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LONG PAPER

Evaluating the benefits of introducing "BIM" based on Revit in construction courses, without changing the course schedule

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Abstract Recently, the building industry has shown great interest in building information modeling (BIM) due to the many benefits BIM provides. During the last decade, the government of Dubai has been working toward a BIM environment, where any new building project that is ten floors or higher shall be submitted in BIM format. The need for BIM creates more job opportunities for technicians with BIM skills. This inflates the need to prepare related field engineers with BIM background before graduation. This report analyzes the implementation of BIM in a construction course, which is currently using AutoCAD, by splitting the laboratory skills. Through this implementation, we will test whether adding BIM based on Revit to a currently existent course will improve the students' motivation, performance and satisfaction. The authors use the results of the Architectural Engineering (AE) students at the United Arab Emirates University (UAEU) in construction courses to study the performance before and after implementing BIM. The authors found some issues, which can decrease the students' performance with a 97% certainty. The students' motivation and satisfaction was tested using a pre-test/post-test quasi-experiment design. The tests showed that BIM based on Revit reduces student performance time while increasing student motivation and satisfaction. The causes behind the last statement were analyzed with the use of interviews with related students.

Keywords BIM · AEC · Higher education · Mixed methods · Construction · User-centered evaluation · Motivation · Satisfaction

1 Introduction

Studies have proven that implementing IT technologies into the engineering curriculum is a common practice to enhance the students' motivation, satisfaction and performance. Architectural Engineering and Construction (AEC) industry has improved productivity since the 1970s by implementing IT technologies into engineering processes. Our study aims toward an implementation framework for the new information technology (IT) concept building information modeling (BIM) which the architecture engineering construction industry demands from graduates. This research studies the effects on the students of this new subject at the Architectural Engineering program. BIM is a very complex concept, which leads to a collaborative work environment, and creates an easier approach to the universal access of the architectural information, due to this cooperative environment.

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BIM has many definitions; the National BIM standard of the USA [1] defines BIM as "BIM3" because it has three different related concepts named by the same program. Building information modeling refers to the process of generating building data to design, construct and operate the building during the life cycle; the BIM simulates the digital representation which includes all the data that the shareholders will use the same information in order to produce, manage and make decisions; and finally BIM, is the organization and control of the process using the information supplied by the digital model.

The BIM concept has shown many benefits since the 1990s when it was first introduced; however, building modeling based on 3D solid construction was introduced in the 1980s. BIM helps shareholders to be involved at an earlier stage, interacting from a distance and using real-time data at every stage of the project to help clear conflicts earlier. Furthermore, BIM helps to improve working efficiency, estimates accuracy, decision-making and project schedule. On the other hand, not too many professionals are aware of BIM in the Middle Eastern region. According to Banawi [2], various reasons that could delay the implementation of BIM in this area include legal barriers, high implementation costs, workforce qualifications, work process and model management. The government of Dubai in the United Arab Emirates recently raised their demands to implement BIM to all building projects that are higher than ten stories. According to a recent report released from Dubai's chamber of commerce, some projects are already built and many are approved to be constructed in the near future using BIM.

The United Arab Emirates encourages all sectors including public and private to rely more on the local universities graduates, and therefore, most schools appreciate the industry feedback when developing the program curriculum. Recently, the Architectural Engineering (AE) Department at the United Arab Emirates University made changes to the course curriculum. A major change was introducing BIM into the building construction courses to be considered at the focus of the AE program.

This study hypothesis states that the introduction of BIM based on Revit at the intermediate course of construction will improve the work efficiency and the understanding of the concepts studied in the course. This will increase the students' motivation, satisfaction and performance. In order to test our hypothesis, we have formulated three main research questions, which will be tested in this study:

- Does the introduction of BIM improve motivation, satisfaction and performance of the student?
- Does the introduction of BIM improve future intentions to use this IT technology for students' projects?
- Can AutoCAD and Revit coexist in the same course?

2 Background

2.1 IT in higher education

Nowadays, IT is everywhere, changing our society, modifying the way people interact and behave. These technologies offer the possibility to access the information needed at any moment and everywhere almost instantly. However, the inclusion of new IT into the learning process is not an easy experience and does not always succeed. In fact, there are various documented problems and failures in educational IT implementation as illustrated in the articles by Miliken, Phui Fung and Educaweb [3–5]. Due to this difficulty, there is a wide variety of articles which address this issue from different points of view, including for example Rogers and Bates [6, 7] regarding the teaching methodology, content design and effectiveness on IT technologies in higher education implementation, Kymmell and Chang [8, 9] targeting the main barriers, and SERC, Redondo and Valverde [10–12] which are specifically targeting "good teaching practices."

All efforts toward the implementation of IT into the engineering curricula are targeting the improvement of the students' learning process. Certain "good practices" based on the studies mentioned previously as well as Fonseca and Redondo [13] define specific recommendations which should be considered, including the following:

- Promotion of more communicative professor–student environment, allowing more interaction and effective feedback process;
- Dynamic development among students, 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.

We have to understand that new technologies evolve constantly and it is very important that the students interact with them and the professors, in order to engage and involve them into the process.

2.2 ICT evolution in the AEC

Using and assessing Information and Communication Technologies (ICT) as part of the educational methodology is a common practice at many undergraduate and master's program curricula, including architecture engineering, which is the focus of our study as well as Guney, Gorghiu, Wang and Reffat [14–17]. The architectural teaching method must be approached as a combination of tradition and technology, where one cannot be understood without the other; even though there is a lot of controversy whether the design can be started only by traditional methods or it can also be done using IT tools, no one addresses the fact that the application of IT in AEC processes is a must. The introduction of these technologies at the academic level also involves a very tough debate with two clear sides from those who consider IT as a tool to enhance AEC industry and those who consider it as a part of the AEC process itself.

ICT development at the AEC industry, evolved during the twentieth century totally changing the way we represent, create and deliver building project information. The process-working environment has constantly been developed from a paper-based one to the actual BIM interdisciplinary and collaborative team-working environment.

As Oxman [18] states, the main difference between paper-based and digital-based design is the cognitive process during the evaluation of the two designs. While the original design process was clearly defined and took place mainly at the designers' mind, digital design offers alternatives to develop the design and collaborate with the other shareholders.

The evolution of the representation tools has affected the nature of the information represented. During the study and initial stages of the digitally based representation, the information embedded was geometrical as Ibrahim [19] stated earlier generations of CAD software like AutoCAD only represented the geometrical properties of the architectural elements; while the introduction of Building integration management/modeling (BIM) added the value of integrating the information and graphics within the building model, new models add specifics 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 as Kocaturk explains [20].

In their paper [9], Yi-Feng and Shen-Guan present a thorough study of ICT evolution related to the AEC industry outlining the following five main phases:

- Mainframe age, 1960–1970, first research design experiments, with a very primitive computer, on a text interface, used mainly to record and calculate;
- Workstations age, 1970–1980, first drafting applications, still with a very primitive computer and a text interface, used as drafting tools and auxiliary tools to manufacture products;
- Personal Computer age, 1980–1990, appearance of the first Personal Computer and AutoCAD, which provides a quick and accurate 2D drafting tool, and the beginning of 3D modeling;
- Internet age, 1990–2000, improvement of the Personal Computer and creation and improvement of the tools to create, draft, model, calculate and manage the projects like 3Dmax, sketch up, Cype, Microsoft office or Primavera; early stages of collaborative environment at the design, production and management process, we begin to share information but it is spread into different tools, formats and files. Shareholders use their own tools and models, which are usually not compatible;
- Cloud computing age, 2000–2010, beginning of building information modeling, where all the partners will be able to share information in the same model, to design, develop, produce and manage the whole life cycle of the project.

This evolution also changed access to information and its availability. From the ancient times since the 1970s, few plans were produced by pen at the AEC industry. At the early stages of ICT, the plans could be printed as many times as needed, making it easier to communicate and share. The next evolution was to create digital files with the plans, scheduling and project documents that could be shared instantly through the internet and read at any place in various devices. Finally, BIM provides a new jump into the information access providing not documents but a working model itself with all the information of the project, to be reviewed, analyzed, and modified as needed.

As we can understand from this evolution, the AEC industry is developing tools and processes for designing projects based on the ICT. It is thus very important for the new generation of engineers and technicians to be introduced to the new trends as soon as possible as this evolution is accelerating fast, and they should be able to keep on track in order to successful in the AEC industry.

2.3 BIM at the AEC curriculum

As already stated, BIM is a new platform on the information access of the project, where all people involved can have access to a unique model which holds all the information, so that the development of the project can be done from different aspects of the project at the same time. To make this possible, the BIM implementation at the AEC curriculum should not be seen as a skills course, but rather integrated as part of the Architectural, Engineering and Construction process, explain Taylor and Barison [21, 22]. Barison [23] provides quantitative data for BIM implementation at higher education institutions, where BIM is introduced at architecture curriculum mainly in design studio, digital representation and construction management courses, while in engineering is also implemented as a BIM-specific course.

Most of the studies divide the BIM implementation in three main stages, which can vary from one author to another. Hietanen [24] States that BIM principles can be first introduced into a subject and then between disciplines. However, we have to take into account the three stages from Kymmell [8] where the first two years would focus on the individual skills of modeling and analysis; then, it will lead a teamwork collaboration phase; and finally interaction with third parties.

As Barison [23] explains, BIM implementation at the AEC curriculum lacks data, and each college and program is working on their own toward BIM implementation, although the "building smart" community—a worldwide standard community—the Academic Interoperability Coalition (AIC) with more than 40 higher education institutions all over the world, and many other research groups are dealing with the idea of a common framework for the BIM industry and Academy.

3 Case study

This study aims to be the first stage toward the creation of a BIM implementation framework in the intermediate construction course of the AEC curriculum. The analysis is done at the preliminary stage of the BIM implementation in the building components (BC) course of the Architectural Engineering (AE) department of the United Arab Emirates University (UAEU). This study aimed to validate whether BIM can be added to a construction course developed to use CAD or whether the course should be modified to fit this new technology.

The analysis of the course followed different approaches to understand the whole picture of students who are at an intermediate stage of their bachelor's degree. They were introduced to BIM based on a 3D model while continuing learning construction processes and developing details on 2D CAD software. The study was based on three steps. First, we analyzed the grading performance of the students throughout all construction courses before and after applying new IT. Second, we designed a pre/post-test experiment [25] to understand their motivation and satisfaction toward the use of this new IT. Finally, we interviewed students once they completed the construction courses. This helped us understand the results from the previous analysis and know their opinion about the tools implemented on the intermediate course and their motivation to continue using this new IT tool. These three steps will be explained in depth in the following section.

This study involved students at the construction courses in the Architectural Engineering Department (AE) of the United Arab Emirates University (UAEU). Three groups of students that already completed the three courses of construction were used. The first two groups served as a control group, and the third one is where the variable (IT) was introduced. The data collected from these students include the grades for all construction courses, motivation and satisfaction questionnaires, and interviews from students of the third group after they finished the advanced building systems (ABS) course.

3.1 Introducing Revit into building components course

Building components (BC) course is the intermediate construction course in the AE program of the UAEU. At this stage, the students study the construction components properties, specifications and application methods in order to be able to create their own details for their projects. During the BC course, students are introduced to different types of flooring systems, interior and exterior wall systems, false ceilings, building joints, vertical circulation and openings.

In our former course, before the introduction of Revit, each explanation was followed by an exercise where the students had to research about real products, their specifications and application method. Then, they had to select the best fit for their project and create their own detail by AutoCAD using the product selected.

The approach tested in this study is the simplest one. Revit is introduced into the course by splitting the laboratory sessions into two classes lasting for 1 h each. In the first hour, we kept the same course with the same content. The second part, involved Revit classes where the students have to develop their projects, test the products and create details. In this way, we introduce two different approaches developing 2D and 3D details at the same time. AutoCAD 2D detailing gives more freedom, while Revit 3D improves understanding of the construction elements and the way they fit together.

4 Data collection and methodology

Our research is a mixed-method study based on a quasi-experiment supported by a pre/post-test design implemented with grading performance analysis and interviews of the students. All data are used to quantify and understand the real effects on the students of the BIM implementation and the reasons for quantifiable data.

4.1 Performance based on grading

To create a proper assessment, we follow the performance of each group of students through all construction 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. As can be seen in Table 1, the performance assessment process is based on a continued follow up of the construction groups of students.

The first step for the performance assessment is 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 to compare. To test this assumption, we run a Wilcoxon–Mann–Whitney test comparing the final grades of BS course from the students of groups 2 and 3; none of these groups had yet been introduced to BIM, so we should get a *P* value near one. This will confirm that our different groups of students have a similar performance level in construction course.

The second course (BC) is the one where the new IT technology (BIM based on Revit) was implemented, which is our variable. Here we will check the difference of the performance due to the modification of the course tools. In this case, we will use the same test comparing Groups 1 and 2 against Group 3. However, the result of the P value should be near to zero. This means that their performance is different. We will also check the means of the groups, the standard deviation and type of distribution of the data to make sure which groups has a better performance.

Finally, we control the same group of students in the third course of construction (ABS) which has no modification, to check how the implementation of this technology in the previous course has an impact on the student's' performance in other courses without this new IT. In this case, we will use the same groups as in the second test, but we will read the values to check the results without an expected value.

4.2 Pre-test and post-test questionnaires for student's profile, motivation and satisfaction

The pre-test and post-test questionnaire design is based on the one developed and explained by Redondo and Fonseca [26, 27]. Those questionnaires were slightly modified with the supervision of one the original authors (Fonseca) to fit this research. The development of our questionnaires is explained on our previous work [25], and any questions about the tests should be answered there. Those tests are used to identify students' profiles, motivation with IT in architecture, satisfaction with the IT tool, satisfaction about the course and motivation to continue using this tool after the course has terminated to develop their projects.

The pre-test was delivered to the students in the third week of the course, once the number of students is final. The post-test was delivered during the last laboratory session before taking their final exams. Both tests could be filled in on paper and online as both tests include the same questions. The tests were created using the Google Forms tool. This part of the study quantified the student's motivation and satisfaction toward BIM technology. To analyze the data, we performed two types of studies.

The first study tested student motivation and satisfaction from those students enrolled in the BC course with BIM. Data were collected, after the BC and ABS courses (Table 1), to compare the evolution of the same group of students. Using the Wilcoxon ranked signed test and descriptive data analysis, we established the *p* (value), ranks, means and standard deviation. The second study compared the motivation and satisfaction, after the ABS course, of the students who did not use BIM at BC (Group 2) with the students who did use it (Group 3). To compare these two groups of students, we used the Wilcoxon–Mann–Whitney test and descriptive data analysis. Both types of analysis should be carried out for all the motivation and satisfaction tests.

4.3 Interviews

Students were interviewed after they finished the ABS course. The interviews were performed in a very relaxed environment at the UAEU, under the direction of Jose Ferrandiz. Questions were directed to find out and understand students' opinions about the BC course, suggested improvements, ways to deal with the use of two different IT technologies at the same time, their satisfaction toward BIM tools, their motivation and intentions to use Revit in their studies and future work and the need to implement Revit, or not, in the colleges.

At these interviews, the students had the opportunity to explain their reasons and feelings about the BC course, their performance, how they feel about using the new IT, and the reasons to succeed or not in the use of it. The data collected in the tests are quantitative, but they do not have the possibility to explain themselves. Therefore, after finishing all the construction courses, when they have the whole picture, they were given 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 would continue using it afterward.

During the interviews, the interviewer was taking notes of their comments. Right after finishing the interview, these comments were read to the interviewees to make sure that the notes were correct, giving them the opportunity to rectify any discrepancies, to make sure that they represent their real opinion. These opinions are summarized in the following section.

Table 1 Data collection schedule for each group of students

Group of students		Sp. 2014	Fall 2015			Spring 2015			Fall 2015			Spring 2016		
		BS	BS	BC	ADS	BS	BC	ADS	BS	BC	ADS	BS	BC	ADS
BIM in the course		No	No	No	No	No	No	No	No	Yes	?	No	Yes	?
1	Grades	*		Got				Got						
	Pre-test			Got				Got						
	Post-test			Got				Got						
	Interviews							Got						
2	Grades		Got				Got				Got			
	Pre-test						Got				Got			
	Post-test						Got				Got			
	Interviews										Got			
3	Grades					Got				Got				Got
	Pre-test									Got				Got
	Post-test									Got				Got
	Interviews													*

BS building systems course (1st course of construction), *BC* building components course (2nd course of construction), *ADS* advanced building systems course (3rd course of construction), *YES* the students have to use Revit as a must for some of their exercises, *NO* the students do not use Revit for their exercises

? The students can decide to use or not Revit, * data not available, but we are expecting to get it and use it in the research

5 Analysis and results

The results and analysis presented in this section 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 nonparametric analysis due to the small size of the study sample, which does not allow to test the normality of the data itself. The first study uses 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 [28]).The second study uses independent samples represented as the study comparing two different groups of students at the same stage of the curriculum. For those, we used the two samples comparison developed by Wilcoxon in 1945 and Mann–Whitney [29–31]. These tests are more accurate for non-normal distribution than the usual P-test and Anova. We have ran 13 tests divided in three categories, motivation, performance and satisfaction. Motivation and satisfaction tests were assessed on a Likert scale ranging from 1 to 5, (1—no interest/disagree, 5—very keen on it/totally agree). Performance is measured on a scale from zero to 100 points.

IT is supposed to help students engage more often and get motivated during classes, which leads to better performance and grades. The first test is to measure the student's motivation toward learning BIM using Revit platform for their studies and after graduation. Test 1.1 shows that the students from Group 3 (labeled as G3 in the tables) are more motivated to use Revit for their studies and future career evolves from one year to another. The data are 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 implies two groups of students with very different levels of motivation, one very motivated and the other not so motivated. The motivation of this group of students increased to over four in a scale of five with a low deviation after advanced building systems (ABS) course. This can be due to many factors, which will be discussed after the students' interviews. Test 1.2 shows that the level of motivation of the students of G3 is 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 students' confidence of BIM applying Revit to improve their grades. Students of G3 after BC had almost the same results with the previous tests. We found groups of students split into two subgroups. Referring to Table 2, we see that student performance is related to their motivation about Revit to improve their grades. The data from tests 2.1 and 2.2 show 90% confidence that the students who went through the BC course with Revit have a lower perception of this tool to improve their grades.

Table 2 Motivation—statistical description and analysis of results

Motivation													
Descriptive							Analysis						
Test	Variable	*N* Obs.	Min	Max	Mean	SD	*U* (independent) Z (dependent)	Expected value (independent)	Variance (*U*) (independent)	*p* value	Alpha	Confidence
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						
1.2	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						

The analysis of the motivation tests provides the first turning point to our research questions. The motivation of G3 students toward BIM increased after finishing the ABS course in comparison with the students of g2. Meanwhile, G3 students had less confidence on Revit to improve their grades than the g2 students did.

The performance analysis consists of three parts. The first (Test 3.1) of Table 3 is the performance comparison of the students groups to check whether the students have similar proficience for the construction courses. The statistical analysis shows that the students of G3 had performed similarly in the building systems (BS) course compared to the former group of students with a confidence of 96.4%. This result validates our hypothesis that the students' 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 performance of students from G3 decreased by 25% meaning that it splits 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 this 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 will provide some answers and recommendations that will be implemented in the next semester of the BC course.

On the satisfaction level, the students were asked about two main issues. The first was their satisfaction with Revit to develop their projects. The second 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 on student 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. However, this increase of G3 students' intention is still lower than the intentions of g2 students.

Tests 6.1 and 6.2 were about intentions to use Revit to deliver projects after graduation. BC G3 data show that the

Table 3 Performance—statistical description and analysis of results

Performance														
Descriptive							Analysis							
Test	Variable	*N* Obs.	Min	Max	Mean	SD	*U* (independent)	Z (dependent)	Expected value (independent)	Variance (*U*) (independent)	*p* value	Alpha	Confidence
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 4 Satisfaction—statistical description and analysis of results

Satisfaction												
Descriptive							Analysis					
Test	Variable	*N* Obs.	Min.	Max	Mean	SD	*U* (independent) Z (dependent)	Expected value (independent)	Variance (U) (independent)	*p* value	Alpha	Confidence
BIM based on Revit to develop their projects												
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	24,770.143	0.002	0.05	99.8%
	ABS-G3	52	2.0	5.0	3.827	0.879						
Tools usage for the 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	BC-G3	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						

students are neutral, though with a high deviation. This effect is seen in all data analyzed for BC G3. Creating two groups of students is already explained. The statistical data of the 6.1 and 6.2 test show increased student motivation with Revit and intentions to use it in their future projects compared to G2 students. This increased effect continues after finishing the course.

5.1 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, even the ones who succeeded in using Revit agree that they need 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, 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 are 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;
- 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 come up with a set of recommendations for implementing BIM for better outputs. These recommendations will be discussed in the next section.

6 Conclusions

The students believe that BIM improves their work efficiency and the understanding of the course materials, which lead them to improve their motivation and satisfaction in the use of Revit. We did not accomplish, however, the improvement of their performance at the course due to the students' lack of skills with the new ICT and the wrong approach of the course. The building components course should be redesigned to use several ICTS as delivery methods. A deep analysis of the results concludes that:

- From the group who used Revit during the building components (BC) course, motivation decreased during the c 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 ICTs simultaneously, which can deliver similar outputs, so they dropped the ICT in which they had fewer skills;
- The satisfaction with Revit to develop their projects increased since they began to use it and is constantly growing as they improve 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 time. This situation confused those students. Students explained in the interviews that currently they are highly motivated and they would rather have that course separating AutoCAD and Revit in two different stages of the course;
- The intention of using Revit in their future projects grows at the same time as their skills due to the work efficiency improvement.

A conclusion regarding 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 will improve not only student motivation and satisfaction but also their learning process and performance. Due to this recommendation, the BC course has been redesigned totally to fit both IT tools without overlapping them.

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