Teaching and Learning Design Management tools during the sanitary emergency

Enseñanza y Aprendizaje de herramientas de Gestión de Diseño durante la emergencia sanitaria

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HIGHLIGHTS

- Dissemination of a successful teaching and learning experience
- Teaching and Learning Construction 4.0
- Using tools in the AEC industry

TITULARES

- Difusión de una experiencia exitosa de enseñanza y aprendizaje
- Enseñanza y Aprendizaje de Construcción 4.0
- Uso de herramientas en la industria de la Arquitectura, Ingeniería y Construcción

RESUMEN

Durante el año 2020, la normativa de la emergencia sanitaria obligó a las universidades a impartir la docencia bajo la modalidad de enseñanza a distancia, lo que representó un desafío en el diseño de cursos que requieren una alta efectividad. El propósito de este trabajo es presentar las estrategias que se aplicaron con éxito durante la enseñanza y aprendizaje de las herramientas de gestión del diseño de un proyecto de edificación, implementadas en un curso de la maestría en Ingeniería Civil de la Pontificia Universidad Católica del Perú. La metodología consideró el efecto de la Pandemia del Covid-19 y tuvo como objetivo desarrollar habilidades blandas y empleabilidad, para lo cual se propuso un uso equilibrado de plataformas colaborativas virtuales, así como software para videoconferencia y laboratorios. Por otro lado, durante esta asignatura, los estudiantes desarrollaron una propuesta de planificación y gestión integrada de la fase de diseño utilizando herramientas de guías y directrices de sistemas de gestión de proyectos. Bajo este marco, se analizó la participación de los interesados, la toma de decisiones multicriterio, el desarrollo de los entregables del diseño del proyecto y la secuencia del proyecto. El éxito de esta metodología se refleja en la alta calidad de los trabajos y exposiciones finales, el resultado de las encuestas realizadas -eficacia del 99%-, y en las oportunidades de mejora detectadas. Se diseñó e implementó una asignatura no presencial flexible y exitosa, que podría adaptarse a la modalidad Blended Learning.

Palabras clave: *Enseñanza; Aprendizaje; Construction 4.0; Gestión del diseño; Toma de decisiones*

ABSTRACT

During the year 2020, the sanitary emergency norm forced universities to teach under the remote learning method, representing a challenge of designing courses that require high effectiveness. The purpose of this work is to present the strategies that were successfully applied during the teaching and learning of design management tools for a building project, implemented in a course of the Civil Engineering master of the Pontifical Catholic University of Peru. The methodology considered the effect of the Covid-19 Pandemic and had as objective to develop soft skills and employability, for which a balanced use of virtual collaborative platforms as well as software was proposed for videoconference and laboratories. On the other hand, during this subject, students developed a proposal for integrated planning and management of the design phase using tools of norms and guidelines of construction management systems. Under this framework, the participation of stakeholders, multicriteria decision making, development of project design deliverables and project sequence was analyzed. The success of this methodology is reflected in the high quality of final papers and expositions, the result of surveys taken - effectiveness of 99%-, and in the improvement opportunities detected. A flexible and

successful non-face to face subject was designed and implemented, which could be adapted to the Blended Learning modality.

Keywords: *Teaching; Learning; Construction 4.0; Design Management; Decision making*

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1. INTRODUCTION

At the beginning of 2020, COVID-19 virus started to spread all over the world, affecting a large number of citizens. For this reason, on March 13th, the World Health Organization (WHO) declared a global pandemic. [1]. The WHO directives were taken into consideration by most countries' regulations, including Peru, with the objective of controlling the spread of the virus with diverse measures, such as stoppage of many sectors, including education and construction [2]. Before this scenario, the design, construction and commissioning phases of construction had to adapt to protocols that imposed strong restrictions for the restart of projects, maximum number of workers in an area, staggered entries, among others [3]. All these measures had to be embodied in the courses of architecture and construction at universities. Indeed, the sanitary emergency norm forced universities to apply remote teaching as an alternative to give students the opportunity to continue and successfully finish their semester [4]. Most of these students were not used to this, so strategies needed to be developed for both teachers and students to adapt. The main purpose of this article is to describe the strategies implemented during the pandemic in the course "Planning and Integrated Management of the design of a Building Project", a course part of the master's degree of the civil engineering program at the Pontifical Catholic University of Peru. This teaching methodology had to be implemented in a very short period, so that the academic semester wouldn't be delayed any longer.

2. THEORETICAL FRAMEWORK

The switch starts with the lead professor who needs to involve the interested parties to assume the responsibility and act rapidly to develop a joint plan to face these challenges, trusting their leadership, vision, culture and capacity to create the needed relationships with innovation and creativity [5, 6]. Even before the pandemic, universities had already been offering face-to-face, non-face-to-face, and Blended Learning (BL) teaching and learning modalities. BL is a modality that develops a face-to-face and non-face-to-face teaching educational environment, where technological applications create multiple ways of communication [7]. In terms of educational technologies, prior readiness significantly improves BL experience. The BL environment promotes social participation and improves collaboration among students, generating an integrated community [7].

On the other hand, there is a study that indicates that before the pandemic the student dropout rates in online modality were considerably higher than in face-to-face modality, and evidence indicates that there are factors contributing to this, such as the sense of isolation, technological challenges, academic expectations, and the pressure on students' lives [8]. However, there is also evidence that online 'teacher-presence', combined with attractive, inclusive, and interactive design, content, and delivery improve student retention [8].

The pandemic made all sectors successfully adapt to remote education, such as the health sector. In this sector, there is an important study

that proposes 12 tips in a compilation of key principles and practical recommendations that can be applied in non-face-to-face teaching and learning, whose design characteristics can be quickly implemented and optimized during the pandemic [9]. The following were the tips: (i) Anticipate and move through the change management stages, (ii) Use the current Learning Management System, (iii) Modality – Optimize the potential of online lectures; (iv) Modality – Optimize online small groups using intentional design, (v) Modality – Optimize the potential of asynchronous online tutorials, (vi) Modality – Optimize the potential of online videos, (vii) Modality – Optimize the potential of social media, (viii) Modality – Optimize the potential of online reflection, (ix) If you can't teach the whole task, start with part-task online training, (x) Simplify the massive online world for learners, (xi) Encourage and support co-creation of online resources and activities, and (xii) Demonstrate the value for active clinicians of the shift to online learning. [9].

A study decided that the critical success factors for e-learning during the pandemic were the following: (i) Technology management, (ii) Support from management, (iii) Increased student awareness to use E-learning systems, and (iv) Demanding a high level of information technology from instructors, students, and universities [10]. It was also determined that BL was the most appropriate learning system during the pandemic. In addition, readiness for e-learning played a very important role in the educational process during the pandemic [10].

On the other hand, the sense of isolation that our students had at the beginning of the health emergency can be mitigated by combining face-to-face teaching with high-quality online learning, interaction among students is essential [11]. It must be guaranteed that student continues having a pleasant experience, developing the university education. During the pandemic, materials and strategies for post-COVID-19 online teaching have been generated and updated, but this is only the second half of the game. The first one is to ensure that our students have the infrastructure required to access online classes and laboratories [11].

Technological advance has a positive impact on different industries and institutions, such as the education and engineering sectors. Education 4.0 can be defined as the implementation of current and emerging technologies combined with innovative pedagogical procedures and best practices [12]. Education 4.0 has four core components used as a reference for the design of new educational innovation projects: (i) Competencies, (ii) Learning Methods, (iii) Information and Communication Technologies, and (iv) Infrastructure. Besides, innovative online and physical infrastructures have appeared in response to current challenges [12].

Therefore, to design a non-face-to-face subject, the tips and components described above should be considered, taking into account that face-to-face activities will be authorized very soon. In that case, the subject could be restructured into the BL modality.

3. TOOLS AND TECHNOLOGIES

Construction 4.0 is based on a confluence of trends and technologies that have an impact on the way a construction project is designed, built, and operated [13]. Construction 4.0 is a framework for the confluence and convergence of topics, such as: (i) Digital and computing technologies (BIM, video and laser scanning, reality capture, simulation, augmented reality, AI and cloud computing, big data and data analytics, others), (ii) Industrial production (prefabrication, 3D printing and assembly, offsite

manufacture), and (iii) Cyber-physical systems (drones, robots, sensors, actuators, others) [13]. The design of this subject is based on Construction 4.0, which is currently highly demanded in the industry and, therefore, generates employability. During the times before the sanitary emergency, the teaching methodology was face to face and consisted of the development of classes, laboratories, and visits of professionals specialized in design and construction management, where students observed and discussed the design, constructability, and planning processes of a project. On the other hand, since 2019, the research from GETEC research group has been incorporated in courses, especially the ones generated by tools and technologies applied in design, planning and construction. However, as a consequence of COVID-19, the norm enforced that those classes, laboratories and evaluations were made virtual. [2, 4]. The real conditions of design and planning stages of a building Project were simulated, these accessible technologies were selected for the student body.

3.1 Building Information Modeling (BIM)

BIM is a system that promotes innovation and allows the management of digital representations of physical and functional characteristics of construction projects, creating long term value [14]. BIM system is a generic term used to name the software BIM, which includes tools, platforms or servers used within a BIM environment to admit the information modeling of a project [15]. During, the pandemic active methodologies are being generated based on real projects though BIM virtual models. With the implementation, students learn through the virtual models without the restriction of online classes, learning to collaborate from anywhere, acquiring skills that help them to face situations like COVID-19 efficiently [16].

3.2 Virtual Reality (VR)

VR is a visualization technique that is applied in different areas, including building construction, and may be immersive or non-immersive [17]. The use of virtual reality (VR) and the creation of digital prototypes (digital mock-up) for the design revision is being implemented more during the design and construction phases [17]. Moreover, there is a software of virtual reality rendering available for BIM tools of common use [15, 18].

3.3 Drones

Drones or UASs (Unmanned Aerial Systems) are equipped systems with video cameras that may be used for data surveys. The use of these systems for project monitoring is expanding and even though it still has its limitations, it's important to consider and identify the opportunities it brings [19].

3.4 Multicriteria Decision Making Methods

Choosing By Advantages (CBA) method consists of listing factors and criteria, to then determine the advantage of each alternative by assigning value to each one [20]. As well as value stream mapping. CBA is based exclusively on advantages instead of advantages and disadvantages, avoiding double counting or sums and subtractions [21]. In addition, it has been proven that the use of CBA and BIM improves the collaboration among stakeholders [22], optimizes project planning [23], and reduces the decision times and improves the transparency of the system [20, 24]. The Scoring is a decision-making system that employs the direct weighting of factors and indicators [25]. Advantages are not explicitly used in this system [26]. If the factor weights add up to 100%, the Scoring is called Weighting Rating and Calculating (WRC) [25].

3.5 Value Stream Mapping (VSM)

A value stream map is composed of the value-added actions and non-value-added actions needed to make a production Flow and manufacture products from the raw material to the client delivery [27]. VSM is a tool of the Lean Production that allows a systemic view of the value in the process of production, identifying problems and real loses, lessons learned and continuous improvement [28]. There are several adaptations to this Lean tool collaboratively implemented by work teams in construction projects [29].

3.6 Delphi Method

The Delphi method is an iterative decision-making method performed anonymously by experts leaded by a moderator who analyses the results each round and communicates them to the participants until consensus is reached [30]. This method spread rapidly since it offers a flexible and simple methodology while also reducing the influence of unwanted psychological effects among participants (inhibition, dominant personalities, etc.) [31]. The methodology of the Delphi study are: (1) Identify the research objective; (2) Identify and select the expert panel according to predefined criteria; (3) Developing questionaries; (4) Transmitting questionaries to the panel; (5) Analyzing responses; (6) Evaluating consensus and, if needed, repeating the process [32].

4. METHODOLOGY

Before the pandemic, the subjects of construction management for civil engineering were already implementing Construction 4.0 technologies in classes and laboratories, generating employability. Classes and evaluations needed to be done remotely, which was, as previously indicated, a challenge both

for students, and teachers. 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. According to this, the proposed methodology for subject update consists of: (1) Syllabus Revision; (2) Subject Re-design; (3) Implementation of evaluations; and (4) Assessment of the subject. Figure 1 shows the flowchart of the research methodology.
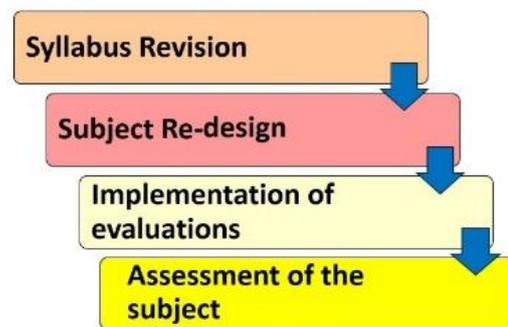

Fig. 1: *Research methodology.*

5. RESULTS AND DISCUSSION

5.1 Syllabus Revision

According to the Institutional Strategic Plan 2018-2022, our university proposes to consolidate the educational model by competences, expand the educational experience of excellence, and improve the employability of graduates. The generic competences defined are independent learning, ethics and citizenship, effective communication, logical-mathematical reasoning, research, teamwork, and participation in projects. Study plans are permanently updated to provide the methods that contribute to fulfilling the strategic plan [33]. The design, update, and evaluation of

the subject by means of a survey meets the following topics: (A) Learning strategy: Online classes and activities are prepared, so that study hours are rationed; (B) Methodology and resources: The development of activities and tasks is clearly oriented, the analysis and reflection of contents is promoted, and activities are related to the social or professional context. The digital resources used, such as platforms, software, ICTs, videos, digital applications, among others, are effective for learning. Activities that promote student interaction are contemplated; (C) Learning assessment: The evaluations are clear and correlate with the objectives of the subject. Teacher feedback is useful for learning; and (D) Communication and interaction: The enthusiasm, respect, and willingness of the teacher promotes the interest in learning. The teacher promotes the dialogue and individual and group participation in synchronous sessions [33].

5.2 Subject Re-design

The proposal was a flexible integration of tools and technologies of construction management that allowed a work team to operate efficiently on the design and planning phases, according to Lean Construction [34, 35, 36], Project Management Institute [37], Building Information Modeling (BIM) [15, 38, 39], ISO 21500 [40], among others. Flexible learning methods were included to prevent eventual damage to the learning trajectory of students, providing resources that are useful during the pandemic and post-pandemic times [41]. Through these strategies competencies and soft skills were generated in our students, which are very valued by the industry, contributing to their employability. This subject had 5 bi-weekly evaluations, which students needed to complete in 3 hours each. These were done in groups of 5 members, encouraging coordination and soft skills in students. These evaluations were divided

in 2 sections, a theoretic part, and a laboratory part. First, the teacher would present a brief case study and explain the theory and tools that needed to be applied. Then, students were divided in break rooms, to work on the assignment. During this period, the teacher was able to enter and exit a breakroom to monitor their progress and to answer any questions. Case studies from our research group were shared with students for a more in-depth vision of the application of the tools and technologies imparted.

5.3 Implementation of evaluations

During the design and execution of the evaluations, it was verified that the 12 tips shown in Table 1 were met. Teachers 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. However, students attended all 5 evaluations. Below there is a summary of some relevant parts of the evaluations:

- **Evaluation 1 Use of Scoring to select the best design alternative**: It consisted of the selection of the best out of 3 design alternatives for the design of an apartment complex with the use of the scoring method. Here, students were given tables with the score for the purposes of both the investor and the final user, and they had to ponder these with the score assigned to each one of the alternatives, that presented a different type of structure, finish, and installations. At the end of the assignment, students were asked to discuss the results and analyze the risks and mitigation actions associated with the selected alternative.

- **Evaluation 2 CBA and VR to select the best design alternative:** For the second evaluation, an intervention project was

presented to students. This project consisted of a structural reinforcement. For the stakeholders of this Project, the CBA method was used to choose between 2 design alternatives. For this case study, the technology applied was laser scanning, point cloud important and virtual reality. Then, in groups, they discussed the alternatives and used the CBA method to choose the best alternative, they also had to discuss the results and the decision-making process, analyzing whether they considered it was transparent or not. Figure 2 shows virtual reality captures on the Kubity app for both intervention design alternatives.

Fig. 2: Intervention Project and design alternatives in VR.

- **Evaluation 3 Using DELPHI and CBA method to select the best construction sequence:** On the third evaluation, students used a combination of CBA and Delphi, to select the best construction process design. In this case, there were 3 alternatives, for a building with the same number of stories and construction area, each one had variable modulation, standardization, and industrialization. Figure 3 shows the typical floor plan of an alternative. During the session, each group chose a stakeholder, to perform the analysis from that specific point of view. After using the CBA method in groups to select the best alternative, all students joined the main session to use the Delphi method and evaluate the consensus. A member of each group presented their winning

alternative and their most important advantage. After 2 rounds, consensus was reached, and students understood the method and its applicability.
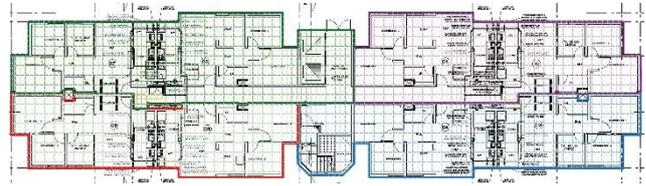

Fig. 3: Typical floor plan of an alternative.

- **Evaluation 4 Using Value Stream Mapping for the design phase of a building project:** At the beginning of the session, students learned Value Stream mapping theory and were given examples of how to use this tool to improve processes and reduce waste. They were then asked to elaborate the Flow chart for the design process of a building Project, including all systems: architectural, structural, mechanical, electrical, and plumbing. For this, they used the app Miro, which allowed students to collaboratively work in the same board simultaneously. Figure 4 is a partial capture of the board prepared by one of the groups. Here, the flow, tasks and decisions are observed.
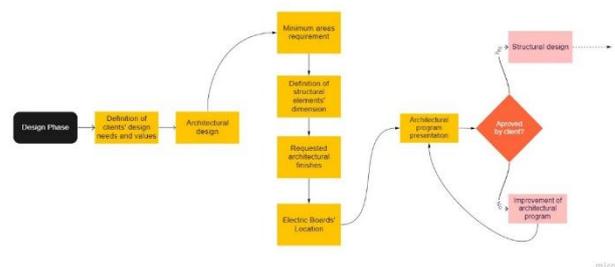

Fig. 4: Real example of a group flow chart.

- **Evaluation 5 Integration of Tools and Technologies applied to a Construction Project:** For the final group Project, students had to develop a proposal for an integrated

planning and management design phase using tools of norms and guidelines of Project management systems like PMI, ISO21500, BIM and Lean Construction. Here they also had the opportunity to apply all the tools, technologies and skills developed during the course for a Project of their choice.

5.4 Assessment of the subject

The feedback was positive and given the students previous experience, more opportunities to apply the tools and technology were given. For example, on the second evaluation, students indicated that the use of virtual reality made the process of using CBA even more transparent, since it increased the understanding of the design proposal, they also felt that it simulated the use of these tools in a real project. Something similar occurred after evaluation 4 where students shared the opportunities where they could also apply value stream mapping on their day to day professional lives. These topics are evaluated by means of an anonymous survey to students. The final subject survey indicated that students benefited greatly from this methodology, as it is shown in Table 1, the course efficiency exceeded the efficiency in all categories, in comparison to the average efficiency of all courses of the engineering department in that semester.

Table 1: Subject survey results.

Survey Category	Average efficiency of subjects of the Engineering Department (%)	Subject efficiency (%)
A. Learning strategy	87	97.6
B. Methodology and resources	84.6	100
C. Learning assessment	84.4	97.5
D. Communication and interaction	88	100
GENERAL QUALIFICATION	85.8	99

The survey showed that students considered the subject to be very satisfactory and that it met the definition of Construction 4.0, i.e., current and emerging technologies were implemented combined with innovative pedagogical procedures and best practices. The proposed innovative online infrastructure was an ideal response to the needs and challenges of the pandemic. It was very useful in the analysis and implementation of the applied educational technology.

6. CONCLUSIONS

It has been observed that virtual courses can be just as efficient and beneficial for students as regular face to face courses when the proper methodology is applied. In this case, being students of a master's degree, they already had experience in building construction, so this had to be enhanced with case studies and examples that resonated with them and complemented their knowledge. Also, the group work was enriching, since they came from different backgrounds and work experience. Dynamism

and permanent interaction between students, teachers and teaching assistants was key, so questions during classes and evaluations were encouraged, moreover, students used the forum outside sessions in the Paideia Platform, to share their personal experiences, doubts, and any resource they considered worth sharing with their classmates. In this subject, all stakeholders become familiar with the technological transformations.

According to students, classes and laboratories successfully simulated real work conditions of the pandemic times and may be also applied post-pandemic. The efficiency of the course is reflected on the excellent average of the class. Moreover, after every evaluation the students gave feedback regarding the methodology and the tools and technology applied. The use of lean tools and technology gave students a more open vision of the design management process. Also, they developed skills that they will be able to apply in their respective work areas, improving the design process of all projects they are involved with. This is very important considering this stage is often neglected. Finally, for these reasons, it is concluded that a flexible and successful non-face to face subject was designed and implemented, which could be adapted to the Blended Learning modality.

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