Using new tools for building construction teaching during the sanitary emergency

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Abstract. Covid-19 pandemic has originated that a great number of countries' governments demand universities to teach online classes, presenting a challenge to redesign the courses that had construction site visits included in the curricula. The purpose of this work is to present the successful strategies employed on the teaching of building construction, applied in a third-year civil engineering program of the Pontifical Catholic University of Peru. The methodology was designed so that one can adapt the pandemic and post-pandemic stages proposing a balanced use of virtual platforms and software for video conferences and laboratories, incorporating tools like Building Information Modeling, Lean construction, among other systems. Given the sanitary emergency, the construction site visits were replaced by virtual visits to construction projects generated with scanner laser technology, photogrammetry, and BIM, generating digital twins that were stored in online platforms. Students toured the construction project virtually and in an interactive manner, and along with the description of the professionals in charge of the project they were able to reach a good level of comprehension of the organization and the construction processes. In addition, students developed the layout plans of the temporary works with BIM models. On the other hand, the course taught to generate and analyze the unit prices and quantity surveying of activities using the BIM methodology with 5D software, developing the project budget. The success of this methodology is shown through the notable quality of papers and evaluations taken, through the results of surveys taken on students—which had an effectiveness rate of 96.4 % --, and on the improvement opportunities determined. This paper presents tools relevant that may be adapted by the academia and practitioners related to building constructions, for virtual or face-to-face learning.

Keywords: Teaching, New tools in education, Construction Management, Building Information Modeling, Lean Construction.

1. Introduction

Covid-19 pandemic has arisen in a great number of countries governments, Peruvian among them, to demand universities to teach online classes [1] presenting a challenge to redesign the courses that had construction site visits included in the curricula. In fact, there is a need to implement an integrated vision of virtual education that combines the technology currently available to support teaching and learning [2]. On the other hand, in the construction sector, there is a challenge with using collaborative platforms, having remote access to computer laboratories and that students use the software needed for the course in their personal computers [3]. Moreover, there are previous experiences of solving the challenges of
this complicated context with the use of BIM technology based on real projects [4]. However, it still lacks the integration with the many management systems tools in the construction phase.

The purpose of this work is to present the strategies successfully applied to the teaching of the course Building Construction-- now called “Economic Evaluation of Building Projects” -- applied during the pandemic in a third-year civil engineering program at the Pontifical Catholic University of Peru.

2. Course Description
Before the pandemic, the teaching methodology was face-to-face and it consisted of the development of classes, laboratories, and construction site visits, where the construction processes were observed and discussed as well as the unit costs. On the other hand, since 2019 research results of the GETEC research group have been incorporated into the course syllabus, especially the ones that were generated by tools and technologies applied in construction projects. However, once the pandemic started, according to the norm it was mandatory that classes, laboratories, and evaluations were virtual [5]; thus, there was a need to design a methodology based in tools and technologies that allowed the development of competencies and soft skills in students, that were also valued by the industry increasing their employability. For this reason, a flexible integration of construction management tools was proposed, which were combined allowing a work team to operate efficiently, according to the Lean systems [6, 7], Project Management Institute [8], Building Information Modeling (BIM) [9, 10], Prince2 [11], among others.

In addition, an assessment of the technologies currently being applied in the industry was performed, to determine what would be compatible with the course and most beneficial for students.

3. Technologies

3.1. Building Information Modeling (BIM)
BIM is a methodology that integrates the 3D model of a construction Project with geometrical and/or parametrical information and is defined as the shared digital representation of the physical and functional characteristics of any object [9]. BIM describes the tools, processes and technologies that generate the digital documentation for rates, planning, construction and functioning of a building argumentation, idea discussion, decision making, among other communication factors [12]. The BIM focus is based on collaborative planning, argumentation, idea discussion, decision making, among other communication factors, which develops soft skills in participants, and thus, increases the student’s employability.

3.2. Virtual Reality (VR)
Virtual reality (VR) is a visualization technique that may be immersive or non-immersive, and it offers a series of applications, from entertainment to marketing, and in this case, building construction [13]. The use of VR and the creation of digital prototypes (digital mock up) for design review are being used more each time during the design and construction phases [13]. Moreover, every day the number of virtual reality software that is compatible with BIM technology of common use is increasing [7, 14].

3.3. Laser Scanning
Laser scanning is a method usually used to determine the position of an object, and data surveying which can be then exported as a point cloud [15]. The terrestrial laser scanners allow the surveying of the 3D position of an object’s surface and is a usual technology for studying 3D information of construction projects [15]. The laser scanning may later be complemented by photogrammetry of the surfaces where the scanner does not provide enough detail. Both laser scanning and photogrammetry are widely used in projects and aerial photogrammetry through unmanned aerial vehicles (also known as drones) is often used to obtain the orthophotos of surfaces [16].

The information generated by BIM, virtual reality and/or photogrammetry may be converted into the same format, with several technological applications, which make this conversion more automated each time [17].
The technology described was used by our research group in several projects [14, 17, 18, 19]. Case studies were shared with students for a more in-depth vision of the application of the tools and technologies imparted. This was the case of the Architecture Faculty project, which consisted of an extension of an already existing building (see Figure 1). The technology applied for this case study was laser scanning, point cloud importing, 3D, 4D and 5D BIM Modelling.

![BIM Model in Autodesk Revit of the Architecture Building](image)

**Figure 1.** BIM Model in Autodesk Revit of the Architecture Building

4. **Methodology**

The syllabus needed to be updated for the pandemic times, adapting the integration of the tools proposed in [6, 7, 8, 9,10,11] with the following steps:

4.1. **Step 1 - Syllabus Revision:**
Starting from the needs, principles, and values analysis of the following stakeholders: students, industry, public and private institutions, users, and society as a whole. Moreover, the laws, norms, statutes, regulations, accreditation guidelines, among other guidelines were reviewed and taken into consideration. With this information, the conceptual design alternatives and course preliminary content were generated in an iterative manner.

4.2. **Step 2 - Syllabus Re-design:**
With the information generated on step 1, the processes are designed and the infrastructure and available technologies of the university, the technological capacity of the student body and the existing logistics are preliminarily evaluated in order to prepare the investment and agreements with the providers according to the budget institution. Along with this evaluation, the initial proposal of the course modification is validated.

4.3. **Step 3 - Employability:**
The profiles of graduates demanded by the industry and institutions are taken into account, since they will ultimately be assessing the competencies, soft skills and use of technology according to the market changes. During the professional exercise of graduates, the environment is dynamic thus the content, tools, and technologies used in the course must be flexible enough for them to adapt to any possible scenario.

4.4. **Step 4 - Course Logistics:**
The results of the previous steps serve as an input. The internal and external available infrastructure is analyzed for both the university and the students. This included hardware, software, agreements with providers, among others, finalizing the logistics management with the design and proposal of laboratories as a fundamental part of the course and complement to classes.
4.5. Step 5 - Laboratories proposal:
During the course, students were expected to virtually assist 5 laboratories. For this, the university’s Moodle platform named Paideia, as well as the Zoom Platform were used. In Paideia teachers uploaded all the content of the course, the folders where students turned in their assignments and the links for the zoom meetings. Zoom, allowed students to connect to a session either with their computer or mobile device. Professors and teaching assistants were aware that given the emergency, not all students may be able to connect at the time of the session for classes, so these were recorded and later uploaded. Laboratories are explained further with detail.

4.6. Step 6 – Course Update:
The approved update is executed, with feedback being received in real time according to the available information. The syllabus must be flexible for rapid modifications of tools, technologies, and education methods to fulfill the objective of generating employability.

4.7. Step 7 - Evaluation and Feedback:
During these processes the proposals, suggestions and feedback of students is considered, after verifying that they comply with accreditation requirements and institutional internationalization. Soft skills and technological skills developed are evaluated as an indicator of employability and the relation with the industry and the environment is maintained.

5. Laboratories
This course had bi-weekly 2-hour laboratory sessions. Before the day of the session, a video explaining the laboratory and the software to be used was shared with students so that they could start using the software and could prepare questions regarding the assignment. During the laboratory students would share their screen to show any problem they may encounter while using the software.

5.1. Laboratory 1: Virtual visit to a construction project using digital twins
Given the sanitary emergency, the construction site visits were replaced by virtual visits to construction projects generated with scanner laser technology, photogrammetry, and BIM, generating digital twins that were stored in online platforms. Students toured the construction project virtually and in an interactive manner, and along with the description of the professionals in charge of the project they were able to reach a good level of comprehension of the organization and the construction processes. Figure 2 shows a capture of the session, including the virtual tour of the project. In addition, students developed the layout plans of the temporary works with BIM models. The following figure is a screen capture of the teacher showing the digital twin while sharing his screen. Students were also shared a link to access the model and navigate at their own pace.

For this laboratory, the assignment consisted of preparing a report, with the main information of the project including stakeholders, subcontractors, construction processes, project organizational chart,
project areas, and heavy equipment employed. Finally, they included screenshots of the layout plans for temporary works modeled on Revit.

5.2. Laboratory 2: BIM modelling and quantity surveying
In the second laboratory, students had to model the first level of the architecture faculty Project in Revit. For this, the blueprints were shared with students. The deliverables were: 1. Revit model, 2. material take-off for all structural elements including foundations, beams, columns, etc., and 3. A final report with screen captures of different views of the model. Figure 3 shows a capture of the session where students are able to clear any doubts regarding the modelling process, the blueprints and the criteria being used for the model. For material take-off, students were asked to export the Revit tables to an excel sheet by material for concrete, reinforcement steel and formworks.

![Figure 3. Laboratory Session explaining the modelling process in Revit](image)

It should be mentioned that students also had basic knowledge using the BIM software Revit since it was taught in a previous course, meaning their BIM knowledge was enhanced with the software used.

5.3. Laboratory 3: Scheduling and cost analysis using BIM
For the third laboratory, students had to import the Revit model from laboratory n° 2 to Navisworks, to work on the Project Schedule and construction process simulation. Here, they were able to view the work progress and determine the correct sequence for construction. On figure 4, the construction sequence modeled in Navisworks is observed. As a part of this laboratory, they were also taught how to do Unit Cost Analysis, for the main tasks of a building Project.

![Figure 4. Capture of the video introducing Navisworks](image)
5.4. Laboratory 4: WBS integration and cost analysis using BIM models in IFC format
During this laboratory, students learned how to integrate the work breakdown structure of a Project and the unit cost analysis with the use of the Software Delphin Express, a national software that allows the interaction of BIM models in IFC format. This software is used to create budgets, review unit costs, and link the quantity surveying data directly from the BIM model. With this, the 5D BIM modeling of the Project was completed and students gained a powerful tool for Project control. Figure 5 shows the interface of the software being presented to students, while clearing up any questions regarding the process.

![Figure 5. Capture of the session explaining 5D modeling with Delphin Express](image)

5.5. Laboratory 5: Planning, scheduling, and project budget
For this session students were given a small project, an underground buried cistern, to prepare the quantity surveying, unit cost analysis, budget, and planning in an excel sheet. This allowed students to compare the process of working on a project with a more traditional method. Figure 6 shows the real project in execution and the blueprints of the project.

![Figure 6. Left – Buried Cistern Project in process, Right - Blueprints](image)

6. Results
During the semester, as students learned more about the tools and technology available, they indicated that the tools used in classes and laboratories were very useful and that they had the perception that it was very similar to a real project design, planning and execution. On laboratories 2 and 3 students learned how to model and plan the construction sequence for a project. Students were able to use these
tools collaboratively, which prepares them for their role in a specific project. The feedback from students was positive and the excellent average of the class confirmed the efficiency of the teaching methodology. On laboratory 5, students were able to compare the process learned with the BIM tools and technology and a more traditional process on an excel sheet. Students agreed that the second one was more difficult in terms of automation, collaborative work, integrated project perception, selecting the best construction sequence and identifying restrictions.

The success of this methodology is shown through the notable quality of papers and evaluations taken, through the results of surveys taken on students --which had an effectiveness rate of 96.4%-- that exceeded in all categories in comparison to the efficiency of other courses imparted in the engineering department. Table 1 shows the average score obtained for the course after the survey performed at the end of the semester.

| Survey Section                      | Average efficiency of courses of the Engineering Department (%) | Course efficiency (%) |
|-------------------------------------|-----------------------------------------------------------------|-----------------------|
| A. Learning strategy                | 87.0                                                            | 100.0                                                             |
| B. Methodology and resources        | 84.6                                                            | 94.8                                                              |
| C. Learning assessment              | 84.4                                                            | 93.8                                                              |
| D. Communication and interaction    | 88.0                                                            | 98.2                                                              |
| **GENERAL QUALIFICATION**           | **85.8**                                                        | **96.4**                                                          |

7. **Conclusions**

The use of BIM software in this course gave students a more open vision of construction processes and building construction, regardless of the impediment to visit onsite construction projects, students were able to navigate a Project, from the blueprints to the 3D, 4D, 5D model and digital twin. The methodology was designed so that one can adapt the pandemic and post-pandemic stages proposing a balanced use of virtual platforms and software for video conferences and laboratories, incorporating tools and technologies like Building Information Modeling, Virtual Reality, Lean construction, among other systems. This may be adapted by the academia and professionals related to building constructions, for virtual, and face-to-face learning as well. This will be very useful in countries as Peru, where the Access to construction projects is highly restricted due to the pandemic, since the sanitary norm in the construction industry is strict in terms of forum and maximum allowed number of people in each area of a project [20].

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