

# Introducing a New ICT Tool in an Active Learning Environment Course: Performance Consequences Depending on the Introduction Design\*

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This paper presents a case-study, quasi-experiment in the framework of Architectural Engineering (AE) Bachelor (BA) degree in the United Arab Emirates University (UAEU) and the Architecture (Arch) BA at the American University of Ras Al Khaimah (AURAK). To analyze the best approach to introduce Building Information Modelling (BIM) tools into Academia, we evaluated three different approaches by introducing a new BIM tool (Revit) into a construction course. These ICT tools (Information and Communication Technologies), are currently required by the Architectural, Engineering and Construction (AEC) industry. We tested the students' performance, submissions and opinions of the course methods in order to evaluate these approaches. In this study, we compared the students' performance in the Building Components course (BCC) at UAEU and in the Construction III course (CIII) at AURAK, analyzing how these new course designs affected the students. We tested the BCC course during six semesters and the CIII for two semesters. To achieve a better understanding of the impact of the course on the students, we used the grades of the students to quantify their performance, compared their submissions and interviewed three random students from each semester. There are few studies on the architectural introduction of Revit and BIM into the Architectural curriculum, even though these tools are currently necessary in the Architectural, Engineering and Construction industry. Based on the data obtained from the academic files, the interviews with the students and the analytic study of the data, we created a set of recommendations to introduce Revit into construction courses in the AEC curriculum while preventing a drop in the performance, skills and knowledge acquisition of the students.

**Keywords:** architectural engineering; student performance; curriculum; BIM; Revit; educational assessment; academic analytics

## 1. Introduction

We are in the midst of a technological paradigm shift in the Architectural, Engineering and Construction (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" [1]. BIM is a worldwide reality, but each country, company and university is adopting BIM individually without a common procedure, method or framework. As can be observed in Barison's research [2–4] every university included in the study introduced BIM at a different level, in a different course, and with very different approaches. There is no communication between institutions regarding specific courses or curricular designs to evaluate possible strategies and their positive and negative aspects. A quick view of the status of BIM globally will provide a picture of the different realities [56]:

- Countries or states where BIM is a legal requirement for some projects (e.g., the UK and Dubai);

- Countries where it will be required soon (e.g., Chile and Germany);
- Countries where it is not regulated but is in high demand (e.g., Canada and the USA); there are several varying standards set by third parties, so that technicians are uncertain which certificate they should obtain;
- Countries where it is beginning to be introduced (e.g., India);
- Countries where its use is not yet a reality (in some developing countries).

BIM skills are required by the industry; therefore, the introduction of these new ICT (Information and Communication Technologies) should be required as well in Academia. There are few studies on the introduction of Revit and BIM in the architectural curriculum, even though the use of these tools is now a necessity in the AEC Industry.

This paper presents a study of the framework of Architecture & Architectural Engineering BA degree in the United Arab Emirates. The aim is to evaluate three different approaches to introducing a new ICT tool (Revit) into a construction course. In

this study, we compare student performance during two semesters in the Construction III (CIII) at the American University of Ras Al Khaimah (AURAK), and six semesters in the Building Components course (BCC) at the United Arab Emirates University (UAEU), analyzing the impact of the course modifications on the students. We use student grades to quantify their performance and interview three random students from each semester to obtain qualitative data.

This study uses a mixed methodology. Quantitative data is used to evaluate the performance of the students during the course, while qualitative data is gathered to determine the reasons behind those results. These methodologies are based on the research and publication of Fonseca, et al, about the introduction of new ICT into the Architectural curriculum [5–15]. These studies provide the proper background and confirmation of a well-tested and reliable methodology. The quantitative data used in our study is comprised of the grading from six semesters taken from the official e-portfolio of the course. The data is tested using a nonparametric test because of the smaller number of samples, which would not provide an accurate normality test. A non-parametric test is used for independent variables and is more accurate for non-normal distribution than the usual P-test. The two different groups of students represent our samples for an Analysis of Variance (ANOVA) at the same stage of the curriculum. The new technology was introduced into the intermediate course of Construction in the Architectural Engineering degree program at the United Arab Emirates University. This course was originally designed using a different tool, but due to the market and ABET recommendations, it was decided to introduce Revit.

This paper includes a description of the original course content, the two different approaches applied introducing a new tool, the performance of the students during the three phases and interviews of the randomly-selected students. These elements were evaluated to comprehend how these modifications affected student performance and their approach to the course. In order to determine the impact of different methodologies on the students, this analysis was compared with the curriculum that is being developed at the American University of Ras Al Khaimah (AURAK) in the Construction III course, which is the same level as BCC at UAEU. Based on our hypothesis and the obtained data, the results indicate a set of recommendations for introducing Revit into construction courses in the AEC curriculum, focusing on preventing any decrease in the performance, skills or knowledge acquisition of the students.

## 2. Background

### 2.1 ICT in higher education

In 2003 a special committee defined the information and knowledge society, as cited by Almenara [17], 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. ICT 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 [18].

Academia is seeing an increase in ICT motivation, primarily because they are an allure to our current digital native students [16]. Prior to the development of the internet and ICT, knowledge was stored and transmitted within a very limited range by the family, professors, books and other means. Schools and universities were the repositories for most information [16], but with the creation of the internet, it is now widely available almost everywhere. The proper use of ICT has given people access to a limitless database of knowledge, requiring new and different skills to search, filter and organize the abundance of information in order to extract whatever specific data is needed from it [19].

UAEU has made a large investment in its infrastructure on the university campus to install equipment such as projectors, wireless internet connectivity and smart boards [20]. However, the introduction of ICT into a class has been left completely in the hands of the faculty. The faculty will naturally only use ICT when he or she has the requisite skills, confidence and support, and his or her teaching methodology will correspondingly be oriented to maximize the use of these new technologies [21, 22]. ICTs are essentially a method and resource to be used to facilitate the learning process. Their importance is directly related to the context—the way and for what purpose we use them [22]. They should be adopted as tools to enhance learning and improve skills development, used in conjunction with other teaching methodologies [16].

The benefit of developing a set of learning methodologies that include ICTs is that they provide the students and/or the faculty great satisfaction, which translates into an improvement in their skills and performance [23]. The use of ICT in the classroom generates great interest in the students, improve their spatial comprehension, visual education, performance and overall satisfaction [23]. ICT are having a demonstrable positive effect and are rapidly changing class participation, the interaction between students, and collaboration between them and classes in higher education. There is a clear need for new ICT strategies and innovation in the teach-

ing of construction [16]. It is important for Academia to be linked to Industry, but it should be at the forefront of the evolution [24] and not slowly following developments in the industry. Education should be supported, planned, maintained and reviewed by governmental policies in order to see innovations in teaching, minimization of difficulties in introducing ICT, and improvement in both access and skills of faculty and students [22]. The training and improvement of faculty skills are one of the keys to the proper introduction of ICT at the university level. If faculty motivation and attitude are not positive towards ICT, changes will be nearly impossible [22].

Most of the AEC industry's problems can be linked to the lack of R+D+R around the world [16]. The AEC industry requires ICT and BIM skills; therefore, faculty should use the new ICT efficiently [25] in order for our graduates to succeed beyond graduation. Technicians should be able to update their ICT skills, collaborate and work in interdisciplinary environments [24].

There is a gap between the current skills used in the AEC industry and the knowledge and skills being taught in higher education [26]. This split is growing as most universities continue the same traditional methodologies, ignoring the interdisciplinary and collaborative processes introduced by BIM [27]. AEC students in the USA, Europe, Australia and the Middle East are taught in closed departments in an isolated environment, with little or no collaboration among different disciplines [28]. This affects the industry as these students graduate and enter the workforce with inexperience in developing an overall view of the project, which in turn creates problems in the collaboration and interaction between the different disciplines and professionals involved in a project [16]. Few universities began teaching BIM between 2006 and 2009; although now there is an increase in the number of departments introducing BIM, this is being done without a common methodology, level or framework [2].

A key change that must occur is an increase of interaction between students and faculty in the classroom, which will lead to greater student motivation. This will require a radical, fundamental, methodological shift by the faculty of the class, to change from being the storehouse and source of knowledge to a guide who can facilitate student learning [16]. The current methodology is not optimal for transmitting knowledge [29]. It develops skills, which may soon be outdated so that by the time students graduate they will lack the required digital skills and the skills they do have will be obsolete [30]. This is due to the fact that the current educational system was designed before the advent

of the internet and ICT, which provided global information and allowed for greater collaboration between disciplines [31]. Digital native students are eager and willing to use ICT and have good skills [32], so faculty should use ICT a tool for learning instead of increasing the generational gap [33].

Although most programs are currently developed using CAAD instead of BIM [34], BIM actually increases the motivation and satisfaction of the students [35] because they see it as intuitive and easy to learn [33, 36]. Current students find 2D drawings difficult to understand [37] and this creates mistakes and misinterpretations by the students. These problems directly impact the industry [38]. Therefore, student ability to use ICT should be regarded as a critical means to improve performance and create innovative teaching methodologies—using the students' own digital native skills to create better professionals [16].

## 2.2 BIM in the AEC curriculum

BIM is a new platform for accessing information in a project, where all involved professionals can access a unique model, which houses all pertinent information and data, therefore the project can be developed in different aspects at the same time [40]. To achieve complete BIM implementation in the AEC curriculum, it should not be considered a skills course, but rather fully integrated as part of the Architectural, Engineering and Construction process, as explained by Taylor and Barison [41, 4]. Barison [2] provides quantitative data for BIM implementation in higher education institutions—BIM is introduced in the architecture curriculum incorporated into the design studio, digital representation and construction management courses, while in engineering it is also included as a BIM-specific course.

Most studies divide the implementation of BIM into three main stages, with some differences from one author to another. Hietanen [42] states that BIM principles can be first introduced into a subject and then between disciplines. Kymmell [39] suggests three stages, where the first two years of the program would focus on building the individual skills of modeling and analysis; these would lead to a teamwork collaboration phase and then in the final phase interaction with third parties. As Barison [2] explains, BIM implementation in the AEC curriculum lacks comprehensive data and currently each college and program are working individually toward BIM implementation. The “buildingSMART” community—with international chapters committed to establishing industry standards, the Academic Interoperability Coalition (AIC)—with members from more than 40 higher education institutions all over the world, and many other

research groups are grappling with the idea of a establishing a common framework for the BIM industry and Academia.

The interest 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 [43–46]. Published research in the BIM field has likewise seen a marked increase [47]. 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 [48]. However, research to date, while covering a broad range of topics and issues within BIM, both technical and non-technical, [49] 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 the university curricula.

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 [48].

The increase in published articles in BIM research was confirmed, as two (2) publications were noted in 2007 and fourteen (14) in 2014 [50]. 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*” [50]. Their studies show a steady increase in publications since 2012 (doubling from seven (7) papers to fourteen (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*” [51] at the Human Computer Interaction conference in Toronto, Canada, and “*BIM Implementation at the Building Systems Course at the United Arab Emirates University*,” 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, are 65% and 35% respectively [50]. 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 growing, the number of studies on pedagogical issues of BIM-based collaboration and object-based platforms in architectural education is relatively small [50]. 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.

### 2.3 Hybrid methodology

Historically quantitative and qualitative methods have been the main means of scientific research. A hybrid approach to experimental methodology has been developed that sees methodological problems more holistically: the mixed-methods research approach. This model is based on a pragmatic paradigm that considers the possibility of combining quantitative and qualitative methods to achieve complementary results [60]. The value of research lies not so much in the theory behind the research method but in its practical effectiveness [52]. On one hand, quantitative research focuses on analyzing the degree of association between quantified variables, as promoted by logical positivism or verifiable empirical observation. Therefore, this method requires induction to understand the results of the investigation. Because this paradigm considers that phenomena can be reduced to empirical facts that represent reality, quantitative methods are considered objective [53, 54].

On the other hand, qualitative research focuses on determining and processing intentions. Unlike quantitative methods, qualitative methods require deduction to interpret results. The qualitative approach is subjective, with the assumption that reality cannot be reduced to a universal indicator [55]. Qualitative methods have traditionally been associated with the social sciences because of their consideration of human factors. The mixed approach proposes integrating quantitative and qualitative approaches, aiming for greater facilitation of interpreting experimental results. This combination of quantitative and qualitative experimental methods leads to a wider variety of results

since it includes human factors as well as numerical results as the basis. The ability to work with both types of information concurrently in an individual study offers a great advantage to a research team: multidimensional outcomes facilitate the development of possible solutions and further research steps in a given field of study [11].

### 3. Comparison of introducing BIM based on REVIT at UAEU and AURAK

In order to properly understand the introduction of BIM in different programs and the difficulties involved in modifying an existing program, which has been running for years, we decided to compare the UAEU trial with a new program which is still being developed and where most of the professors are willing to include BIM. The introduction of BIM into the program is not an easy task, as the program curriculum was determined and set years ago without the inclusion of BIM. AURAK is in the process of obtaining the United States (US) National Architectural Accrediting Board (NAAB) accreditation, which creates another layer of complexity and makes any changes additionally difficult.

The biggest difference between the circumstances at UAEU and AURAK is the will of the professors. Out of twenty-two professors at UAEU, four were willing to teach and help students acquire these new skills; three agreed to use BIM as long as no extra effort was required on their part; and fifteen rejected the idea of including BIM outright, because they were not convinced of its benefits or were not personally motivated to improve their skills and make substantive changes to their courses. At AURAK, out of six professors and three teaching assistants, three professors and all three teaching assistants agreed to help students improve their BIM skills and to attempt to introduce it by modifying the desired courses. Of the remaining three professors, one recognizes the importance of BIM implementation but has not improved his skills

choosing to rely on others, and the other two have no interest in BIM at all.

From the data, only 18% of the professors at UAEU were willing to introduce BIM, and only one of those is a head professor in the core courses. Looking at this data and the research from Barison and Kymmel [4, 39], we hypothesize that one of the chief problems is that after a long period of teaching a course, some professors are reluctant to improve their skills, change the design of their courses or alter their traditional, established way of working. It is easier for professors to introduce new skills into new courses, as they already are designing the courses from scratch.

Although it was decided in a departmental meeting at UAEU to introduce BIM based on Revit skills in six core courses, Fig. 1 indicates that it has been done only in one. In that one, the desired level was not achieved, as it was not the first course. Based on the surveys done in this research, we can say that 90% of the students arrived at the BCC course with literally no Revit or BIM skills and no knowledge of the underlying concepts. This forced us to modify the BIM lectures from an intermediate level to a basic level in order to properly introduce the topics and develop their skills from the beginning stages. Therefore, we could only accomplish 70% of the anticipated results in 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.

The introduction of BIM in the AURAK program has been done progressively and is still not complete. During the fall of 2016, half of the students in the course were creating 2D models using CAAD programs and the other half BIM using Revit. By the fall of 2017, the entire course used BIM skills with Revit for 2D or 3D models, and collecting all data and information of the project. In the fall of 2016, we switched the format of Construction II from a traditional course to using BIM, adding site visits to the course, in the fall of 2017, in

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

Fig. 1. UAEU and AURAK course structure.

order to improve student comprehension. 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 students learned how to use BIM to improve project management, 4D simulation, clash detection, and solar and sustainable energy performance analysis.

Comparing the topics covered in both university programs, we can see they are basically the same. However, at AURAK, since there is more support from the faculty, the students accumulatively acquired the skills through a progressive learning experience, reaching a deeper level of understanding of the BIM concepts. Therefore, it is clear that faculty is the most critical element in seeking to change and develop BIM courses and curriculum. On the other side, the student motivation and satisfaction will give them the determination to improve their skills and continue increasing their knowledge from using a BIM model in a course to creating and maintaining a collaborative working environment in the Graduate Project (GP). Then, this will be reflected in their professional work in the AEC industry.

### 3.1 Comparative examples

Several issues must be clarified before comparing the student work from both universities. The courses to be compared are BCC at UAEU, which focuses mainly on detailing, and Construction III at AURAK, which includes two extra topics—modular coordination and long span structures. The traditional method of class instruction is used in the BCC course at UAEU, a combination of lectures, individual research and AutoCAD drawings. In the last five weeks, they learn how to create details in a 3D/2D BIM model using Revit as a tool to develop the details and include information about the local materials they found during their research. In the Construction III course at 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 on a certain level to compare two

courses quantitatively that are not entirely the same, however, this paper regards the results of each course as qualitative data for consideration and analysis. First, we will present a collage of selected course assignments by a successful student from each course, then a detailed review of each course to analyze both outcomes.

#### 3.1.1 BCC Course at UAEU, Assignments

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

The first BIM assignment in the BCC course is the design of the structural system of the house used throughout the course, as shown in Fig. 2. In the second assignment, the students have the task of defining three details in 2D and 3D, and must include all information found while completing the research assignments, as shown in Fig. 2.

#### 3.1.2 Construction III course at AURAK, Assignments

The Construction course is offered in the second semester, and for the first time is given using BIM. In this course there was one site visit, as shown in Fig. 3; this is planned to be included on a more regular basis throughout the next semesters, hopefully with better notebook results. There are five BIM assignments, including modular coordination, a long span case study (Fig. 4), a long span application (Fig. 4) and two final assignments which require detailing (Figs. 4 & 5). All 2D drawings are created from a 3D BIM model, based on 3D objects, which hold materials, physical properties, costs, and more information from the project.

#### 3.1.3 Detailing comparison UAEU/AURAK, Assignments

Comparing the samples in Fig. 5, we can see that the level of 2D detailing is similar in both universities. This suggests that both traditional and BIM project-based learning produce similar 2D and construction learning outcomes. A difference is noted when considering the level of the BIM models created by the students. The traditional teaching

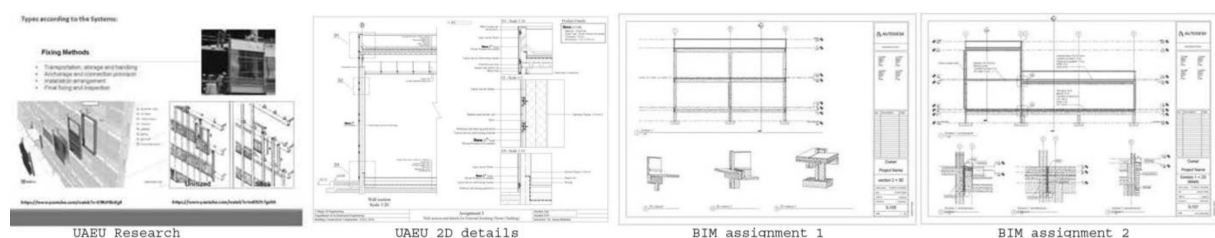


Fig. 2. BCC assignments.

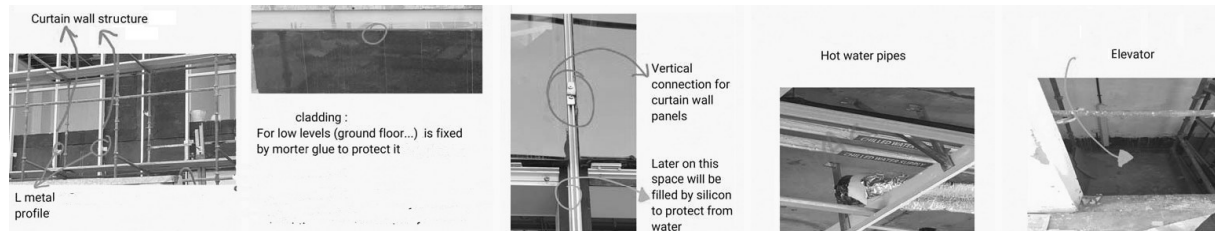


Fig. 3. Site visits at AURAK Arch331.

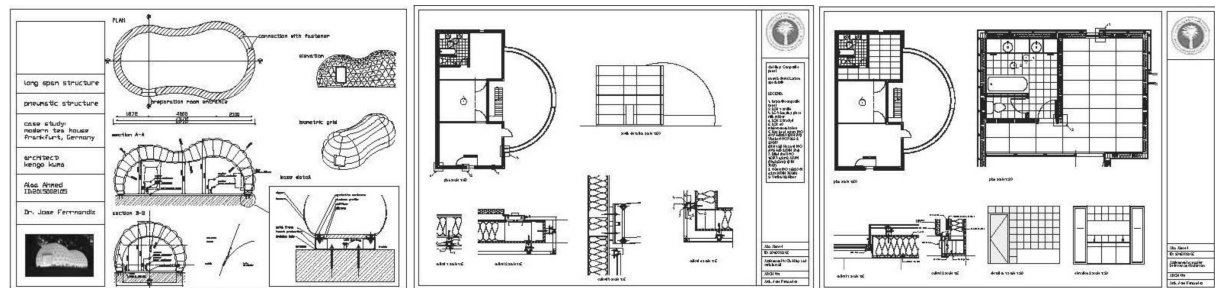


Fig. 4. AURAK Arch 331 examples.

methodology produces a good level of understanding of construction that is evident in the students' work; however, the BIM models produced are very basic, and in fact, could barely be considered BIM models because they hold such a low amount of information. Project-Based Learning using BIM provides students the same construction capacities as well as experiencing a new working environment methodology, and they create a BIM model which will hold most of the information and data related to the project.

This model can generate 2D or 3D views of each element and could be used to produce most of the construction, maintenance and demolition processes, in addition to a quantity survey and solar, energy performance, and structural analyses. The recommendation generated by this comparison is that the introduction of BIM into the AEC curriculum should be done with a re-design of the course. It results in a level of student knowledge that is comparable to the level that is achieved with the traditional teaching methodology, while simulta-

neously providing a BIM collaborative working environment that our students will need when they become industry professionals.

### 3.2 Comparison of performance improvement data

In considering the outcomes of both courses—a traditional course and a course conducted in a BIM learning environment, the comparison leads to the hypothesis that students will gain the same construction knowledge in both courses, but in the second course, they will additionally acquire BIM skills. In order to test this hypothesis, we will further compare the two courses by examining the deviation of student grades in each of the courses, determining the direct effect of the different course methodologies on student performance.

The same mixed methodology will be used as has been previously explained. To achieve a proper evaluation of student performance, we will observe several groups of students as they go through each modification of the courses, comparing and analyzing their grades and any other observable changes.

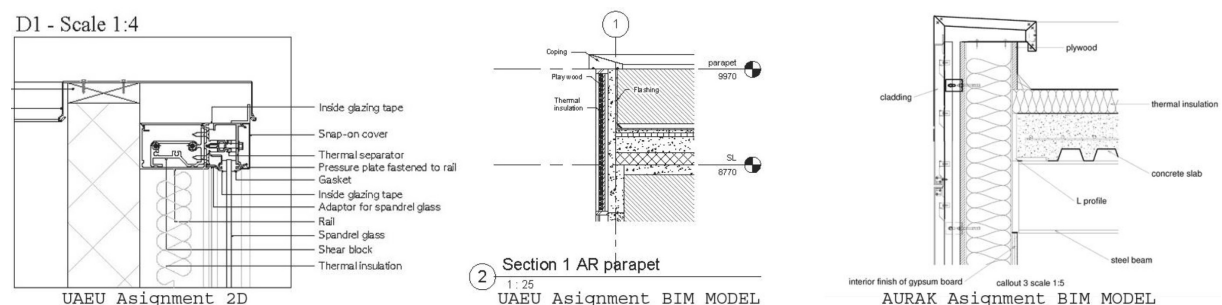


Fig. 5. Detailing examples comparison.

The grades are divided into theoretical, practical and final for each course, and are collected directly from the lead instructors. This will ensure the same evaluation criteria and approach for all. Our performance assessment process is a continuous follow up of the construction course as it is modified, to evaluate the variance of student performance with each iteration. This quantitative data is analyzed along with two types of qualitative data—samples of student work and interviews with three student randomly selected from each group to obtain feedback about the course.

The statistical analysis of their performance in this study uses independent samples represented as two different groups of students at the same stage of the curriculum. We use the two-sample comparison as developed by Wilcoxon in 1945 and Mann-Whitney in 1947 [57–59]. These tests are more accurate for non-normal distribution than the usual P-test and Anova. Student performance is additionally evaluated where the grades are measured on a scale from 0 to 100 points.

In the BCC course at UAEU there are three different course methodologies under review:

- Traditional methodology;
- BIM approach 1, following the traditional methodology but dividing the lab sessions—half traditional and half BIM, each part with its own exercises;
- BIM approach 2, following the traditional methodology but dividing the lab sessions into six blocks, the first block merging some exercises in order to reduce the total number while maintaining the same content, and the last 5 blocks 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.

### 3.2.1 BCC course in the UAEU

The completed analysis focuses on student academic performance in the course of “BC” Construction 2, incorporating BIM into the curriculum through Autodesk products. To achieve this, we examined the variation in student performance with

each semester, taking into account the incorporation of different tools, the timeline of their introduction, and any other modifications in the methodology of the course. This will generate an analysis of the global level of the group and the effect on their performance by adding Revit—that is, incorporating a BIM tool into a construction course that was originally designed to be taught using AutoCAD. The difference between these two is that while AutoCAD is a drawing tool, Revit is a BIM tool, which allows for the building of a 3D model while also incorporating information about the project, such as physical properties, the cost of materials, and energy efficiency.

The three different methodologies towards BC course instruction that we are studying and comparing are divided among student groups as follows:

- Groups 1 and 2 (G1 and G2) experienced the course as they had in prior years before the introduction of BIM at UAEU, using AutoCAD as a production tool;
- In group 3 (G3), because of the instructor’s insistence not to modify the course and continue as before, it was decided to carry out the same course with the same exercises, adding on Revit and other new tools;
- For groups 4, 5 and 6 (G4, G5, and G6) the course was reorganized so that the standard exercises of the course and the BIM assignments did not coincide. In order to reduce conflicts, the AutoCAD exercises were combined to reduce the total number, and the introduction of Revit was delayed until the last five weeks of the course instead of integrating it throughout. The study at UAEU finished during the Spring 2017 and it was not possible to collect data from the G6 at the ABS course.

Reviewing the data there is a very clear initial analysis: introducing BIM into a course designed for another ICT without modifying anything is a disaster. This attempt split the students into two groups, those who failed or left the course (which somewhat held the average) and those who adapted and received very good grades. This clearly indicates that it is not a successful learning method. The increase in the teaching load had a polarizing

Table 1. UAEU performance descriptive statistical analysis

Variable	Obs.	Min.	Max.	Mean	Std. deviation
ABS G1	12	65	78	72	4.403
ABS G2	16	61	79	71	5.407
ABS G3	5	60	70	66	4.336
ABS G4	14	64	82	74	4.994
ABS G5	20	31	92	80	12.588
ABS G6	–				



effect, causing increased productivity in good students, but frustrating the rest and leading them to struggle or even surrender and abandon the course midway.

In the analysis of the second method, we see student performance increasing in each new semester, presumably due to the maturity of the material and the introduction of new tools such as video tutorials for tools and elements that are more complicated. The G4 data confirm that student performance in the course without BIM recovered and G5 and G6 saw their performance improve by 5%. It is notable that G6 is the lowest performer in the BS course, whereas they obtained the best performance in the BC course; this may be due to the change of instructor in the previous section of the practical part of the course, who evaluated the students more strictly. This would suggest that the performance of the students had not fallen, rather the evaluation criteria changed with a new instructor, which resulted in a different grade range.

As for the statistical analysis in 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, or 100%. G3 is different from all the others as observed in the descriptive data, because of the split between students who excelled and those who did not reach the minimum level or dropped the course. G5 and G6 are increasingly different from G1 and G2 because they are improving over the performance of the previous groups. However, we can verify that G2 and G5 are still quite similar although the average of G5 is higher.

### 3.2.2 Construction III course at AURAK

The Architectural Program at AURAK is new and the CIII course has only been offered for two semesters. The first semester the course methodology was traditional, in line with a standard course of construction with lectures and AutoCAD 2D drawings, while in the second semester a project-based learning environment based on BIM and Revit as a tool was introduced.

In the data analysis outlined in the following table, the first line corresponds to the traditional teaching methodology and indicates that this method produces more regular outcomes from the students than BIM. Some of the students had difficulty in acclimating to the new working processes, as this was the first semester in the university where BIM has been applied, even though the average and the statistical analysis provide us a 95% of certainty that both courses ultimately have a similar performance. The analysis indicates that student performance was constant when we added BIM skills and conceptual knowledge in addition to the construction information already present in the course.

This is encouraging and inspires us to continue the BIM introduction process. We must recognize that to increase the level of student understanding of BIM and the acquisition of necessary skills, a course should be designed from scratch to introduce BIM. The data have shown that the students will not lose any construction knowledge, but the students' point of view will also be considered to confirm whether the BIM tool also helps them to comprehend the construction concepts explained during the course.

**Table 2.** UAEU performance statistical analysis (p-values)

p-values:	BC g1	BC g2	BC g3	BC g4	BC g5	BC g6
BC g1	<b>1</b>	0.793	0.866	0.994	0.275	0.173
BC g2	0.793	<b>1</b>	0.360	0.987	0.934	0.628
BC g3	0.866	0.360	<b>1</b>	0.514	0.082	<b>0.026</b>
BC g4	0.994	0.987	0.514	<b>1</b>	0.525	0.237
BC g5	0.275	0.934	0.082	0.525	<b>1</b>	0.919
BC g6	0.173	0.628	<b>0.026</b>	0.237	0.919	<b>1</b>

**Table 3.** AURAK performance statistical analysis

Variable	Observations	Minimum	Maximum	Mean	Std. deviation
78.9	12	76.400	92.500	85.167	4.885
68.2	6	74.200	98.200	85.800	10.644
Mann-Whitney test / Two-tailed test:		The p-value is computed using an exact method. Time elapsed: 0s.			
U	30	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.			
U (standardized)	0.000				
Expected value	30.000				
Variance (U)	90.000				
p-value (Two-tailed)	0.959	The risk to reject the null hypothesis H0 while it is true is 95.93%.			
alpha	0.05				

### 3.3 Interviews

Interviews were conducted only for those courses where we introduced BIM. We will separate the results by the different course methodologies, collating 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 Pena [40].

#### 3.3.1 UAEU method 1 (1 group, 3 students interviewed)

- 66% of the students interviewed did not finish the BIM assignments with the tools required, instead, they used the tool that they had been utilizing for the non-BIM assignments;
- None of the students interviewed had previous experience with BIM or skills with BIM tools;
- All students wanted more BIM skills but felt there was not enough time to complete both traditional and BIM assignments.
- Half of the students mentioned that the BIM tools helped them better understand construction concepts.

#### 3.3.2 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 conducted in a rushed manner, and they would have liked to have had more time;
- 89% of the students mentioned that the BIM tools helped them better understand the construction concepts;
- Only 11% of the students interviewed had prior experience with BIM tools.

#### 3.3.3 AURAK method 3 (1 group, 3 students interviewed)

- All the students interviewed had some Revit knowledge, but had not applied these skills to construction or structures;
- All the students felt that Revit helped them understand construction concepts;
- As they improved their BIM skills their work speed increased with each assignment;
- All the students asked for YouTube tutorials to be added.

## 4. Conclusions

This study yielded some important results regarding the proper approach to introducing BIM into construction courses. The data reveal that introducing

BIM without making any course modifications results in a decrease in student performance; however, a minor modification of the lab sessions—dividing them into two blocks and dedicating one to the introduction and use of BIM tools—would be sufficient to maintain the level of student performance. This second method tested in the BCC course in the AE program at UAEU should be regarded as a success overall because even though the BIM knowledge acquired was less it was enough to encourage some 78% of the students to continue to work with the BIM tools and develop skills on their own.

The last method, in which the course itself was designed incorporating BIM as opposed to adding it in later, was tested in the Architectural program at AURAK. The results showed that if we design a course introducing PBL based on BIM skills, the students will gain more knowledge of BIM while keeping the same level of performance and acquired construction knowledge. The students from the second and third method indicated during the interviews that the 3D BIM model helped them to understand better the construction concepts explained during the course. This means that it is not only a tool needed by the AEC industry, but it is also a tool to aid in understanding construction concepts in academia.

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