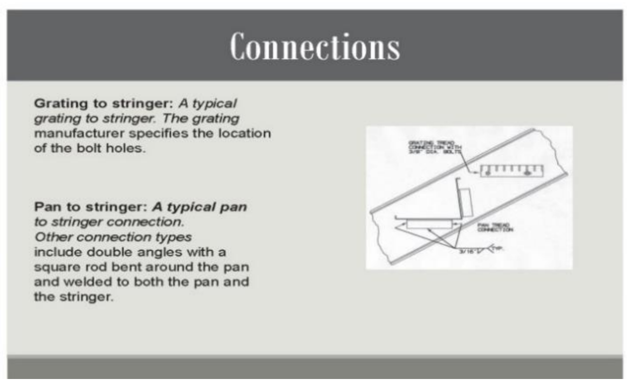












Assignment 10 – Steel Staircase

The drawing shown illustrates the **first floor plan** for a 3 flights steel staircase in a two floors office building. The staircase is connecting between the ground floor reception of the building (Level + 0.45 m) and a first floor lobby (Level + 4.30 m).

A- Calculate the required number of the steps in each of these 3 flights, the riser's height, the tread's width and the two landings' dimensions (note: the lines indicating the steps in the sketch below are just indicative so do NOT count them as the required number of steps!).

B- Draw scale 1/10 Plan for both the Ground and the First Floor Plans (2 Plans).
C- Draw a scale 1/10 Section from the shown direction.

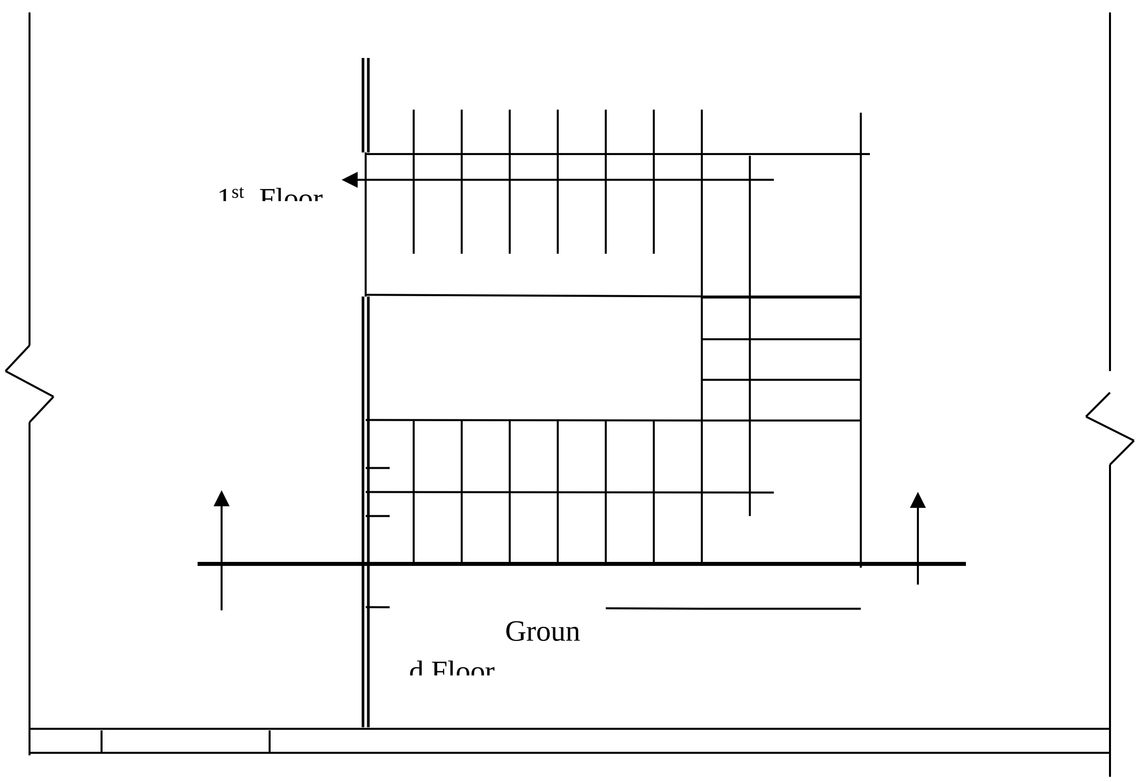
The drawings should include:

- The used steel skeleton structural system.
- The cladding wall elements and its fixation.
- The window frame, sash and fixation.
- The steel roof with finishing (in section).
- Structural axial lines (for columns).
- External and internal levels and dimensions.
- The names and specs of the used materials as relevant.

- Assume any needed dimensions and materials and apply the relevant building codes.

- Adhere to the shown 3 flights shape of the staircase.

Good Luck… Course Instructor: Dr. Khaled Galal Ahmed



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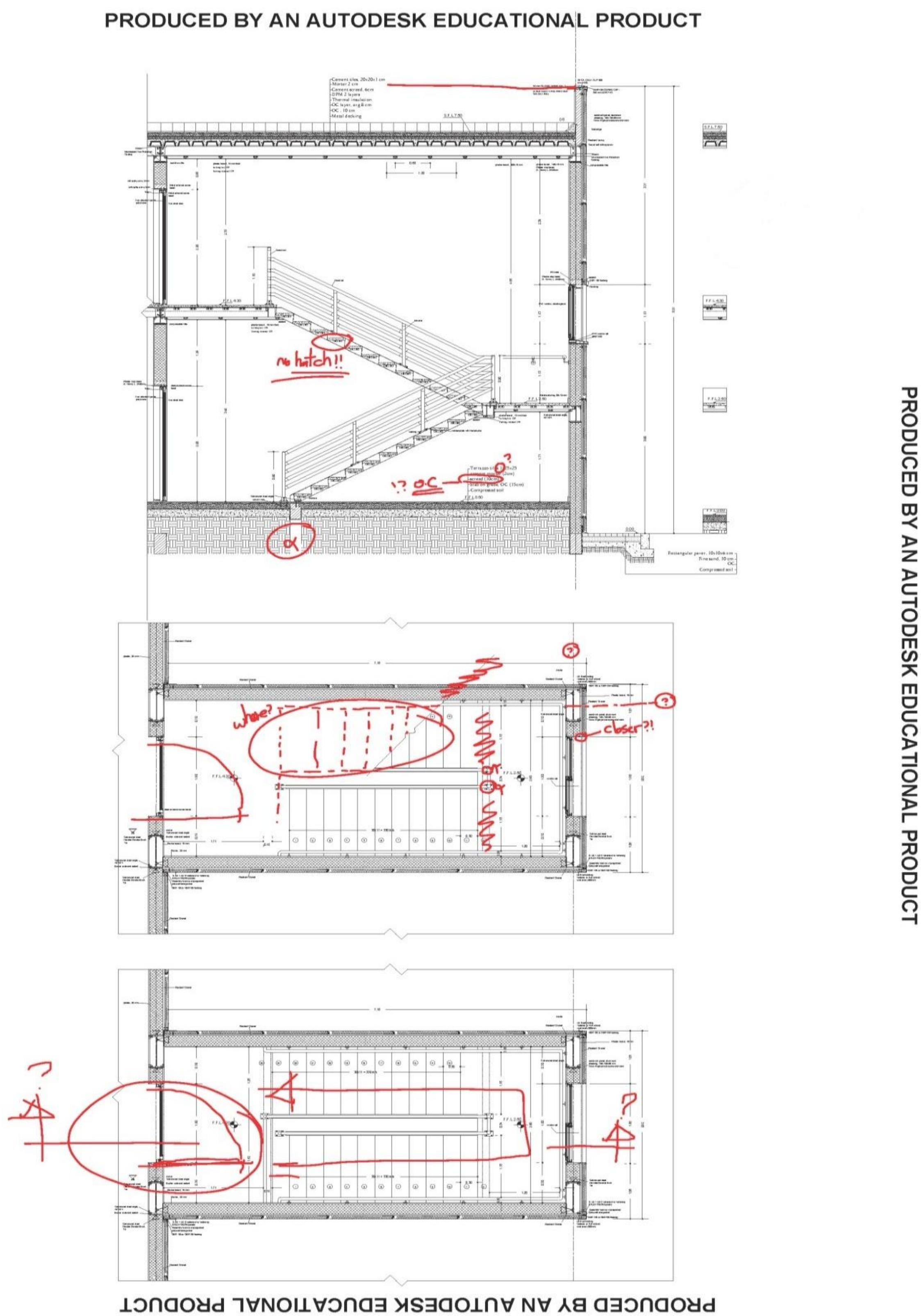

PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
no hatch!!
!? OC
where?
closer?!
Rectangular paver, 10x10x4 cm
Fine sand, 10 cm
OC
Compressed soil
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT

14.3. Advanced Building Systems

This course is the last core construction course of the Architectural Engineering Bachelor curriculum. At this course the students will learn about modular coordination and the systems integration into the project. During this course the students will research, analyze and apply modular coordination, long-span structural systems, prefab construction methods, sustainability and mechanical systems. During the research they will improve their understanding of the course concepts, in the analysis they will develop skills and in the application part they will prepare themselves to integrate these concepts in their project.

14.3.1. Course Learning Objectives

- Acquire knowledge of advanced building techniques needed for better construction efficiency [E and K].
- Evaluate alternative advanced structure systems and materials and relate their studies to practical applications [C E, and K]
- Comprehend building components and their behaviors [E].
- Examine modular coordination in building design and construction systems rationally, logically and coherently [E and K].
- Use architectural and structural knowledge in the analyzing different technologies and bring that to bear on architecture and communities [C and K].

AE Student Outcome Summary	A	B	C	D	E	F	G	H	I	J	K
Course instruction & assessment			X		X						X

14.3.2. Course Measurable Outcomes

- Student outcome C: Ability to design and evaluate building engineering systems, components or processes to meet desired needs (Ref. Course Outcomes 2, 5).
- Student outcome E: Ability to identify, formulate, and solve engineering problems
- (Ref. Course Outcome 1, 2, 3, 4)
- Student outcome K: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (Ref. Course Outcomes 1, 2, 4, 5)

Evaluation Type	Description	Course	Assessment
A1-P1	Assignments - Presentations	1,2,4	20 %
TP	Term Project	1-5	25 %
Q1 – Q2	Quiz	1,4	05 %
M1	Midterm	2,4,5	20 %
FE	Final Term Exam	2,4,5	30 %

14.3.3. **Course Outline**

Week	Session Content	Assignments
1	**Introduction** and revision	*Assignments*
2-4	**Modular coordination –** Definitions & terminology, Concept & hierarchy of	*Assignments -*
5-6	Long Span Structural Systems, construction materials and construction	*Assignments -*
7-8	**Building Technology I** – Advanced Construction Methods, Building Technology levels and Prefab Systems	*Assignments* *Prefab -*
9-10	**Building Technology II** – Advanced Construction Methods, Machinery and	*Presentation*
11-13	**Sustainability in Construction** – Principles and Strategy, associations,	*Presentation*
14-15	**Building System Integration** –Levels of integration, Technical Systems, services and utilities, cooling system, drainage	*Assignments , case studies - Presentation*
4-15	**Term Project and application,** Architecture, Structural, Tech. cooling system, Drainage, Electrical	*Complete documents and drawings*

14.3.4. **Lecture Samples**

Main Topics

Introduction
- Arch. Design process, building construction, grid in arch design and building system integration

1 Definition
- Modular Coordination concept and meaning
- Related terminology and definitions *Ref. MC Definitions – PDF doc*

2 Why Modular Coordination
- Advantages of Modular coordination/ Benefits/Aims

3 Grids in Architectural Design
- Architectural and structural Grids

4 Modular Grid and Planning

1 – Recommended Modular dimension and applications *Ref. Chapter 3 – PDF doc*

2 – Modular Grid *Ref. Chapter 3 – PDF doc*

3 - Planning Approach *Ref. Chapter 3 – PDF doc*
- Dimensional coordination *Ref. Components – PDF doc - P.24*

4 – Vertical Planning *Ref. Chapter 3 – PDF doc*

5 – Hierarchy of Planning *Ref. Chapter 3 – PDF doc*

6 – Practical Application Guide lines *Ref. Chapter 3 – PDF doc*

5 Controlling Dimensions *Ref. Components – PDF doc - P.29*

6 Tolerances *Ref. Components – PDF doc - P.24*

7 Modular Buildings and components

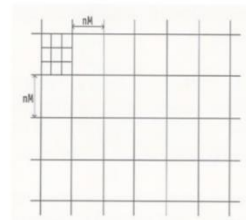


Fig 3-2a: Square Multi-Modular Grid

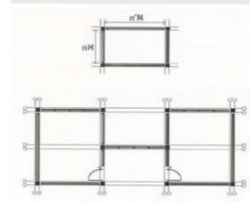
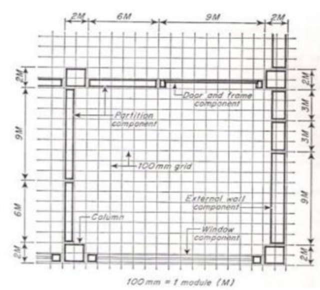


Fig 3-5: Face Planning



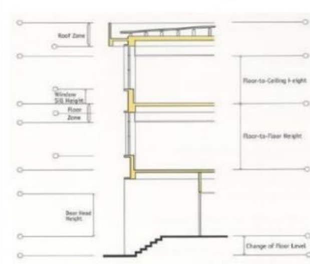


Fig 3-9: Vertical Controlling Dimensions

The topic will has, 2 assignments, MC 1A and MC 1B. MC 1A is an application to a small house/building, MC 1B is a Visual Survey study of selected real building and summary of the topic/analysis of Case study.
The student has to search for more information of the topic, as part of assignment MC 1B.

Notes: New documents could be added to the reading materials as needed.

ADV Building Construction | ARCH 410 | Architectural Engineering Department | Modular Coordination | FALL 15 | Fayez M.Fikry | FM

14.3.4.1. *Long Span Structural System*

Main Topics

Introduction

- Arch. Design process, Building systems, Structural grid and patterns and building system integration

1 Definition *Ref. Building construction illustrated hand book- CHING-CH 2/*

- Long Span Structural Systems
- Related terminology and definitions - system, element , Structural system

2 Construction Materials and Construction Methods

- Materials , in site construction , off site construction and advanced construction methods

3 Structural Forces *Ref. Building construction illustrated hand book- CHING-CH 2/*

- loads in buildings , Structural forces
- structural elements and structural span
- Joints and connections
-

4 System selection Criteria *Ref. System selection Criteria - CH 7 Bb DOC*

- main and minor issues to be considered

5 Structural Systems Classifications *Ref. Structure Systems-Heino Engel*

- different approaches to classify structural systems

6 Long Span Structural systems *Ref. Structure Systems-Heino Engel*

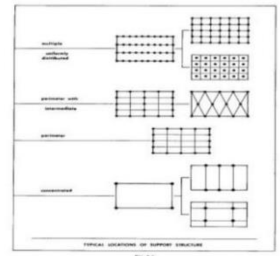
- Frame, folded plates, trusses, space frames, shells, tensile…….
- definition, materials, structural behavior, system limitations, basic details
- **Portal Frames**-Part 6 6-1,6-2,6-3 *Text book 1- Advanced Construction Technology-Chudley 4th edition*
- **Roof Structures**- Part 11 *Text book 1- Advanced Construction Technology-Chudley 4th edition*

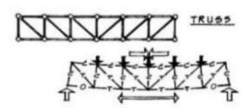
11.5 - Large Span Steel Roofs – **space Deck**, **Space frames**, Shell Roofs, Folded plate Roofs, Tension Roof Structures.

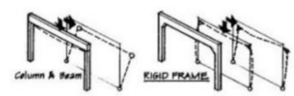
7 Preliminary Design *Visiting Staff – Dr. Omar Al Khatib*

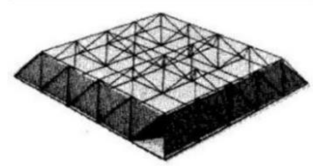
- Concept of load distribution and acting forces
- Concept of calculation
- different approaches to assume structural elements dimensions
- Use of charts/ graphs to determine structural elements dimensions(cross sections)

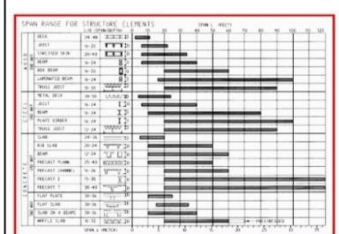
Ref. course handout , tables and graphs











Dr. Omar will follow the structural development of the course project, and will share in the evaluation of the structural phase of the project.

The topic will has, 2 assignments, LS 1A and LS 1B. LS 1A is an application to course project, LS 1B is a summary of the topic and the analysis of selected Case studies as a reference to the project.
The student has to search for more information of the topic , as part of assignment LS 1B.

Notes:
- New subjects could be added to the Lecture structure due to the needs of course project.
- It is essential to read the Bb materials reading list and the revision part of BCS.

ADV Building Construction ARCH 410 Architectural Engineering Department LS Structural Systems Fayez M.Fikry FM

14.3.4.2. *Building Technology I*

Main Topics

I Introduction of Building Technology *Lec Intro notes*

A. Introduction – definition and related definitions, construction methods and types, materials , building Stability

B. Levels of Building Technology - High , Intermediate, and Low

C. Factors/issues of Building Technology - time ,cost, labor, material, environment , pollution, site disturbance .....

D. Advantage and Disadvantage of conventional Building Systems

II Prefabrication Building Systems Technology *Lec Intro notes*

A. Introduction – definition , construction materials , building systems and components, Mechanization and standardization

B. Advantage and Disadvantage of Prefabrication and Mechanization Techniques

B. Types of Fabrication – Total Fabrication, Partial Fabrication - (Open/Closed System)

D. Building Joints and connection – Wet and Dry joints

E. Systems/Methods of Prefabrication – Linear , Panels/Wall , Box – (skeleton/ Load bearing)

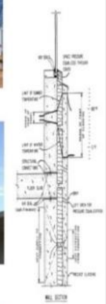
References:

*Ref .0. **Bb material documents***
Ref .1. Building construction illustrated hand book- CHING - BCS
Ref .2. BC Principles, .Materials ,and Systems – 2nd edition - BCS
Ref .3. Advanced Construction Technology-Chudley 4th edition

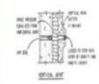
- New references could be added through the progress and development of the assignments,
- At this stage of the course the student has to get the required info of the given REF. as part of the teaching methodology .

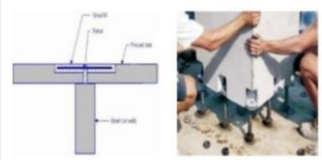
Skeleton System

Box System



Panel/Wall System





Basic connection Details

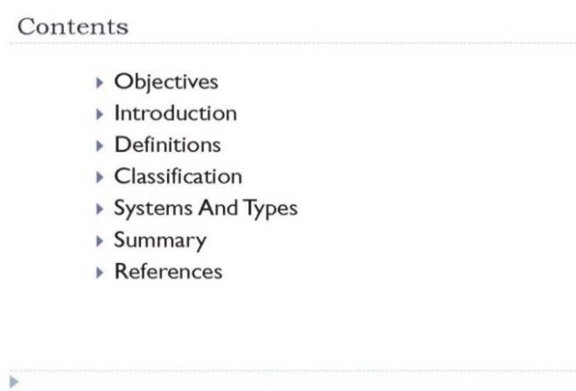
The topic has, 2 assignments, BT I 03 A and BT I 03 B. BT I 03 A is a presentation assignment and it has to include a summary of the TOPIC in a form of tables, graphs or organization chart, and the analysis of case studies.

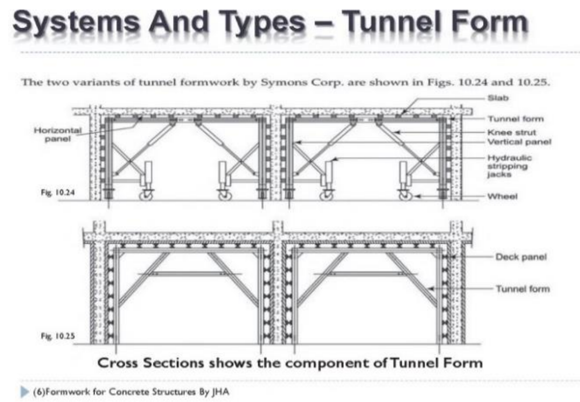
The student has to search for more information of the topic, as part of the presentation assignment.

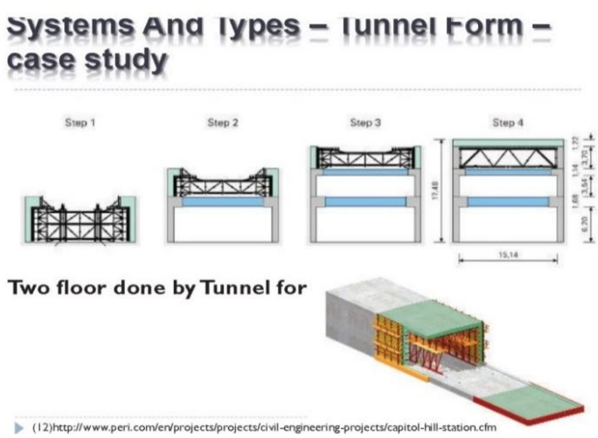
Notes: - New subjects could be added to the Lecture structure due to the needs of the application assignment.
- **It is very essential to read and study the Bb materials**.

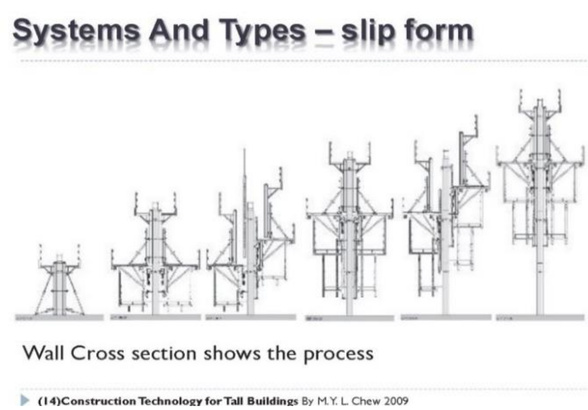
ADV Building Construction ARCH 410 Architectural Engineering Department **Building Technology I** Fayez M.Fikry FM

14.3.4.3. *Building Technology II*









14.3.4.4. *Sustainability in Construction*

Main Topics

Introduction

- Design Process, construction methods, construction process and site management, Sustainability and sustainable design - Building Life Cycle - Public and Private sectors

Sustainable construction, also known as green construction, is concerned with the economic, social, and environmental impact of creating a usable structure.

1 Definitions — *Ref . LEC / internet*
sustainability , sustainability in Architecture and sustainability in construction and related definitions

2 Design Process and Building Life Cycle — *Ref . LEC / internet*

3 Sustainability in Architecture, — *Ref .01A. Introduction to Sustainable Design,Jong-JinKim, Brenda Rigdon, 1998*

- Fundamentals
- Principles of Sustainable Design
- Methods for Achieving Sustainable Design,
  Economy of resources, Life Cycle Design, Humane Design

4 Sustainable Construction — *Ref .02. Bb Doc 02* ***Sustainable Construction***

- reducing construction, demolition and excavation waste to landfill
- reducing carbon emissions from construction processes and associated transport
- ensuring products used in construction are responsibly sourced
- reducing water usage during the construction process
- carrying out biodiversity surveys and following up with necessary actions

5 Good Practice Guidance: — *Ref .03. Bb Doc 03 Good Practice Guidance,2012*

Sustainable Design and Construction

6 Sustainable Construction Strategy – UK — *Ref .04. Bb Doc 04 Sustainable Construction Strategy UK 2006*

7 Associations and Societies

LEED , BREAM and ESTIDAMA — *LEC Discussion and Student Presentation Internet search*

8 Selected Case studies — *Student presentation*

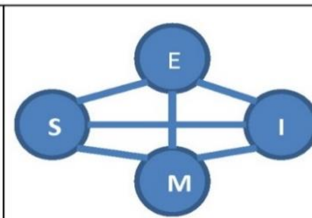
TOPIC 06 SUS in construction SP 16

Notes: - New subjects could be added to the Lecture structure as needed.
- It is essential to read the Bb materials.

ADV Building Construction | ARCH 410 | Architectural Engineering Department | Sustainability in Construction | Fayez M.Fikry | FM

14.3.4.5. *Building System Integration*

Main Topics



Introduction

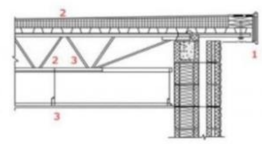
- Design Process, Integrated Building Design Process, Building systems , services and utilities,

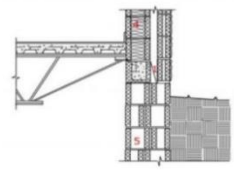
Architectural Engineering should know how those systems are connected to each other to achieve the maximum performance of those systems and to coordinate the intersection of those systems in order to integrate or separate those systems in efficient way.

1 Definition and related Definitions:

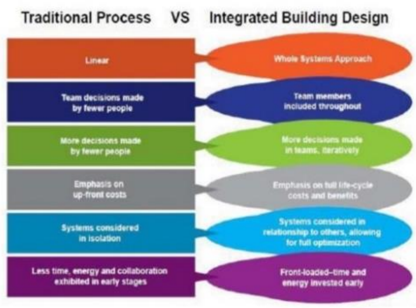
- System:
A system is defined as a coherent set of physical entities organized for a particular purpose. System design is a product of deductive reasoning.

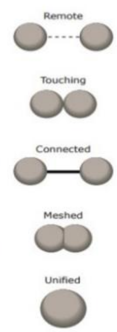
- Integration:
The act or process of incorporating or coordinating different systems/elements or group of elements in a cohesive environment.





2 Primary Building Systems
Structure
Envelope
Mechanical
Interior



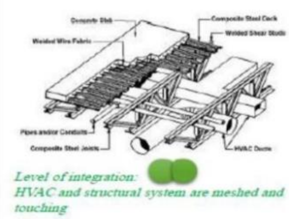


3 Types of Integration

Physical Integration
Visible Integration *
Performance Integration

4 Levels of Integration

Remote	Touching	Connected	Meshed	Unified



5 Systems Integration Problems
Lack of experience
Lack of skill

6 Selected Case studies

Ref: 1. *The building System Integration Handbook, Richard D. Rush, 1991*
Chapter 2- *Integration in Practice* - Chapter 3- *Case Studies* – Chapter 7- *Integration Theory Reading* CH. *5 and 6*

Ref: 2. *Integrated Buildings-The Systems of Architecture, Bachman, Wiley,2003*
Part I-Chapter 4 – *The Architecture of Integration* – *Part II – Case Studies*

Ref: 3. Bb materials

Ref: 4. Selected Websites

Notes: - New subjects could be added to the Lecture structure as needed.

T 05 BSI LS FALL 15

ADV Building Construction ARCH 410 Architectural Engineering Department BUILDING SYSTEM INTEGRATION Fayez M.Fikry FM

14.3.5. **Assignment Samples**

14.3.5.1. *Modular Coordination*

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
- To understand Dimensional Coordination and Modular Coordination concept and space relationship component to grid. - Acquire knowledge of MC terminology and basis of standards modules and basic sizes. - To learn how to select, evaluate and apply MC concept in construction problems and how to express it graphically and technically.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Well understanding of the topic and objective/s of the presentation	Clear introduction and contents conveying facts and issues of the topic in a logical and sequential way, selection of the appropriate presentation material through credibility and integrity of research effort	Summary and appropriate comments /recommendations of the main issues of the topic, which reflect deep understanding of the main issues of the topic	Source of references in an appropriate and scientific format *	- Presentation techniques and visual communication, selection of appropriate images, text, etc. ..... and enthusiasm and Spirit - Sharing of presentation relatively evenly among all members of the group
1	4	2	1	2

C) Presentation Assignment **MC II**

In order to reinforce the concept of Modular coordination in building design . It is required to;

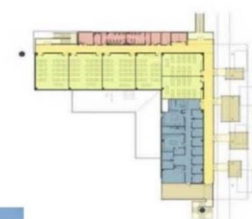
1. ***conduct a visual study of selected building/s showing the level of MC application in the design.***
2. ***Present a summary showing the understanding of module, controlling dimensions lines and the meanings and hierarchy of modular coordination.***

1 The visual study will be conducted to a selected building/s to show the different levels of modular coordination application. The study has to include an analytical images showing the different relation between building components. A set of external and internal images has to be presented to show the relation between interior spaces and exterior image. The presentation has to include plan/s, section/s or any necessary details.

2 The summary has to reflect the level of student understanding of the Modular Coordination concept in building design. This could be presented by definitions, images or analysis of a selected case study.

Notes

- **The team of presentation assignment will be a group of 3 or 4, each student has to present an equal share of the presentation**
- **Presentation techniques and visual communication, selection of appropriate images and text will be highly appreciated**
- **Students should submit a soft copy and a hard copy of the presentation as a report**



The study has to include images , plans, grid, sections and details if necessary.

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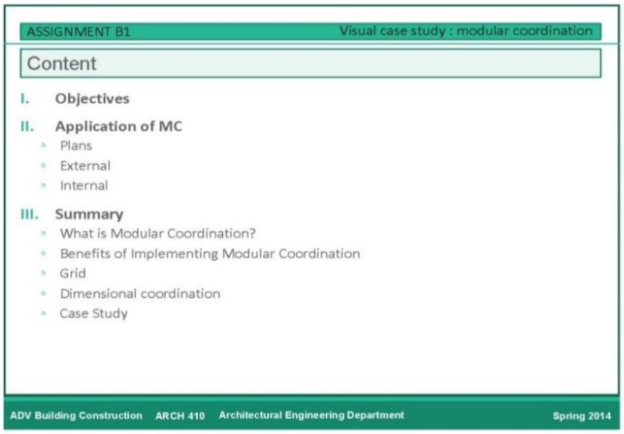
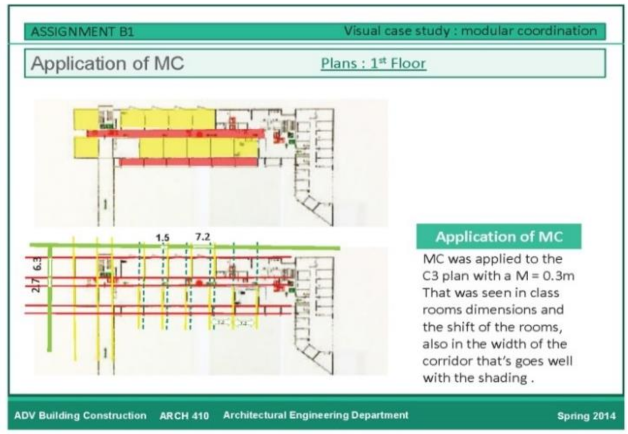
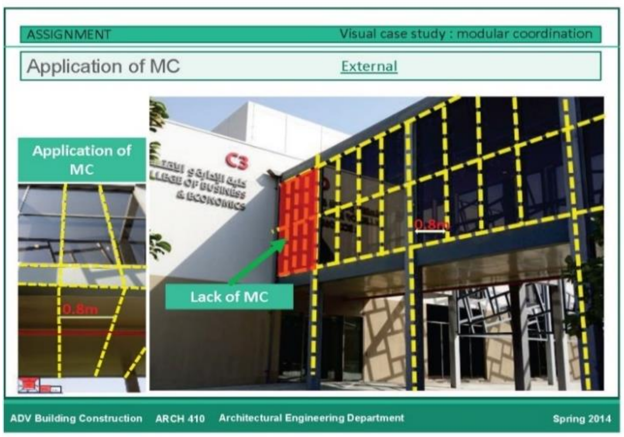
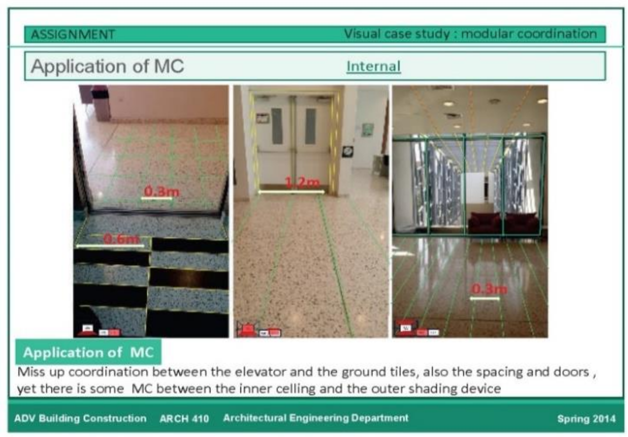
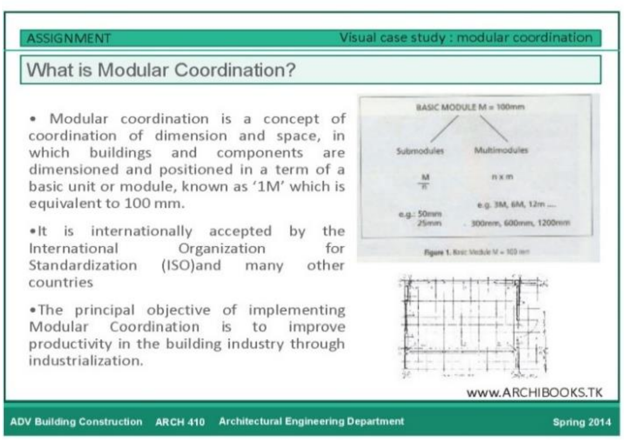
ADV Building Construction ARCH 410 Architectural Engineering Department Modular Coordination FALL 15 Fayez M.Fikry FM

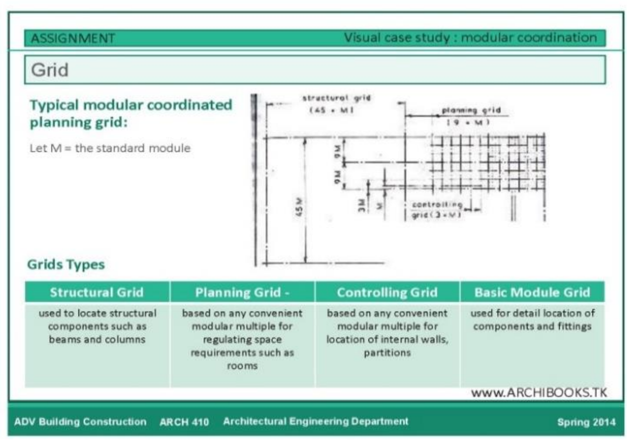

ASSIGNMENT B1
Visual case study : modular coordination
Content
I. Objectives
II. Application of MC
Plans
External
Internal
III. Summary
What is Modular Coordination?
Benefits of Implementing Modular Coordination
Grid
Dimensional coordination
Case Study
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT B1
Visual case study : modular coordination
Application of MC
Plans : 1st Floor
1.5
7.2
Application of MC
MC was applied to the C3 plan with a M = 0.3m That was seen in class rooms dimensions and the shift of the rooms, also in the width of the corridor that's goes well with the shading .
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT
Visual case study : modular coordination
Application of MC
External
Application of MC
Lack of MC
0.8m
0.8m
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT
Visual case study : modular coordination
Application of MC
Internal
0.3m
0.6m
1.2m
0.3m
Application of MC
Miss up coordination between the elevator and the ground tiles, also the spacing and doors , yet there is some MC between the inner celling and the outer shading device
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT
Visual case study : modular coordination
What is Modular Coordination?
• Modular coordination is a concept of coordination of dimension and space, in which buildings and components are dimensioned and positioned in a term of a basic unit or module, known as '1M' which is equivalent to 100 mm.
•It is internationally accepted by the International Organization for Standardization (ISO)and many other countries
•The principal objective of implementing Modular Coordination is to improve productivity in the building industry through industrialization.
BASIC MODULE M = 100mm
Submodules
Multimodules
www.ARCHIBOOKS.TK
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT
Visual case study : modular coordination
Grid
Typical modular coordinated planning grid:
Let M = the standard module
structural grid
planning grid
Grids Types
Structural Grid
used to locate structural components such as beams and columns
Planning Grid -
based on any convenient modular multiple for regulating space requirements such as rooms
Controlling Grid
based on any convenient modular multiple for location of internal walls, partitions
Basic Module Grid
used for detail location of components and fittings
www.ARCHIBOOKS.TK
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
- To understand Dimensional Coordination and Modular Coordination concept and space relationship component to grid. - Acquire knowledge of MC terminology and basis of standards modules and basic sizes. - To learn how to select, evaluate and apply MC concept in construction problems and how to express it graphically and technically.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Application	3) Standards and building codes	4) Assumption/Calculations	5) Construction drawings	Total grade
Clear understanding of building construction problem	Selection and Integration of structure system, construction methods, and building components	Application of Building and Structural Standards and Codes.	Basic calculations / or assumption of basic structural components	Technical and graphical expression of building materials, structural system, and construction methods.	
/2	/4	/1	/0	/3	/10

C) Assignment

In the process of applying Modular coordination concept to a selected case study. It is required to study and analyze a <u>2 Bed room flat</u>/<u>house</u> or <u>small public building</u>

The process will include 2 stages;

1. *Analysis stage;*
   where the student, will analyze the different layers of grid, structural, architectural and other components, in the horizontal and vertical planes.

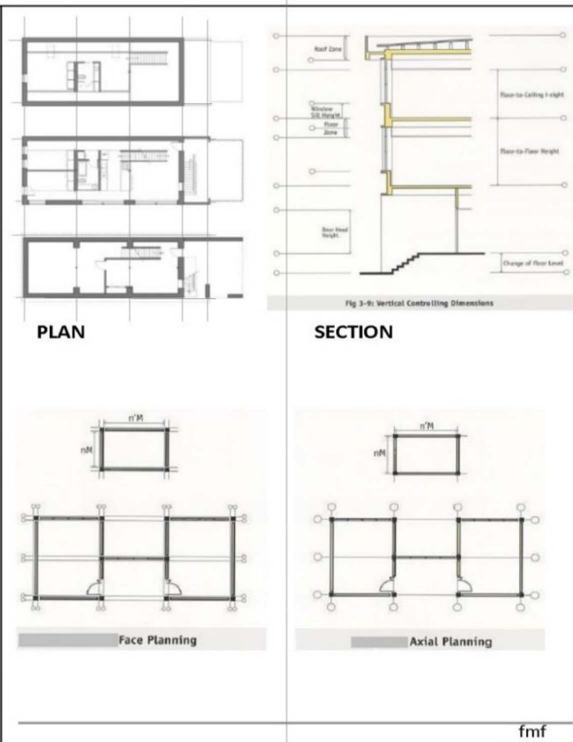
2. *Application Stage;*
   the second stage will be, the development of the selected case study by applying MC concept, this application will include the proposed module grid and space relationship components.

Requirements:

Analysis stage: *a- Main Arch. drawings* *1/50*
b- Analysis of plan and section showing layers of grid and components *1/100*

Application stage: *a- Developed Arch. drawings* *1/50*
b- Analysis of plan and section showing the proposed MC grids *1/100*
c- Three dimensional grid of basic modules, and space relation components to the proposed grid to an appropriate scale.
d- Detailed study of the selected space (kitchen…), scale 1/20 and 3D analytical images

Notes:
- *The assignment should be on A2 size sheet, Students should submit a hard copy of the AutoCAD file using A3 sheet.*
- *Students could add any drawings or details to reinforce his/her proposal.*



Note: ***The scale of drawings could be changed due to the size and shape of the selected project.***

ADV Building Construction **ARCH 410** **Architectural Engineering Department** **Modular Coordination** **FALL 15** **Fayez M.Fikry** **FM**

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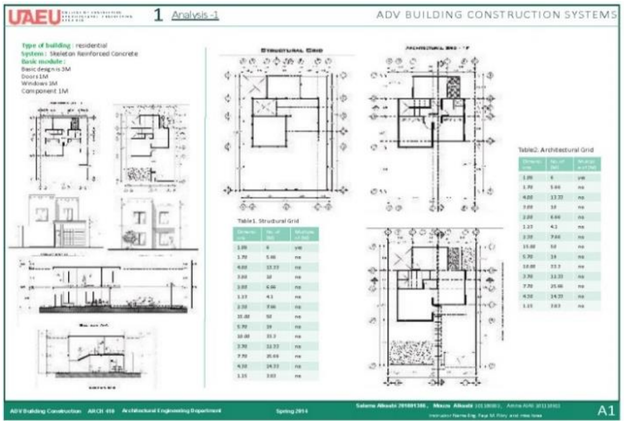
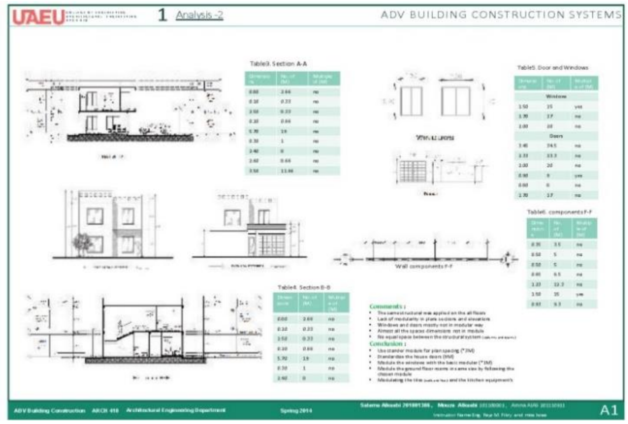
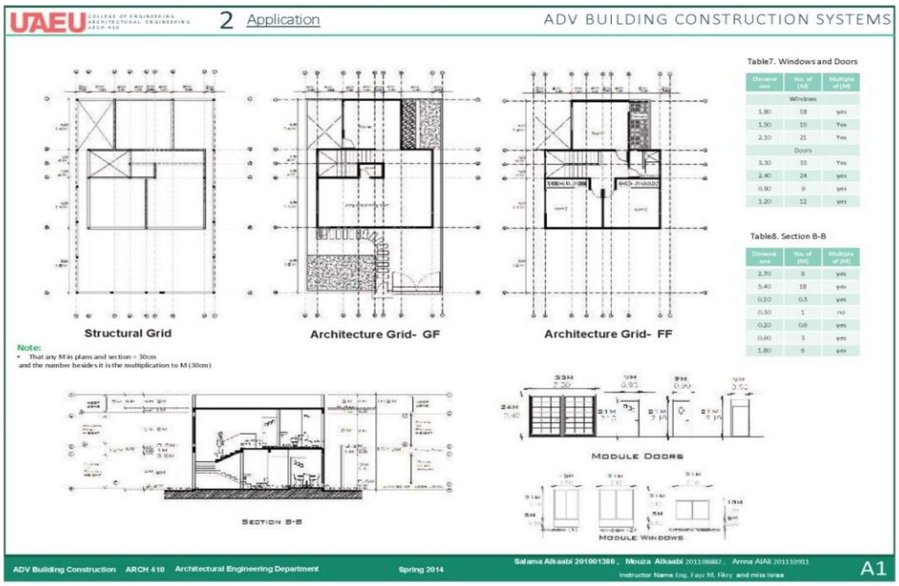
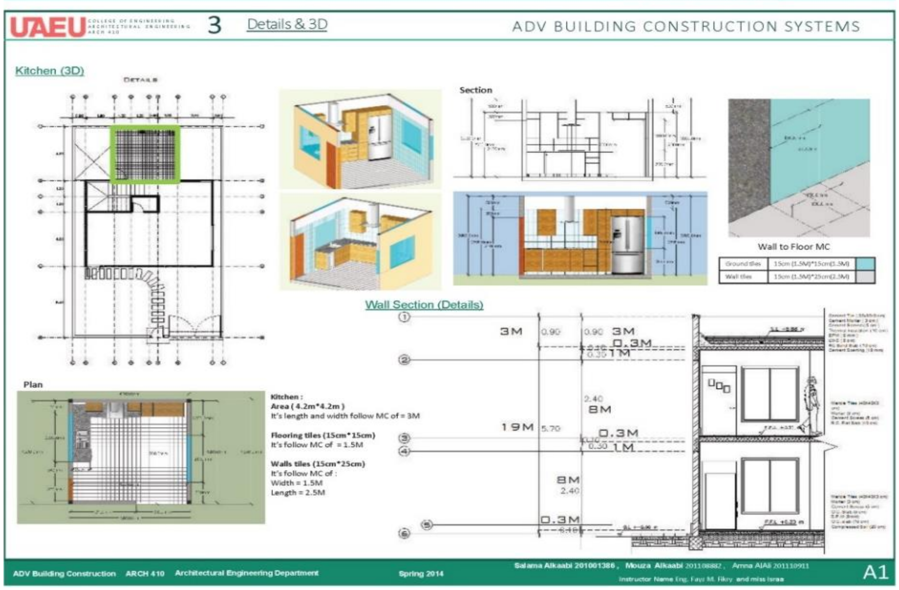

UAEU
1 Analysis -1
ADV BUILDING CONSTRUCTION SYSTEMS
A1


UAEU
1 Analysis -2
ADV BUILDING CONSTRUCTION SYSTEMS
A1


UAEU
2 Application
ADV BUILDING CONSTRUCTION SYSTEMS
Table7. Windows and Doors
Table8. Section B-B
Structural Grid
Architecture Grid- GF
Architecture Grid- FF
Note:
Module Doors
Section B-B
Module Windows
ADV Building Construction ARCH 410 Architectural Engineering Department
Spring 2014
A1


UAEU
3 Details & 3D
ADV BUILDING CONSTRUCTION SYSTEMS
Kitchen (3D)
Section
Wall to Floor MC
Wall Section (Details)
Plan
Kitchen :
Area (4.2m*4.2m)
Flooring tiles (15cm*15cm)
Walls tiles (15cm*25cm)
ADV Building Construction ARCH 410 Architectural Engineering Department
Spring 2014
A1

14.3.5.2. *Long Span Structures*

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1 Acquire knowledge of Long Span Structural systems, structural behavior and construction methods, ability to analyze, study and select an appropriate structural system of a given design problem 2 Ability to understand, study, develop and draw structural system, sub structures and its integration and connection to other building components. 3 Preliminary structural design by applying span depth ratio, tables, and graphs or charts, and the recommended codes and standards.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Well understanding of the topic and objective/s of the presentation	Clear introduction and contents conveying facts and issues of the topic in a logical and sequential way, selection of the appropriate presentation material through credibility and integrity of research effort	Summary and appropriate comments /recommendations of the main issues of the topic, which reflect deep understanding of the main issues of the topic	Source of references in an appropriate and scientific format *	- Presentation techniques and visual communication, selection of appropriate images, text, etc. ..... and enthusiasm and Spirit - Sharing of presentation relatively evenly among all members of the group
1	4	2	1	2

C) Presentation Assignment — **Group work**

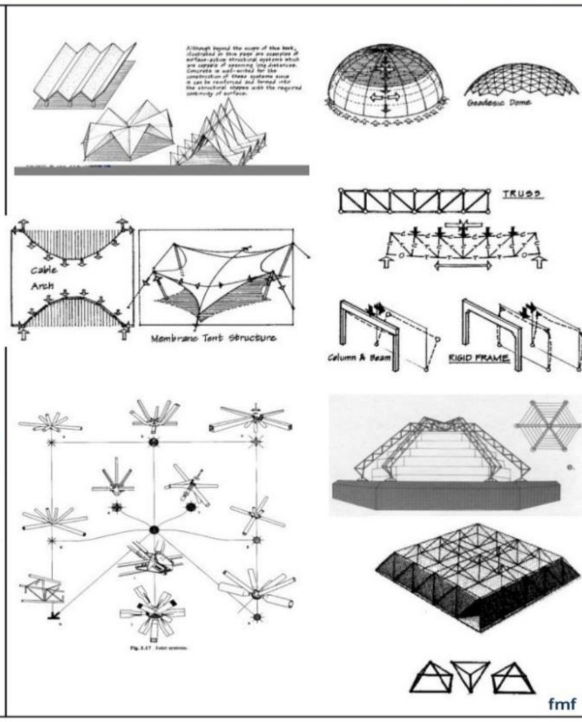
In the process of the preparation for the term project, it is required to conduct a research of <u>Long Span Structural Systems,</u> the study has to include the theoretical background and detailed analysis of an appropriate case studies for the selected term project.

I *The theoretical part* *has to include the following;*
Definition/s , classification, systems and types, construction materials, and each <u>Structural System has to include</u>;
Types, materials, construction method/s, structural behavior, span limitations, components, and basic joints and connections.

II *Analysis of the case study* *has to include the following,*
Location, year of completion, system, construction material and method, span and spanning of the system, structural components, integration to other building systems, construction and structural details. ***(These case studies has to be related to the term project.)***

The presentation will be a team work of 3 or max 4 students, each student has to be responsible of part of the presentation.

Notes:
- the assignment, will submitted as:
1 ***Power point presentation***
2 ***Summary*** *of the, a.* ***Theoretical Background*** *on A3 sheet/s*
b. ***Case studies*** *analysis, each on A3 sheet*
The student can add more materials to clarify the analysis of the case studies.



Assignment 02A – Long Span Structural System - Presentation

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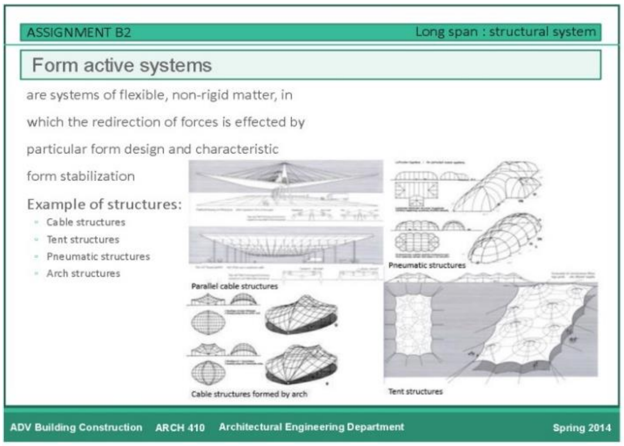
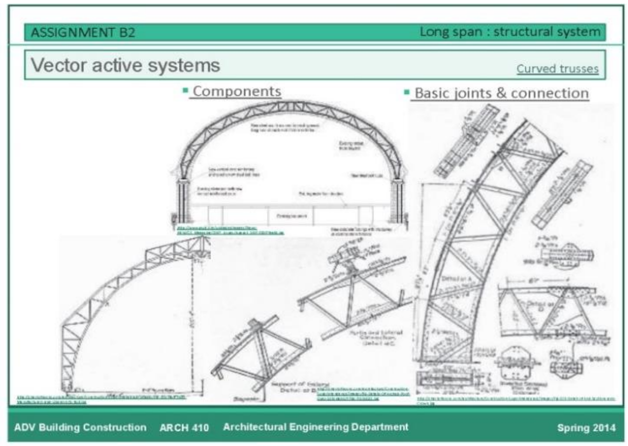
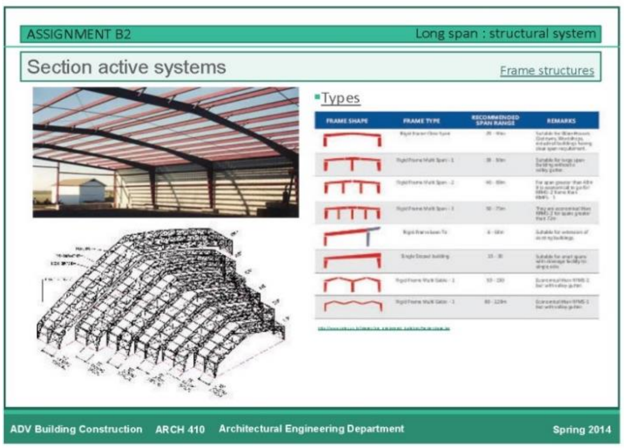
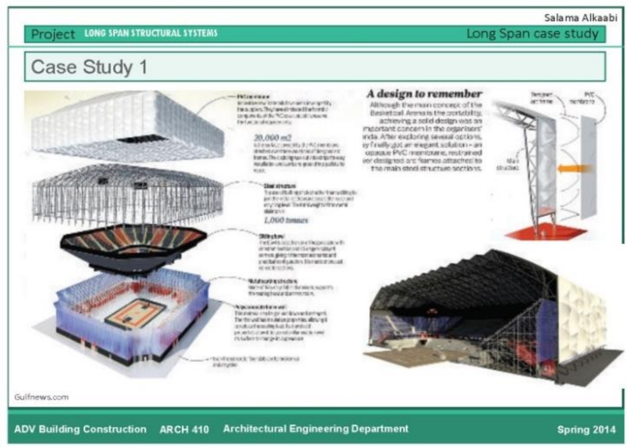
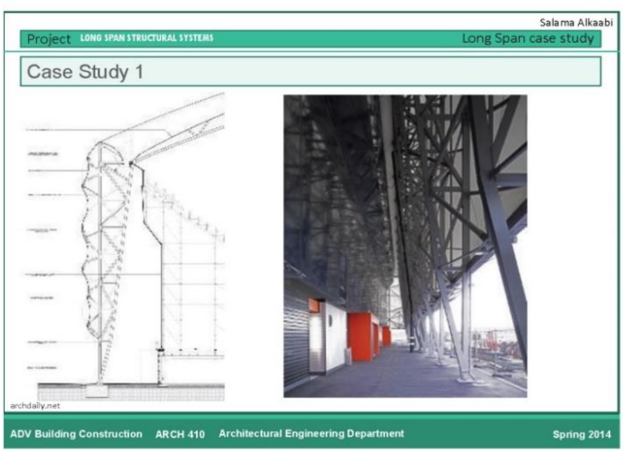

ASSIGNMENT B2
Long span : structural system
Form active systems
are systems of flexible, non-rigid matter, in which the redirection of forces is effected by particular form design and characteristic form stabilization
Example of structures:
Cable structures
Tent structures
Pneumatic structures
Arch structures
Pneumatic structures
Parallel cable structures
Cable structures formed by arch
Tent structures
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT B2
Long span : structural system
Vector active systems
Curved trusses
Components
Basic joints & connection
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


ASSIGNMENT B2
Long span : structural system
Section active systems
Frame structures
Types
FRAME SHAPE
FRAME TYPE
RECOMMENDED SPAN RANGE
REMARKS
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


Salama Alkaabi
Project LONG SPAN STRUCTURAL SYSTEMS
Long Span case study
Case Study 1
A design to remember
Gulfnews.com
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014


Salama Alkaabi
Project LONG SPAN STRUCTURAL SYSTEMS
Long Span case study
Case Study 1
archdaily.net
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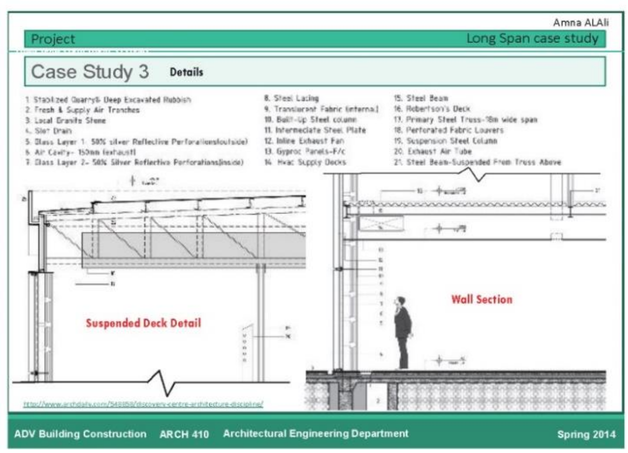

Amna ALAli
Project
Long Span case study
Case Study 3 Details
1. Stabilized Quarry& Deep Excavated Rubbish
2. Fresh & Supply Air Trenches
3. Local Granite Stone
4. Slot Drain
5. Glass Layer 1- 50% silver Reflective Perforations(outside)
6. Air Cavity- 150mm (exhaust)
7. Glass Layer 2- 50% Silver Reflective Perforations(inside)
8. Steel Lacing
9. Translucent Fabric (internal)
10. Built-Up Steel column
11. Intermediate Steel Plate
12. Inline Exhaust Fan
13. Gyproc Panels-F/c
14. Hvac Supply Decks
15. Steel Beam
16. Robertson's Deck
17. Primary Steel Truss-18m wide span
18. Perforated Fabric Louvers
19. Suspension Steel Column
20. Exhaust Air Tube
21. Steel Beam-Suspended From Truss Above
Suspended Deck Detail
Wall Section
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014

- Analysis and application assignment

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1 Acquire knowledge of Long Span Structural systems, structural behavior and construction methods, ability to analyze, study and select an appropriate structural system of a given design problem 2 Ability to understand, study, develop and draw structural system, sub structures and its integration and connection to other building components. 3 Preliminary structural design by applying span depth ratio, tables, and graphs or charts, and the recommended codes and standards.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Application	3) Standards and building codes	4) Assumption/Calculations	5) Construction drawings	Total grade
Clear understanding of building structural/ construction problem	Selection and Integration of structure system, construction methods, and building components	Application of Building and Structural Standards and Codes.	Basic calculations / or assumption of basic structural components	Technical and graphical expression of building materials, structural system, and construction methods.	
/2	/3	/1	/1	/3	/10

C) Application and Presentation Assignment — Group work

In the process of the preparation for the term project, it is required to propose, select and apply 3 structural systems on the selected and approved project.

The study has to include the following;

I Description : *A complete description and analysis of the selected term project. The description must show the main drawings and structural systems analysis. The analysis of the structural system has to name, the long span system, Span, spacing, system components cross sec/depth, materials and construction method, and basic details. It is also important to state the wall system/s and roofing.*

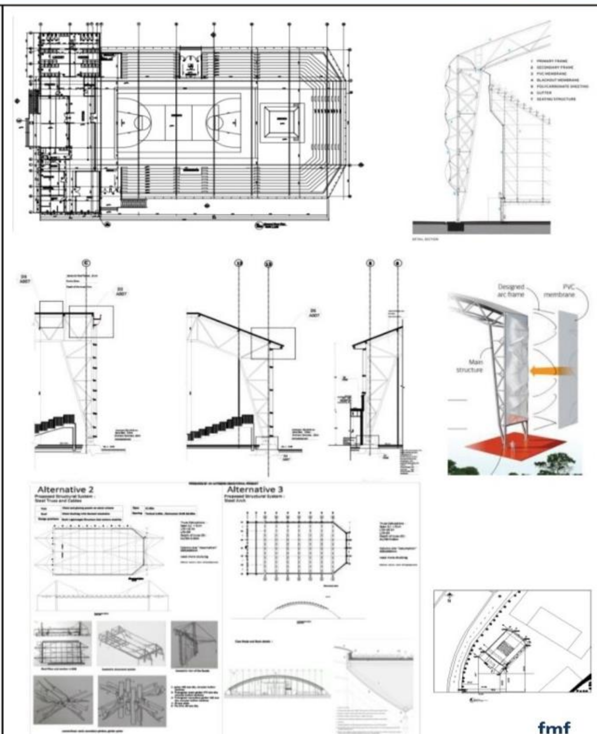
II Application : *The student has to apply the 3 selected structural alternatives to the term project, and do the required developments in plan if required. The study has to have plan/s, section/s, elevations, and necessary added information or study to clarify the application. Basic details has to be added, and a table showing all the systems, proposed structural cross sections and other necessary criteria.*

The presentation will be a team work of 3 or max 4 students, each student has to be responsible of part of the presentation.

Notes: the assignment, will submitted as:

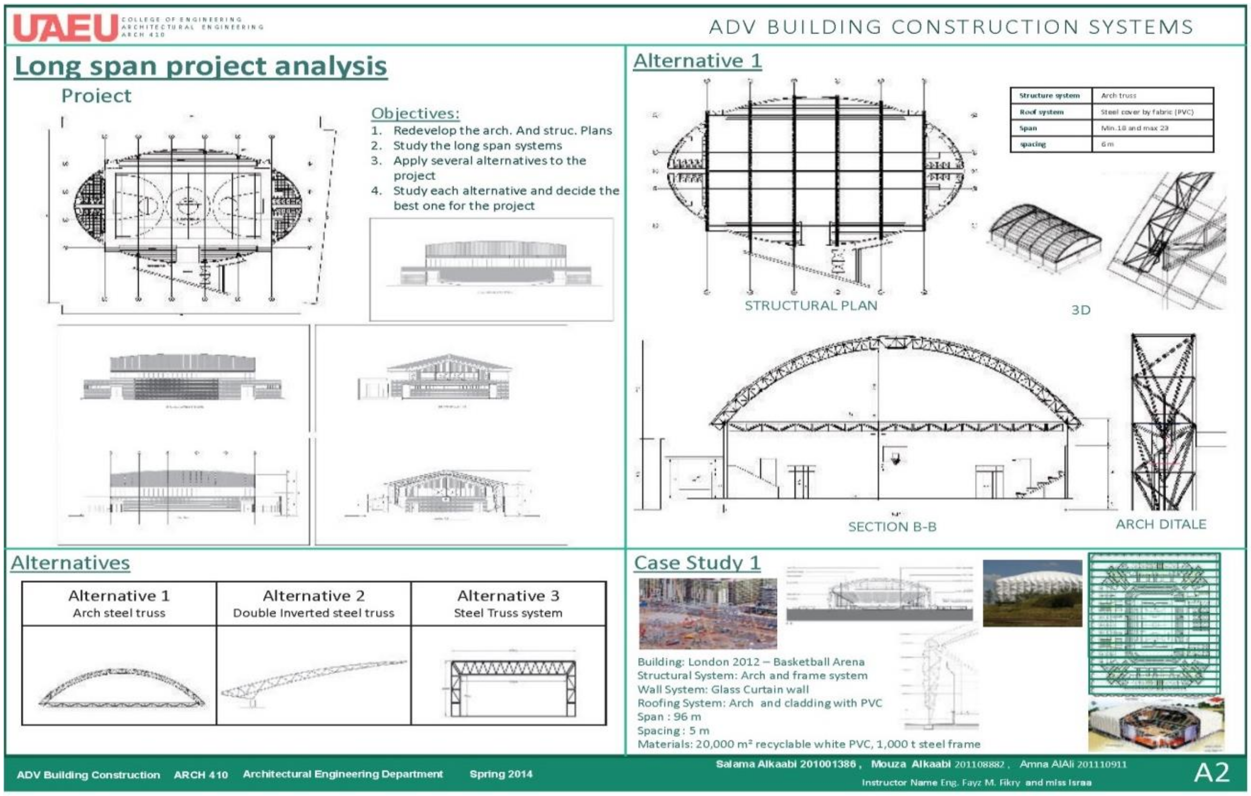
1. ***Power point presentation***
2. ***A2/A3 sheet size for the file***
   The student can add more materials to clarify the analysis of the case studies.

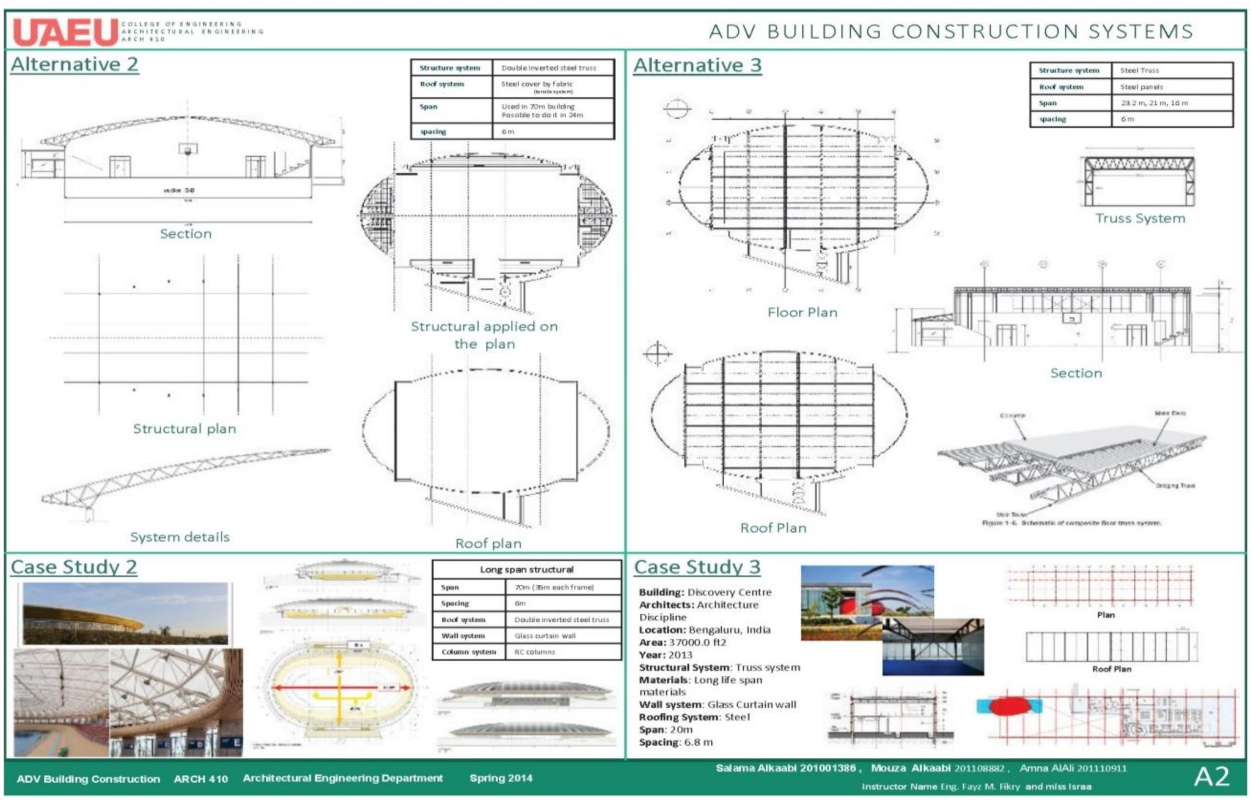
All your work will be submitted as required plus as softcopy



Assignment 02B – Long Span Structural System- Application on the term project

ADV Building Construction | ARCH 410 | Architectural Engineering Department | LS Structural Systems | Fayez M.Fikry | FM


UAEU COLLEGE OF ENGINEERING ARCHITECTURAL ENGINEERING ARCH 410
ADV BUILDING CONSTRUCTION SYSTEMS
Long span project analysis
Project
Objectives:
1. Redevelop the arch. And struc. Plans
2. Study the long span systems
3. Apply several alternatives to the project
4. Study each alternative and decide the best one for the project
Alternative 1
Structure system | Arch truss
Roof system | Steel cover by fabric (PVC)
Span | Min.18 and max 23
spacing | 6 m
STRUCTURAL PLAN
3D
SECTION B-B
ARCH DITALE
Alternatives
Alternative 1
Arch steel truss
Alternative 2
Double Inverted steel truss
Alternative 3
Steel Truss system
Case Study 1
Building: London 2012 – Basketball Arena
Structural System: Arch and frame system
Wall System: Glass Curtain wall
Roofing System: Arch and cladding with PVC
Span : 96 m
Spacing : 5 m
Materials: 20,000 m² recyclable white PVC, 1,000 t steel frame
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014
Salama Alkaabi 201001386 , Mouza Alkaabi 201108882 , Amna AlAli 201110911
Instructor Name Eng. Fayz M. Fikry and miss Israa
A2


UAEU COLLEGE OF ENGINEERING ARCHITECTURAL ENGINEERING ARCH 410
ADV BUILDING CONSTRUCTION SYSTEMS
Alternative 2
Structure system | Double inverted steel truss
Roof system | Steel cover by fabric
Span | Used in 70m building Possible to do it in 24m
spacing | 6 m
Section
Structural applied on the plan
Structural plan
System details
Roof plan
Alternative 3
Structure system | Steel Truss
Roof system | Steel panels
Span | 29.2 m, 21 m, 16 m
spacing | 6 m
Truss System
Floor Plan
Section
Roof Plan
Case Study 2
Long span structural
Span | 70m (35m each frame)
Spacing | 6m
Roof system | Double inverted steel truss
Wall system | Glass curtain wall
Column system | RC columns
Case Study 3
Building: Discovery Centre
Architects: Architecture Discipline
Location: Bengaluru, India
Area: 37000.0 ft2
Year: 2013
Structural System: Truss system
Materials: Long life span materials
Wall system: Glass Curtain wall
Roofing System: Steel
Span: 20m
Spacing: 6.8 m
Plan
Roof Plan
ADV Building Construction ARCH 410 Architectural Engineering Department Spring 2014
Salama Alkaabi 201001386 , Mouza Alkaabi 201108882 , Amna AlAli 201110911
Instructor Name Eng. Fayz M. Fikry and miss Israa
A2

14.3.5.3. *Prefab Construction*

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1 Acquire knowledge of advanced (unconventional) construction methods, the meaning and definition of Building Technology and its levels. 2 Understanding the concept, systems and types of precast and prefabrication, its advantages and disadvantages. 3 Acquire knowledge of systems' components, system limitations and basic and common types of joints and connections of the systems.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Well understanding of the topic and objective/s of the presentation	Clear introduction and contents conveying facts and issues of the topic in a logical and sequential way, selection of the appropriate presentation material through credibility and integrity of research effort	Summary and appropriate comments /recommendations of the main issues of the topic, which reflect deep understanding of the main issues of the topic	Source of references in an appropriate and scientific format *	- Presentation techniques and visual communication, selection of appropriate images, text, etc. ..... and enthusiasm and Spirit - Sharing of presentation relatively evenly among all members of the group
1	4	2	1	2

C) Presentation Assignment **Building Technology I - Prefabrication Systems** **Group work**

"Building Technology," is the knowledge of the technical processes and methods of assembling buildings systems', components and elements.

Drawing proper construction details requires understanding of building systems and how they are integrated with each other.

To verify construction documents with actual building construction on site.

*I **The theoretical part** has to include the following;*

Definition/s , classification, systems and types, construction materials, and each system has to include;

Types, materials, structural behavior, System limitations, components, and basic joints and connections.

*II **Analysis of the case study** has to include the following, Location, year of completion, system, construction material and, systems' components, and details of the system connection.*

- These requirements are representing main basic subjects, the student can add more topics as needed.

The presentation will be a team work of 3 or max 4 students, each student has to be responsible of part of the presentation.

-

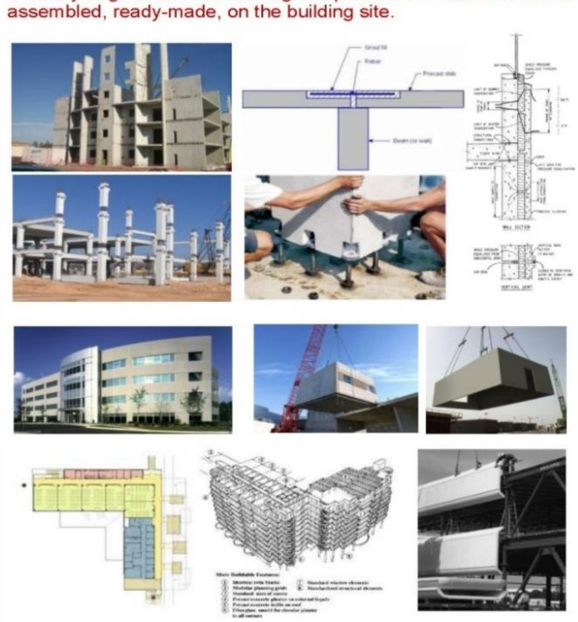
***Notes**: The assignment, will submitted as:*

1. ***Power point presentation***
2. ***Summary** of the, a. **Theoretical Background** on A3 sheet/s*
   *b. **Case studies** analysis each on A3 sheet*

- The student can add more materials to clarify the analysis of the case studies.

- *All work and presentations will be submitted as a digital copy*

***Prefabrication**, in architectural construction, is a technique whereby large units of a building are produced in factories to be assembled, ready-made, on the building site.*



Assignment 03A - Building Construction Technology I – Building Construction Technology- Presentation fmf

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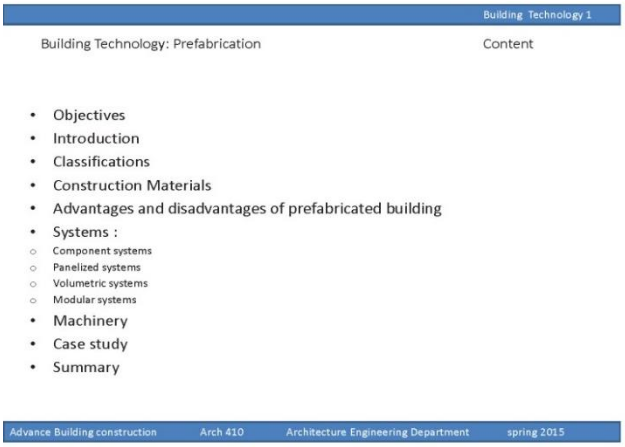
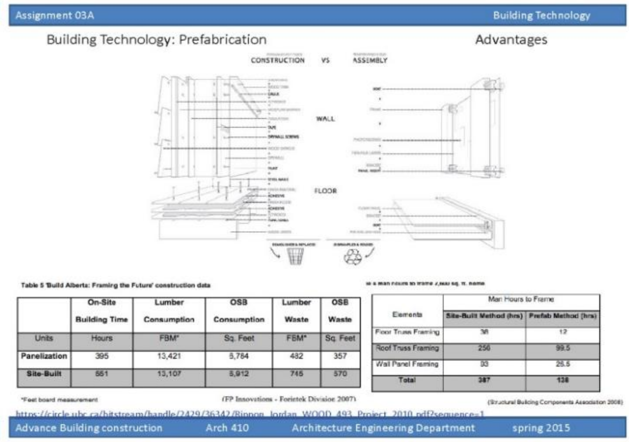
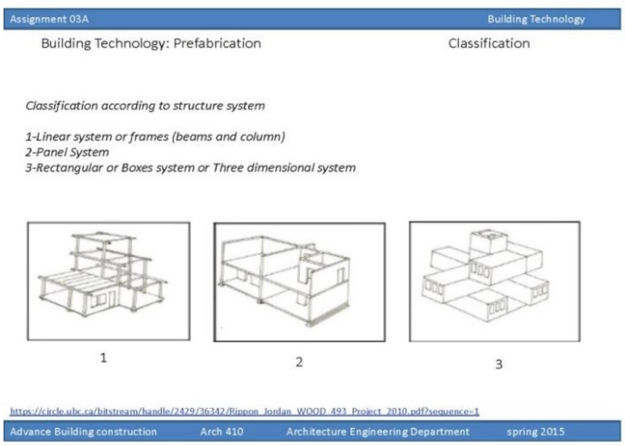
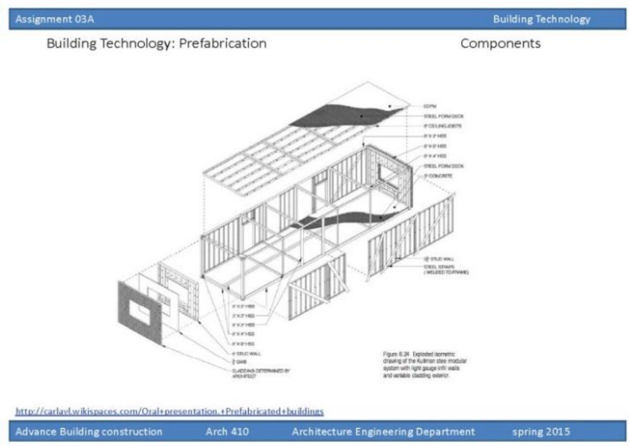


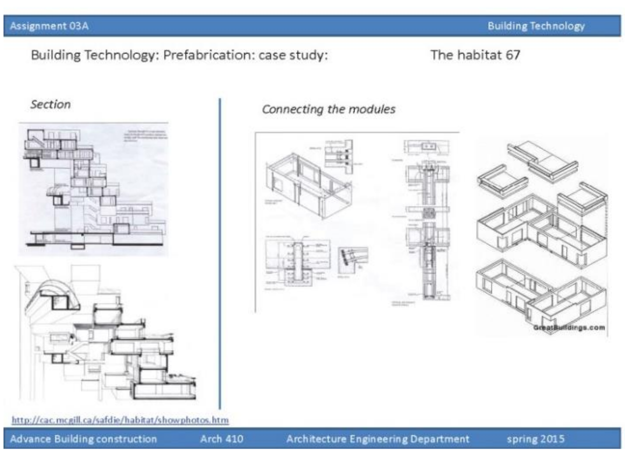


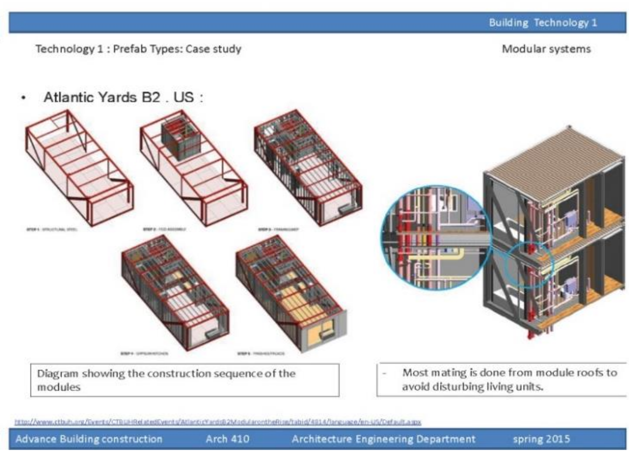
	On-Site Building Time	Lumber Consumption	OSB Consumption	Lumber Waste	OSB Waste
Units	Hours	FBM*	Sq. Feet	FBM*	Sq. Feet
Panelization	395	13,421	5,784	482	357
Site-Built	551	13,107	5,912	745	570

Elements	Man Hours to Frame	
	Site-Built Method (hrs)	Prefab Method (hrs)
Floor Truss Framing	36	12
Roof Truss Framing	256	99.5
Wall Panel Framing	93	25.5
Total	387	138









- Prefab analysis and application

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1 Acquire knowledge of advanced (unconventional) construction methods, the meaning and definition of Building Technology and its levels. 2 Understanding the concept, systems and types of precast and prefabrication, its advantages and disadvantages. 3 Acquire knowledge of systems' components, system limitations and basic and common types of joints and connections of the systems.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Clear understanding of building construction /construction method problem	Selection and Integration of system, construction methods, and building components	Application of Building and Structural Standards and Codes.	Basic calculations / or assumption of basic structural components	Technical and graphical expression of building materials, structural system, and construction methods.
/2	/4	/1	/0	/3

C) Application Assignment — Building Technology I - Prefabrication Systems — Group work

"Building Technology," is the knowledge of the technical processes and methods of assembling buildings components.

***Prefabrication,* in architectural construction, is a technique whereby large units of a building are produced in factories to be assembled, ready-made, on the building site. The technique permits the speedy erection of very large structures.**

It is required to select, propose and apply a prefabrication system, to the project of assignment MC 01B. The study has to include reason of selection, a description of the system, types, components, and system limitations.

Required Drawings:

1 Grid analysis
2 Plan/s showing system components and connections
3 Section/s
4 Details/3D

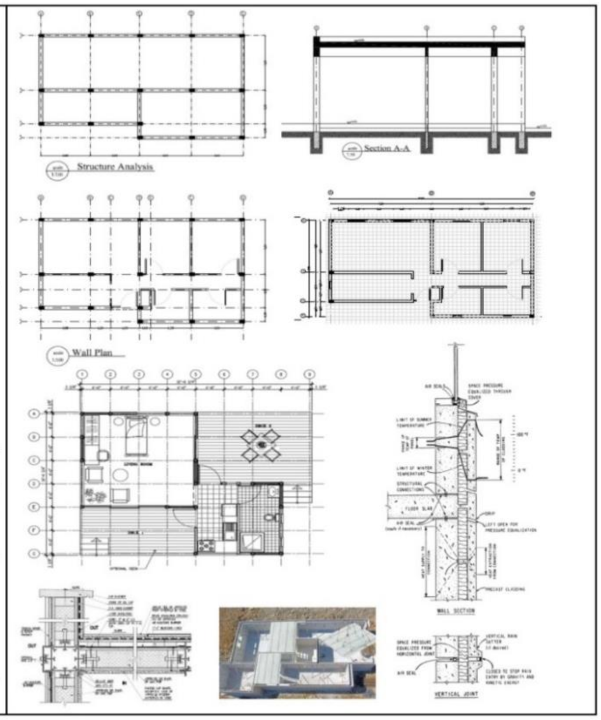
The drawings has to be to an appropriate scale not less than1/50. A detailed partial plan to scale 1/25 to show system connections and joints. The study has also, to include system components/panel study and numbers.

Notes:

The assignment, will submitted as:

1 *A2 sheet size and A3 for the file*
2 *The student can add more drawings if needed to clarify the system*

- *All assignments will be submitted as a digital copy*



Assignment 03B - Building Construction Technology I – Prefabrication Systems - Application

fmf

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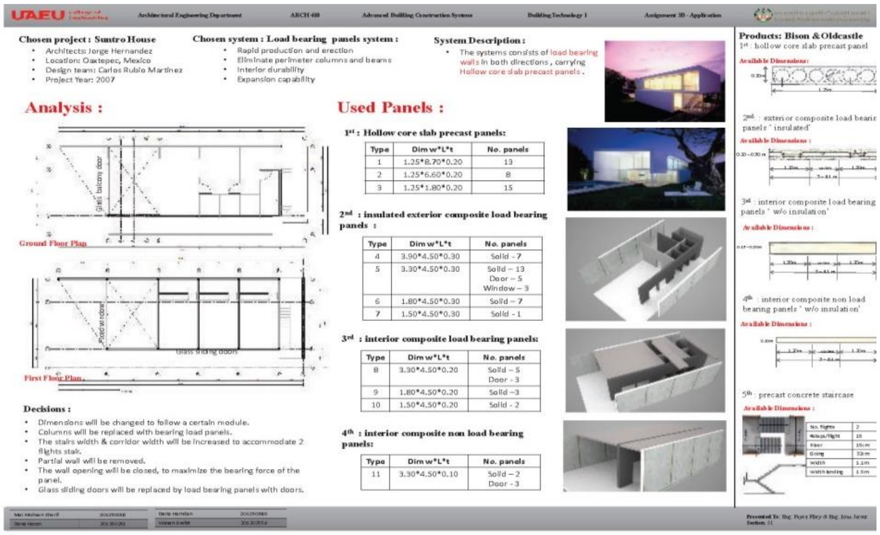
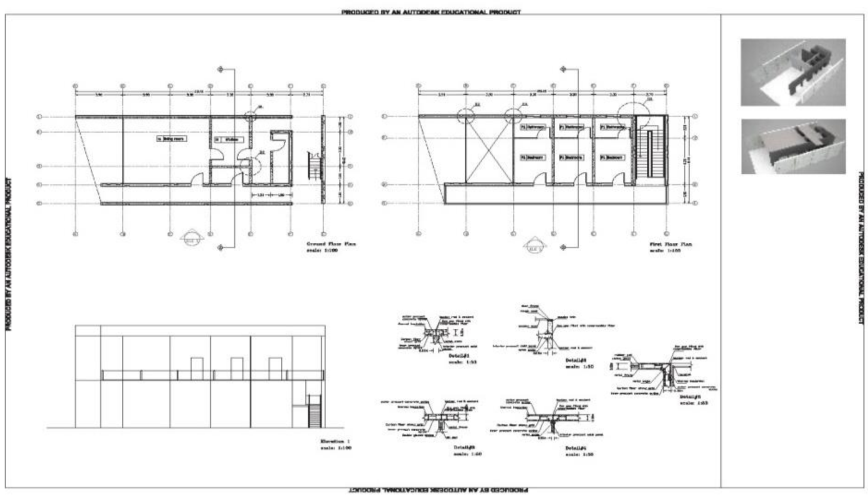

UAEU
Architectural Engineering Department
ARCH 410
Advanced Building Construction Systems
Building Technology 1
Assignment 3B - Application
Chosen project : Suntro House
Architects: Jorge Hernandez
Location: Oaxtepec, Mexico
Design team: Carlos Rubio Martinez
Project Year: 2007
Chosen system : Load bearing panels system :
Rapid production and erection
Eliminate perimeter columns and beams
Interior durability
Expansion capability
System Description :
The systems consists of load bearing walls in both directions , carrying Hollow core slab precast panels .
Analysis :
Glass balcony door
Ground Floor Plan
Fixed window
Glass sliding doors
First Floor Plan
Decisions :
Dimensions will be changed to follow a certain module.
Columns will be replaced with bearing load panels.
The stairs width & corridor width will be increased to accommodate 2 flights stair.
Partial wall will be removed.
The wall opening will be closed, to maximize the bearing force of the panel.
Glass sliding doors will be replaced by load bearing panels with doors.
Used Panels :
1st : Hollow core slab precast panels:
Type | Dim w*L*t | No. panels
1 | 1.25*8.70*0.20 | 13
2 | 1.25*6.60*0.20 | 8
3 | 1.25*1.80*0.20 | 15
2nd : insulated exterior composite load bearing panels :
Type | Dim w*L*t | No. panels
4 | 3.90*4.50*0.30 | Solid - 7
5 | 3.30*4.50*0.30 | Solid – 13, Door – 5, Window – 3
6 | 1.80*4.50*0.30 | Solid – 7
7 | 1.50*4.50*0.30 | Solid - 1
3rd : interior composite load bearing panels:
Type | Dim w*L*t | No. panels
8 | 3.30*4.50*0.20 | Solid – 5, Door - 3
9 | 1.80*4.50*0.20 | Solid –3
10 | 1.50*4.50*0.20 | Solid - 2
4th : interior composite non load bearing panels:
Type | Dim w*L*t | No. panels
11 | 3.30*4.50*0.10 | Solid – 2, Door - 3
Products: Bison & Oldcastle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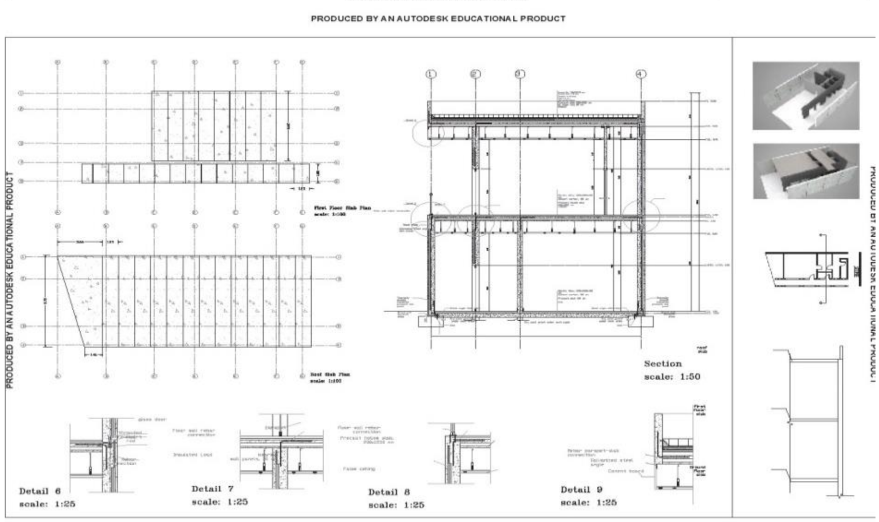

PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
Section
scale: 1:50
Detail 6
scale: 1:25
Detail 7
scale: 1:25
Detail 8
scale: 1:25
Detail 9
scale: 1:25

14.3.5.4. *Advanced Construction Methods {included in the term project}*

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives

1 Acquire knowledge of advanced (unconventional) construction methods, the meaning and definition of Building Technology and its levels.
2 Understanding the concept, systems and types of different advanced construction methods, its advantages and disadvantages.
3 Acquire knowledge of systems' components, system limitations and basic and common types of joints and connections of the systems..

ABET Program Outcomes

C An ability to design and evaluate building engineering systems, components, or processes to meet desired
E An ability to identify, formulate, and solve engineering problems
K An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Well understanding of the topic and objective/s of the presentation	Clear introduction and contents conveying facts and issues of the topic in a logical and sequential way, selection of the appropriate presentation material through credibility and integrity of research effort	Summary and appropriate comments /recommendations of the main issues of the topic, which reflect deep understanding of the main issues of the topic	Source of references in an appropriate and scientific format *	- Presentation techniques and visual communication, selection of appropriate images, text, etc. ..... and enthusiasm and Spirit - Sharing of presentation relatively evenly among all members of the group
1	4	2	1	2

C) Presentation Assignment **Building Technology II – Advanced Building Construction** Presentation **Group work**

*"**Building Technology**," is the knowledge of the technical processes and methods of assembling buildings components.*

The study has to present the most common advanced construction methods, such as Lift slab, Tunnel form, Slip form, Modular Metal Framework, Flying form , …………

***I The theoretical part** has to include the following;*
Definition/s , classification, systems and types, construction materials, and each system has to include;
Types, materials, structural behavior, System limitations, components, and basic joints and connections.
***II Analysis of the case study;** the student has to include the following, Location, year of completion, system, construction material and, systems' components, and details of the system connection.*

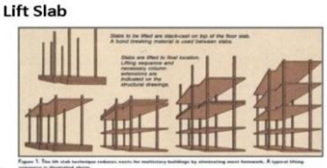
- *These requirements are representing main basic subjects to be covered, the student can add more topics as needed.*

The presentation will be as a team work of 3 students or 4 students max, each student has to be responsible of part of the presentation.

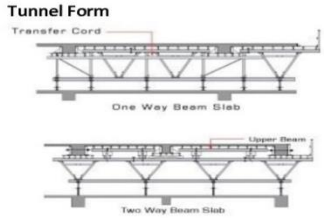
***Notes**: The assignment, will submitted as:*
1 ***Power point presentation***
2 ***Summary** of the, a. **Theoretical Background** on A3 sheet/s*
*b. **Case studies** analysis each on A3 sheet*
- The student can add more materials to clarify the analysis of the case studies.

All work and presentations will be submitted as a digital copy

Lift Slab



Tunnel Form



Slip Form

Flying Form

Assignment 04B - Building Construction Technology II – Advanced Building Construction - **Presentation**

T04B BTII_4B FALL 15T04B BTII_4B FALL 15 FMF

ADV Building Construction ARCH 410 Architectural Engineering Department Building Technology II Fayez M.Fikry FM

14.3.5.5. *Building System integration (sustainability) {included in the term project}*

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1 Acquire knowledge of SUSTAINABILITY in general and the approach and SUSTAINABILITY in construction. 2 Decision making in the design process and its impact on construction stage. 3 Understanding the role and responsibilities of different parties in the construction field and the industry. 4 Sustainable construction strategy and the main issues and requirements needed to achieve it.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Well understanding of the topic and objective/s of the presentation	Clear introduction and contents conveying facts and issues of the topic in a logical and sequential way, selection of the appropriate presentation material through credibility and integrity of research effort	Summary and appropriate comments /recommendations of the main issues of the topic, which reflect deep understanding of the main issues of the topic	Source of references in an appropriate and scientific format *	- Presentation techniques and visual communication, selection of appropriate images, text, etc. ..... and enthusiasm and Spirit - Sharing of presentation relatively evenly among all members of the group
1	4	2	1	2

C) Presentation Assignment — SUSTAINABILITY in Construction — Group work

Sustainable development is an organizing principle for human life on a finite planet. It posits a desirable future state for human societies in which living conditions and resource-use meet human needs without undermining the sustainability of natural systems and the environment, so that future generations may also meet their needs.

Sustainable Construction

Sustainable Construction is the application of sustainable development to the construction industry.

Key words Resources *Materials Industry Construction Methods Economy Cost Public sector Private sector LEED Estidama Transportation Energy Pollution Environment Strategy Waste Management . . . .*

It is required to conduct a presentation about Sustainability In construction, the presentation has to include the following,

1 Definitions; *of all related key words.*

2 Introduction, *the concept of Sustainability in the Architecture and construction fields and other domains.*

3 Topics to be covered, a. analytical study through the design process, including Conceptual and construction phase indicating all related issues, topics, parties …., **b.** sustainable construction strategy, its issues and requirements **C.** case study of an applied strategy in construction.

- *These are the proposed topics, student can add more topics or issues.*

Notes:

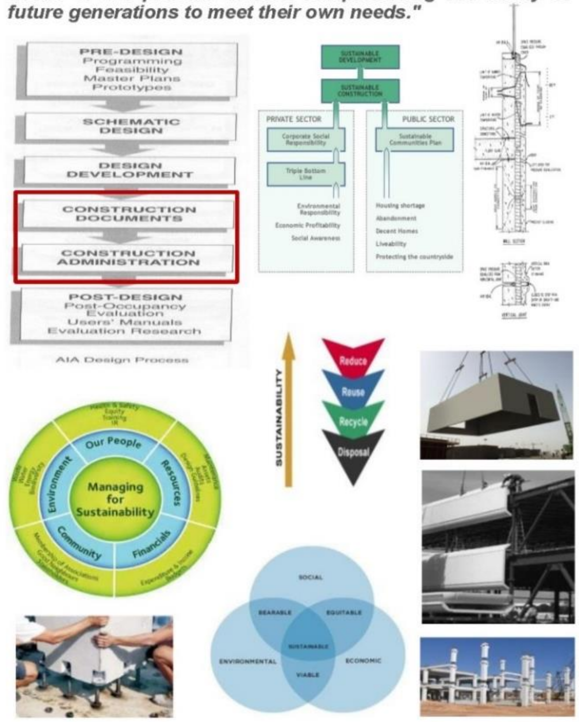
- The assignment, will submitted as:

1 Power point presentation

***2 Summary** of the presentation on A3 sheet,* **will be included in the file.**

- All work and presentations will be submitted as a digital copy

sustainable development: ***"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."***



Assignment 06 B - SUSTAINABILITY in Construction - *Sustainable Construction Strategy*

T06 SUS Assignment 06 B SP16 fmf

ADV Building Construction ARCH 410 Architectural Engineering Department **Sustainability in Construction** Fayez M.Fikry FM

14.3.5.6. *Building System integration (mechanical systems) {included in the term project}*

A) Assignment Objectives and Related Program Outcomes

Assignment Objectives	ABET Program Outcomes
1 Acquire knowledge of building design process and the required services in a building. 2 Understanding Systems components, installation techniques, and spatial requirements. 3 Acquire knowledge of building regulations and codes of building services. 4 Understanding Building system integration and Sustainability issues in decision making of the selection of the systems and its impact on the environment.	**C** An ability to design and evaluate building engineering systems, components, or processes to meet desired **E** An ability to identify, formulate, and solve engineering problems **K** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

B) Grading Criteria

1) Understanding	2) Structure and Organization	3) Summary and comments	4) Documentation	5) Performance and Presentation Quality
Well understanding of the topic and objective/s of the presentation	Clear introduction and contents conveying facts and issues of the topic in a logical and sequential way, selection of the appropriate presentation material through credibility and integrity of research effort	Summary and appropriate comments /recommendations of the main issues of the topic, which reflect deep understanding of the main issues of the topic	Source of references in an appropriate and scientific format *	- Presentation techniques and visual communication, selection of appropriate images, text, etc. ..... and enthusiasm and Spirit - Sharing of presentation relatively evenly among all members of the group
1	4	2	1	2

C) Presentation Assignment **Building Systems Integration –** *Technical Installations* **Group work**

PART I – Building System Integration
The act or process of incorporating or coordinating different systems/elements or group of elements in a cohesive environment.

PART II – Tech Installations/Building services; include heating, ventilation, **cooling, lighting, utilities and services**, energy management, lifts and associated services, communication lines, telephones and IT networks security and alarm systems and fire detection and fighting

It is required to conduct a presentation about Building Systems Integration and Technical Installation the presentation has to include the following,

Introduction, *design process and building engineering systems and services*

Part I Building Systems Integration

*The **approach/concept** of integration, types and levels , integration in practice, and analysis of case studies*

Part II Tech Installation; systems , types , system components, **selection criteria, design consideration** spatial requirements of the following systems; **a. Cooling system** **b. Drainage system** **c. electrical system** **d. water supply ***

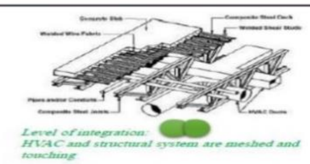
Case studies, 2 of each system, in an analytical process showing , way of fixing and basic details.

Part IV References

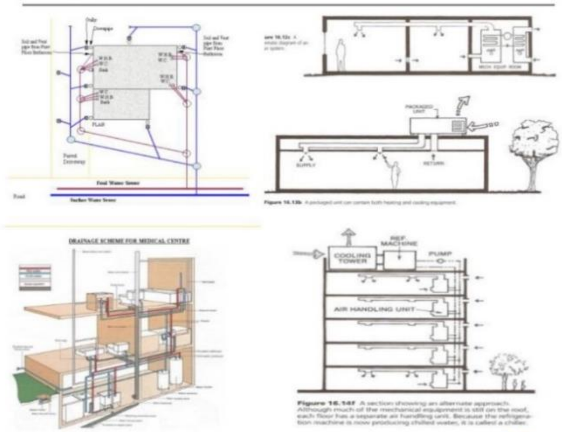
These are the proposed topics, student, can add more topics or issues.

***Notes**: The assignment, will submitted as:*

1. ***Power point presentation***
2. ***Summary** of the presentation on A3 sheet,* **will be included in the file.**
   - *All work and presentations will be submitted as a digital copy*



- Buildings must be designed with features to provide
  - better lighting
  - comfortable space temperature, humidity and air quality
  - convenient power and communication capability
  - high quality sanitation; and
  - reliable systems for the protection of life and property.



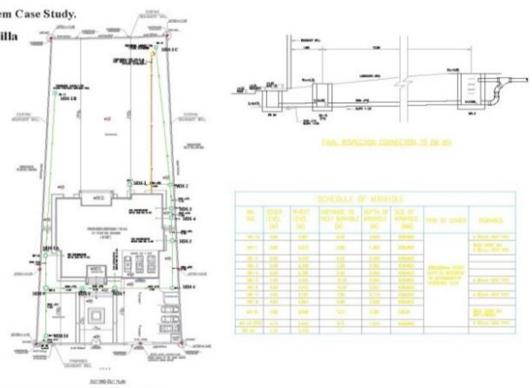
fmf

Assignment 05 B - Building System Integration and Technical Installations - *Approach/concept* T05 BSI 05 B

ADV Building Construction ARCH 410 Architectural Engineering Department Building Systems Integration Fayez M.Fikry FM

Drainage System Case Study.

Residential Villa

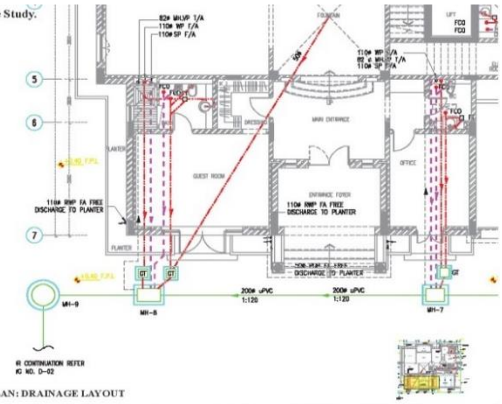


SITE SETTING OUT PLAN DRAINAGE LAYOUT

UAE University College of Engineering — Department of Architectural Engineering Spring 2008 — Building TEC. Installation Eng.Fayez Fikri — Aysha Salem Baloushi, 200104979 Alia Hamad Kabi, 200202833 — Exercise:

Drainage System Case Study.

Residential Villa



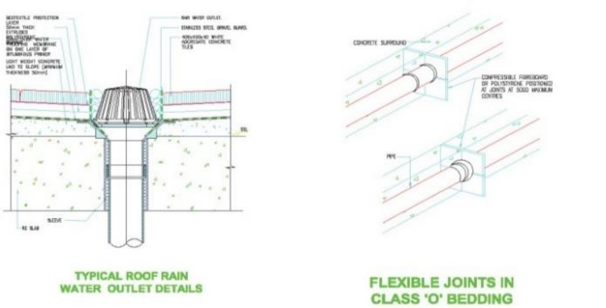
GROUND FLOOR PLAN: DRAINAGE LAYOUT

UAE University College of Engineering — Department of Architectural Engineering Spring 2008 — Building TEC. Installation Eng.Fayez Fikri — Aysha Salem Baloushi, 200104979 Alia Hamad Kabi, 200202833 — Exercise:

Drainage System Case Study.

Residential Villa

DRAINAGE LAYOUT: STANDARD DETAILES

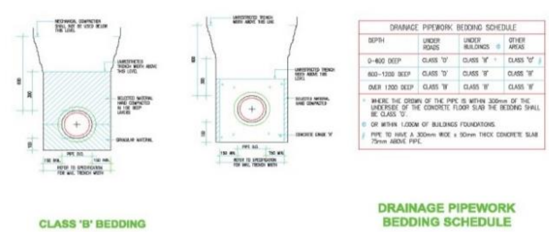


UAE University College of Engineering — Department of Architectural Engineering Spring 2008 — Building TEC. Installation Eng.Fayez Fikri — Aysha Salem Baloushi, 200104979 Alia Hamad Kabi, 200202833 — Exercise:

Drainage System Case Study.

Residential Villa

DRAINAGE LAYOUT: STANDARD DETAILES

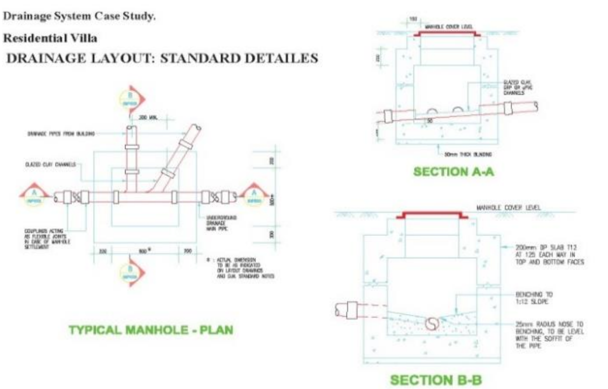


UAE University College of Engineering — Department of Architectural Engineering Spring 2008 — Building TEC. Installation Eng.Fayez Fikri — Aysha Salem Baloushi, 200104979 Alia Hamad Kabi, 200202833 — Exercise:

Drainage System Case Study.

Residential Villa

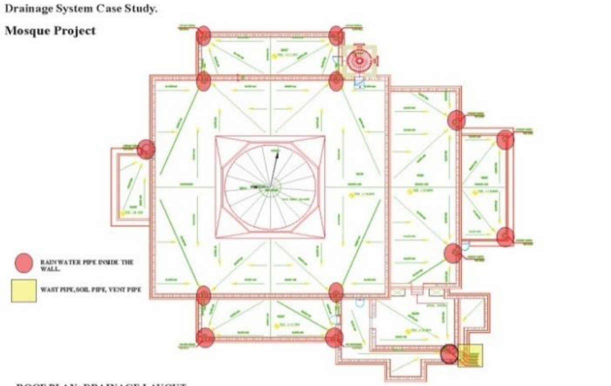
DRAINAGE LAYOUT: STANDARD DETAILES



UAE University College of Engineering — Department of Architectural Engineering Spring 2008 — Building TEC. Installation Eng.Fayez Fikri — Aysha Salem Baloushi, 200104979 Alia Hamad Kabi, 200202833 — Exercise:

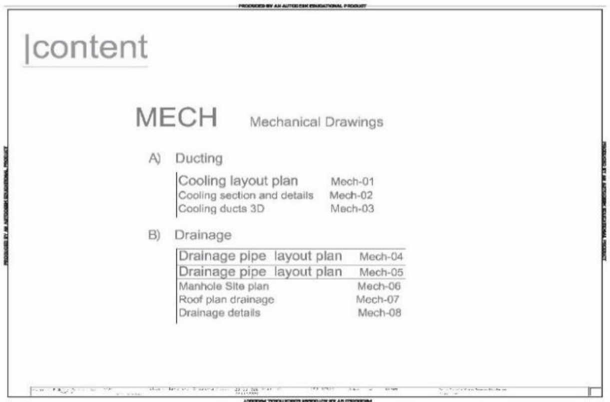
Drainage System Case Study.

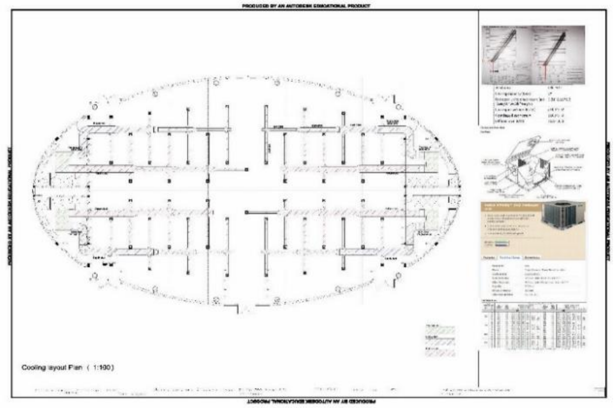
Mosque Project

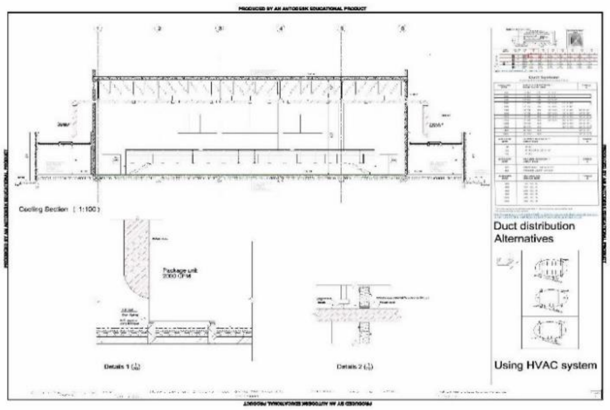


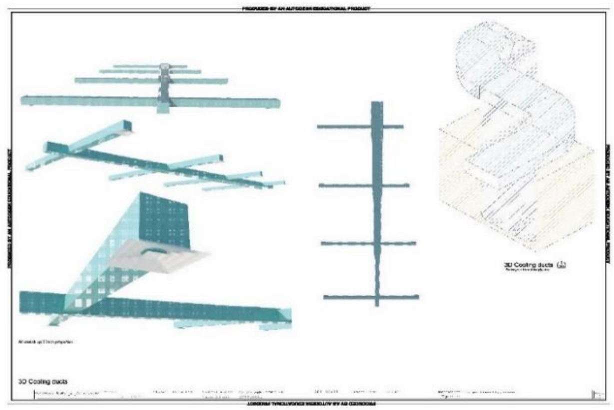
ROOF PLAN: DRAINAGE LAYOUT

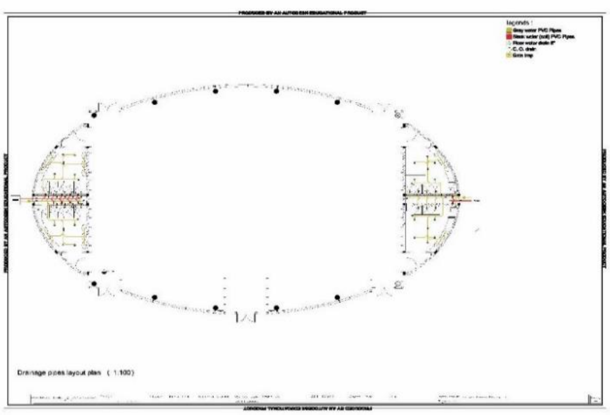
UAE University College of Engineering — Department of Architectural Engineering Spring 2008 — Building TEC. Installation Eng.Fayez Fikri — Aysha Salem Baloushi, 200104979 Alia Hamad Kabi, 200202833 — Exercise:

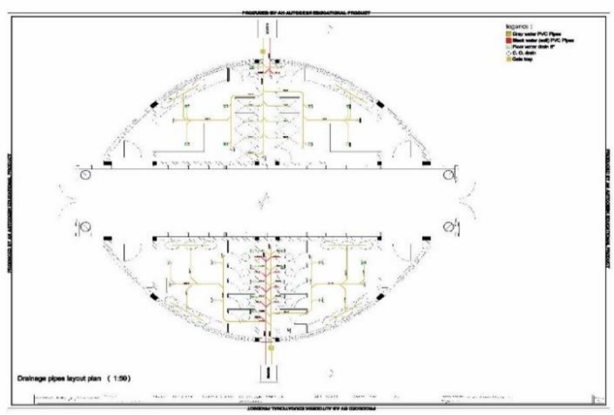

|content
MECH Mechanical Drawings
A) Ducting
Cooling layout plan Mech-01
Cooling section and details Mech-02
Cooling ducts 3D Mech-03
B) Drainage
Drainage pipe layout plan Mech-04
Drainage pipe layout plan Mech-05
Manhole Site plan Mech-06
Roof plan drainage Mech-07
Drainage details Mech-08


Cooling layout Plan (1:100)


Cooling Section (1:100)
Duct distribution Alternatives
Using HVAC system
Details 1
Details 2


3D Cooling ducts
3D Cooling ducts

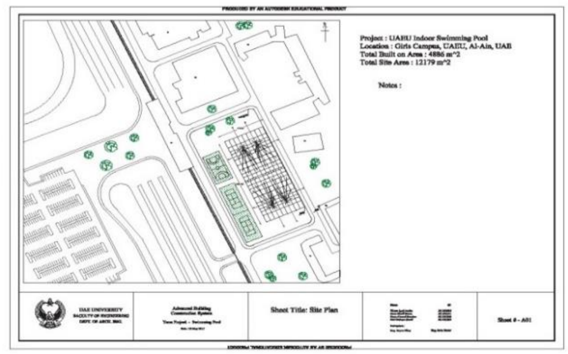

Drainage pipes layout plan (1:100)

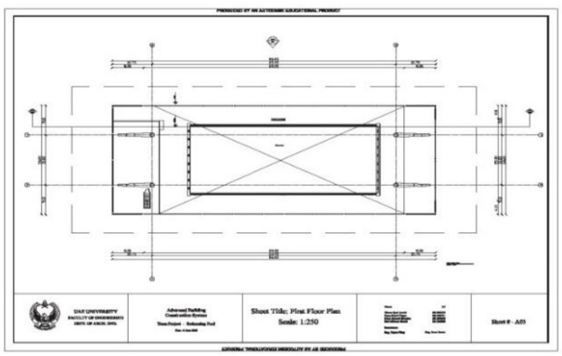

Drainage pipes layout plan (1:50)

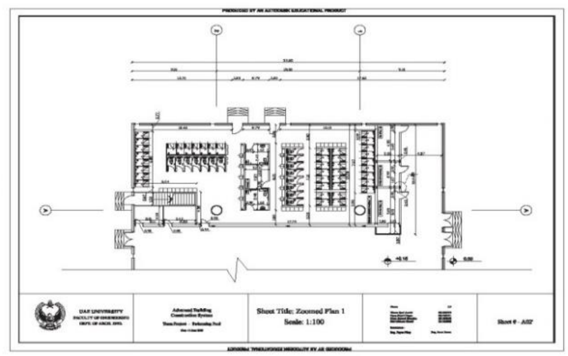
14.3.6. **Project sample**

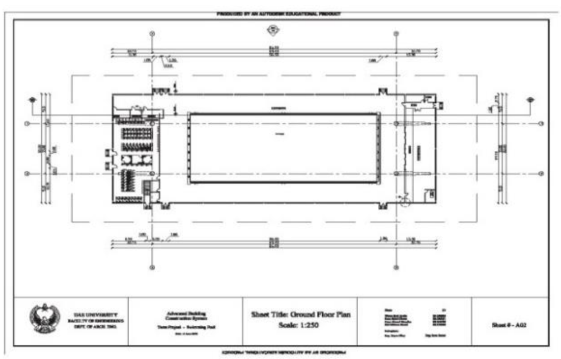
I Architectural

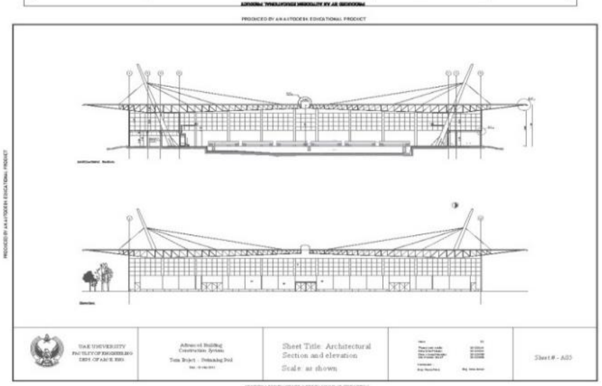
Sheet #	Title	Scale
A01	Site Plan	1:250
A02	G Floor Plan	1:250
A02'	Zoomed Plan I	1:100
A02"	Zoomed Plan II	1:100
A03	1st Floor Plan	1:250
A04	Roof Plan	1:250
A05	Section - Elevation	1:250
A06	Details	-
A07	Wall Sections	1:50
A08	3D	1:250
A09	Tables	-

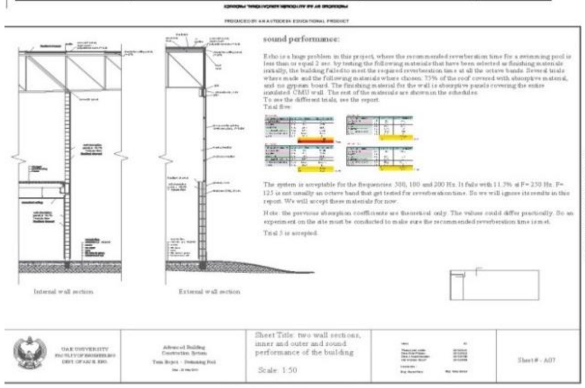


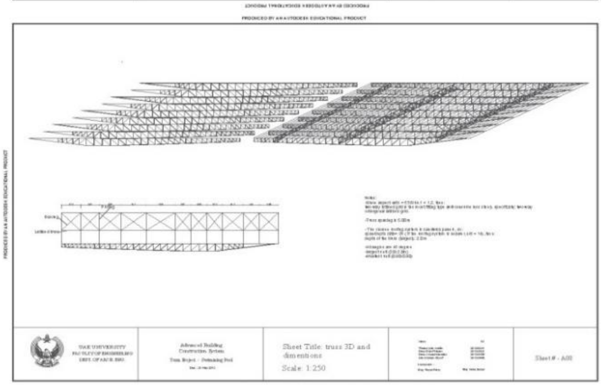


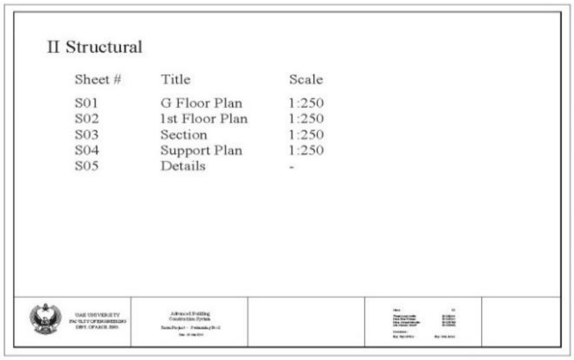






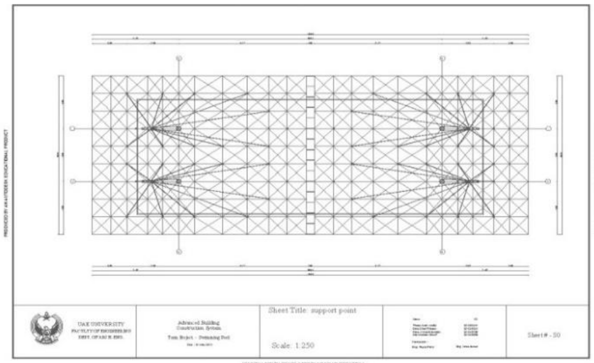


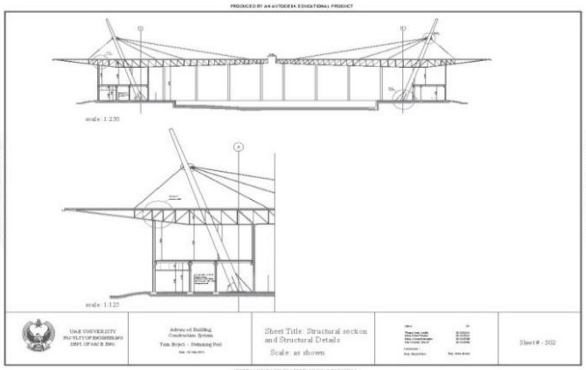


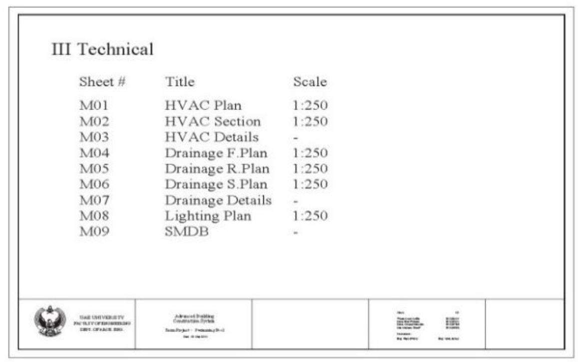


II Structural

Sheet #	Title	Scale
S01	G Floor Plan	1:250
S02	1st Floor Plan	1:250
S03	Section	1:250
S04	Support Plan	1:250
S05	Details	-

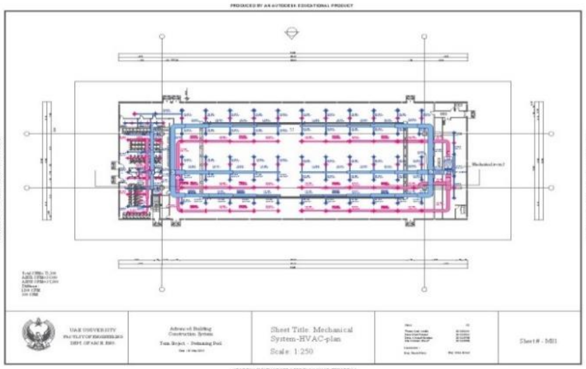


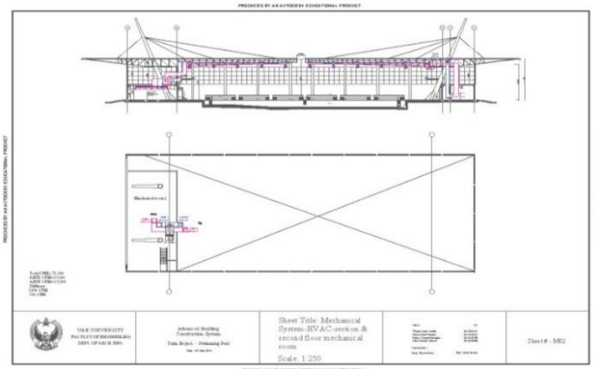


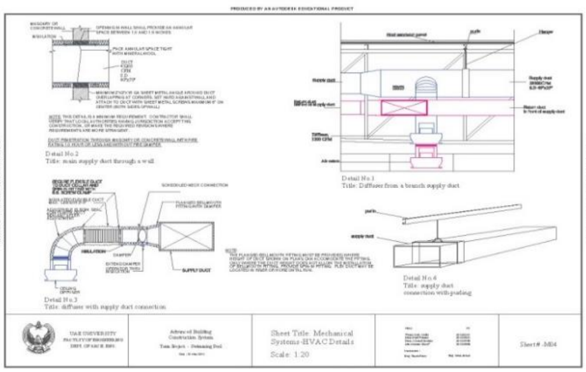


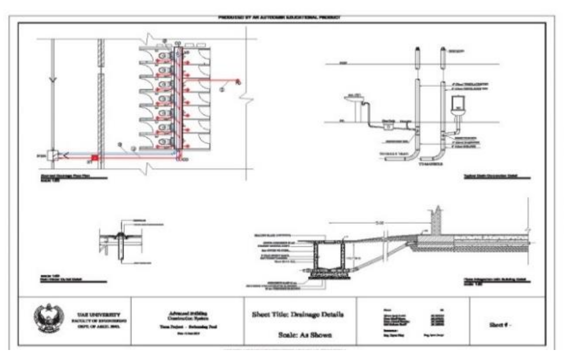
III Technical

Sheet #	Title	Scale
M01	HVAC Plan	1:250
M02	HVAC Section	1:250
M03	HVAC Details	-
M04	Drainage F.Plan	1:250
M05	Drainage R.Plan	1:250
M06	Drainage S.Plan	1:250
M07	Drainage Details	-
M08	Lighting Plan	1:250
M09	SMDB	-









List of Figures

List of Tables

List of Publications:

- **ISI &/or Scopus Journal Publications:**

Under Review Ferrandiz J, Del Ama gonzalo F, Sanchez-Sepulveda M, Fonseca D. "*Introducing a new ICT tool in an active learning environment course: performance consequences depending the introduction design.*" The International Journal of Engineering Education; 2018

Peña E, Fonseca D, Marti N, Ferrandiz J. "*Relationship between Specific Professional Competences and Learning Activities of the Building and Construction Engineering Degree Final Project*" The International Journal of Engineering Education; 2018

Invited Paper Ferrandiz J, Banawi A, Peña E. "*Evaluating the benefits of introducing "BIM" based on Revit in construction courses, without changing the course schedule*" Universal Access in the Information Society Journal; 2017.

- **Conference Publications:**

Ferrandiz J, Del Ama gonzalo F, Fonseca D, Galal K. "*BIM implementation at the Construction courses in the Architectural Engineering in the United Arab Emirates university*"; BIM Academic Symposium 2018; Orlando, FL; March 27-28; 2018.

Del Ama gonzalo F, Ferrandiz J, Fonseca D, Hernandez JA. "*Field Measurements of Electrical Consumption in a Multi-purpose Educational Building*"; Trends and Advances in Information Systems and Technologies. WorldCIST'18, Naples, Italy, 2018.

Ferrandiz J, Fonseca D, Banawi A. "*Mixed Method Assessment for BIM implementation in the AEC curriculum*" Human Computer Interaction Conference 2016, Toronto, Canada; July 17-22 2016.

Ferrandiz J "*BIM implementation at the building systems course at the United Arab Emirates University*"; BIM Academic Symposium 2016; Orlando, FL; April 4-5; 2016.

Ferrandiz J "*Damage Analysis, Standardized protocol to identify the problem, Code and Standard development*" SCEC 2015 annual meeting poster; Palm springs, AZ. Sept 2014