TEACHING AND LEARNING LEAN CONSTRUCTION IN SPAIN: A PIONEER EXPERIENCE

Eugenio Pellicer[1] and José Luis Ponz-Tienda[2]

ABSTRACT

This paper presents the origins, approach and outputs of a course on Lean Construction developed at the Universitat Politècnica de València within the Master of Planning and Management in Civil Engineering: a unique experience in the Spanish academic system so far. This course takes into consideration most of the key issues of lean construction: historical evolution, flow and value stream mapping, pull management, last planner system, standardization, optimization of construction operations, building information modelling, and integrated project delivery, among others. The main element of the course is the last planner system of planning and control. An average of 30 students per year has attended this elective course in the M.Sc. degree since its implementation in 2011, indicating the extraordinary success of the course. The teaching and learning method is dynamic and is based on lectures, exercises, games in the classroom, and a project course. This paper presents this pioneer introduction of this graduate course in the Spanish academic system and some of the outputs obtained.

KEYWORDS

Last Planner System, Lean Construction, Learning Construction Management, Project Based Learning.

INTRODUCTION

Academics and professionals consider lean construction as the most efficient practice to increase the efficiency and productivity in construction projects. Nonetheless, as Lean Construction is an emerging methodology, multiple approaches and different theoretical interpretations can be found in the literature and in practical implementations. Furthermore, Lean Construction concepts and terms such as “value”, “flow”, or “waste” seem very abstract for students and novice professionals.

These different approaches, theoretical interpretations, complex terms, and abstract concepts cause that teaching Lean Construction may become one of the biggest challenges that faculty members can found in their professional careers, either for an academic environment with novel and inexperienced students, or for professionals who need practical solutions to improve their performance.

[1] Associate Professor, Ph.D., School of Civil Engineering, Universitat Politècnica de València, Spain, pellicer@upv.es

[2] Assistant Professor, Ph.D., Civil and Environmental Engineering. Universidad de Los Andes, Bogotá, Colombia, jl.ponz@uniandes.edu.co

Innovative initiatives have been undertaken during the last years by different universities all over the world with courses in their academic programs, summer schools, undergraduate, and graduate curriculums, etc. promoted by lecturers and researchers. These courses are focused on different aspects of Lean Construction depending on the lecturer focus, his/her personal interpretations, and the needs and interests of the students and professionals involved.

Currently, Lean Construction is integrated within the curriculum of many construction management programs (Johnson and Gunderson 2009), with students and profesionals coming from different fields within the Architecture, Engineering and Contruction (AEC) industry, mainly architects, architectural/building engineers, and civil engineers. This multidisciplinary environment requires a new approach from the different stakeholders involved in the contruction process, promoting the creation of collaborative teams in different disciplines interested in the design of transversal courses that meet the demands and needs of the industry.

With this aim in mind, the authors decided to start a new course on Lean Construction in the Master of Planning and Management in Civil Engineering at the Universitat Politècnica de València, where they have been lecturing for several years. The course on Lean Construction (3.0 ECTS) takes into consideration most of the key issues of the subject: historical evolution, waste and flow, value stream mapping, pull management, Last Planner System™ (LPS™ henceforth), standardization and optimization of construction operations, building information modelling, integrated project delivery, as well as other lean techniques (5S, Poka-Yoke, Kan-Ban, A3 report, etc., among others). The LPS™ of planning and control is the main element of the course.

The teaching and learning method is dynamic and focused on students, as the central characters of this learning process, aiming to develop on them the skills of leadership and team working. The teaching and learning process is based on lectures, exercises, and games in the classroom; it is also complemented with a project course as the vehicle to implement a Project Based Learning (PBL) methodology. This paper presents the pioneer experience of introducing and teaching this graduate course in the Spanish academic system and some of the outputs obtained, considering an average of 30 students per year attending the elective course since it was first implemented in 2011. These numbers can be considered a success because the average number of total students in the M.Sc. degree has been 35 during those same years, reflecting that most of the students take the course year after year because of word of mouth from the previous academic year's students.

The remainder of this paper is organized as follows. Section 2 provides a review of the most usual methods in teaching Lean Construction at major universities in the world. Section 3 details the method of teaching and learning applied at the Universitat Politècnica de València. Finally, some conclusions from this pioneer experience are drawn.

TEACHING LEAN CONSTRUCTION

Organizations around the world claim for improvements in productivity, waste reduction, and profit gains in the construction industry with the use of Lean methods and principles. As in the industry, construction management academic programs have steadily incorporated these key trends within their curriculums. Different universities

all around the world have undertaken innovative initiatives during the last years including courses with teaching Lean Construction principles in their academic programs. In this section, some methods and tools for teaching lean construction are presented.

READINGS AND CLASS DISCUSSION

The "Readings and Discussion" method gives students the opportunity, and even the obligation, to express their points of view and opinions on certain issues, requiring the students to think critically on the subject and use logic to evaluate others' positions through open and active participation. Some of the benefits of using "Readings and Discussion" as a learning method, are (Bonwell and Eison 1991): (a) it helps students to explore and analyze a variety of perspectives, increasing their intellectual agility and habits of collaboration; (b) it develops on the students the skills of synthesis and integration; and (c) it leads to transformation.

This method is applied by Hamzeh (2013) and Tsao et al. (2013), among other lecturers at the American University of Beirut in a 16-week semester. Hamzeh (2013) starts introducing lean with the readings of the Toyota way (Liker 2003) and the transformation-flow-value theory of production (Koskela 2000). After these readings, Hamzeh (2013) asks the students to post questions into the course website and these questions are used as a basis for class discussion.

Rybkowski at the Texas A&M University (Tsao et al. 2013) organizes readings and asks students to write brief essays that summarize their conclusions, allowing a common discussion and exchange of ideas later. Tsao et al. (2012) at the University of Cincinnati schedule readings as Critical Chain (Goldratt 1997) to provide students a basic background.

GAME & SIMULATION BASED METHODS

The game-based methods (also known as "gamification"), incorporating game-like interactions, may be the most popular and gaining attraction in Lean Construction learning methodologies, demonstrating lean principles in action and involving the audience. With gamification, students can fail with minimal consequences and learn from their mistakes. If a student fails, this simply means that he/she needs to try to play again with a new approach. Furthermore, it promotes a long-term retention of the knowledge gained and problem solving skills (Ghosh and Bhattacharjee 2011).

The game-based methodologies are imported from lean management environments; they are very useful to teach, and prove some abstract concepts such as: continuous process flow, waste, pull planning, variability, production levelling, collaboration, and teamwork. A brief description of some of the most popular follows:

- The Technion LEAPCON™ (Sacks 2007) simulates the construction of an eight story building with four apartments on each floor. It was developed to test the impact of the Lean management model in response to the significant waste identified in the conventional approach to scheduling and managing construction.
- The Dice Game was inspired on Goldratt´s "boy-scout hike" and used by Howell (1998), Ballard (1999), and Alarcon & Ashley (1999) to demonstrate the impact of uncertainty on the production rate.

- The Airplane Production Game (Dukovska-Popovska, Hove-Madsen and Nielsen 2008) is a simple, but powerful, Lean teaching tool that allows the demonstration of nearly every "just in time" principles and of the difference between pull and push systems, creating flow in the working processes.
- The Lean Hospital Game (Dukovska-Popovska, Hove-Madsen and Nielsen 2008) is designed to give the students an experience of the Lean way of working, having in mind that clients usually do not have any knowledge about production planning and control.
- The Origami Game or Frog Factory Kanban Game (Tsao, Alves and Mitropoulos 2012) is a lean quality Kanban simulation in which teams compete trying to run the most efficient factory making the most money as possible, avoiding unbalanced work flow, which can block the process. With the Origami Game, students learn about the impact of "batching work", "one-piece flow", "balancing work" between stations, and "quality control".
- The Delta Design Game was developed by Bucciarelli (1999) and was planned to demonstrate to the students that design is a process of negotiation among several conflicting disciplines and requirements. At the University of Cincinnati, Tsao et al. (2012) uses the Delta Design Game to help students to appreciate the challenges of design management and to explore how lean thinking can help.
- The Win As Much As You Can Game (WAMAYC) was designed to give teams experience in designing indicators and data collection methods, showing different ways of graphically displaying data and starting a discussion about data stratification, mean, and range. The discussion at the end of the game can lead to concrete plans to make data more available, and the merits of collaboration and competition in both intragroup and intergroup relations. Actually, the WAMAYC game is used at the Illinois Institute of Technology (Chicago) and, occasionally, at the Lean Construction Institute (Tsao et al. 2012).
- Other games used in teaching lean principles are (Tommelein 1998): The 5S Shapes Game, Lean Start-up Snowflake Game, Kanban Game with Lego©, The Kanban Pizza Game, Stuffing Envelopes Game, Lean Dot Game, Never-ending Card Game, etc.

THE OPEN FORUM METHOD

The "Open Classroom Forum" is a dynamic teaching method in which students interactively share thoughts and learn from class discussions about case studies and required readings. The purpose of "Open Classroom Forum" is to establish a new pedagogy in teaching Lean Construction (Hamzeh 2013). This method is applied in the Construction Management Department of the Colorado State University, and the lecturers expect to facilitate the understanding of lean principles while "preparing students to enter the workforce with a solid theoretical understanding of lean and its transferability to the construction operating platform" (Hanzeh 2013).

As an evolution of the "Open Classroom Forum" method, the "Online Discussions Forums" method arises as the most preferred by students (Tsao et al. 2012) posting questions to discussion that weave several strands of conversation into a summary

that may prompt people to pursue the topic further (Berge, 1995) or even seek help when necessary.

INTEGRATION OF LEAN, GREEN & BIM

Bradley and Hyatt (2011) at California State University explore the integration of lean construction, sustainability, and BIM into an undergraduate construction management and scheduling course, structured using the framework of the Last Planner System™ and 4D assignments (BIM), allowing students to visualize the construction of a green project throughout the course

IMPLEMENTING THE LEAN CONSTRUCTION COURSE

More than one hundred professionals and students attended the First Meeting of the Spanish Group for Lean Construction in April 2011 at the Universitat Politècnica de València. The success of this event has to be well put into context: in 2009 a Meeting of the European Group for Lean Construction gathered only one native person (the first author of this paper) in Barcelona. During the three year-span (2009-2011), a small group of academicians at the Universitat Politècnica de València was able to convey a feeling of restlessness and need for fresh air in the Spanish construction industry through workshops, classroom effort and word of mouth. As a result, currently, the Spanish Group for Lean Construction in Linkedin has more than one thousand members, and it keeps growing.

Hence, due to the achievement of this First Meeting, the professors involved in this process decided to start a new course on Lean Construction at the Master of Planning and Management in Civil Engineering at the Universitat Politècnica de València, where they were already lecturing; there was an announcement during the closing session of the previously mentioned First Meeting. The course on Lean Construction was implemented as an elective course in the second semester of the 2011-2012 academic year. Eighty-three per cent of the students enrolled in the Master chose the course and the promoters considered this fact as a success. In the last two years, all students enrolled in the Master selected the Lean Construction course as one of their electives subjects (Figure 1).

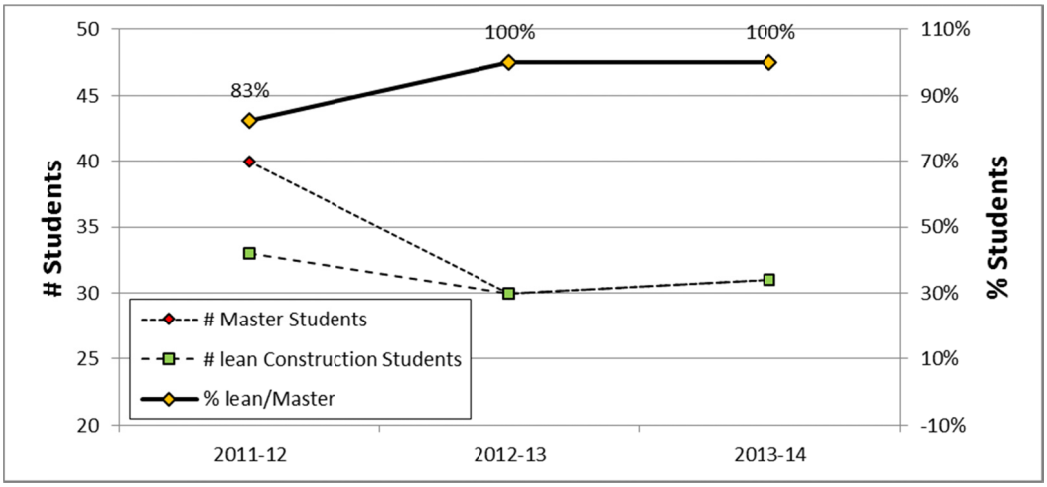

Figure 1. Historic election of Lean Construction subject

However, the task was not easy. At the early stages, the M.Sc. Theses dealing with "lean construction" were not well received by the dissertation committees, getting back comments as "utopian methods", "far from reality", "idealistic", "pointless", “confusing”, “we already know that”, or "not applicable to the Spanish idiosyncrasy", among others.

Currently, the number of Spanish students in the course has decreased slightly due to the economic crisis; however, the number of foreign students has doubled (Figure 1) largely due to word of mouth, especially within students from Latin American countries, who select Lean Construction as an elective course for their second semester (Figure 2).

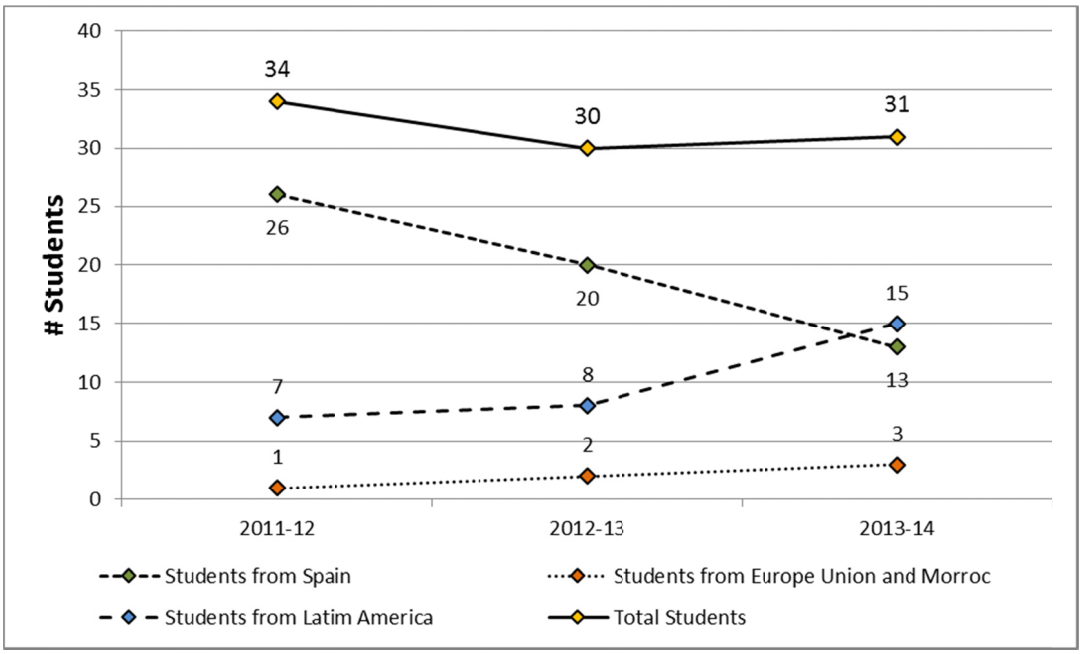

Figure 2: Historical evolution of student’s origin in units

Nowadays, Lean Construction is considered an essential topic in the curriculum of many engineering areas; it is included in subjects such as Quality Control, Safety and Health, or Scheduling in the industrial engineering field.

LEARNING LEAN CONSTRUCTION.

The M.Sc. degree approaches construction management from both a production and a business point of view and is composed of one year of coursework based on four mandatory subjects (project assessment, construction site administration, innovation and quality, and business management), some elective courses, plus an additional semester to prepare a M.Sc. thesis. The Lean Construction course (3.0 ECTS) takes into consideration most of the key issues of the matter: historical evolution, flow and value stream mapping, pull management, Last Planner System, other lean techniques (5S, Poka-Yoke, Kan-Ban, A3 report, etc.), standardization and optimization of construction operations, building information modelling, and integrated project delivery, among others. The course of Lean Construction is based on a mixed method of active and collaborative techniques, overcoming the limitations of the classical

methods. Through this approach, students become protagonists of their own learning, and teachers play the role of advisors, guiding the learning process as they progress in their research (Blank 1997, Harwell 1997).

The structure of the course is based on: (a) reading & class discussion; (b) Problem Based Methodology with games; (c) advanced scheduling techniques for the Last Planner System™; and d) a real project. The Lean Construction course is being lectured by three professors, each one of them with different professional and academic skills, giving students an enriching and multidisciplinary approach. The reading and class discussion sessions are taught by Eugenio Pellicer who introduces students into the lean philosophy, the history, and the main concepts (value, flow and waste) as well as the Earned Value Method (some basic concepts have been already introduced in a previous project management course where the reading of the Critical Chain book is mandatory). The second part is coordinated by Fernando Cerveró, introducing the techniques of Value Stream Mapping, 5S, Poka-Yoke, Kan-Ban, A3 report and pull approach with games and simulations. The third block is taught by José Luis Ponz-Tienda who integrates the standardization and balanced design of work cycles, analysis of resources and durations, advanced project scheduling, optimization with spreadsheets (Ponz-Tienda 2011) and commercial software applied to the Last Planner System™, finishing with the application of Earned Value under a production-system point of view.

Regarding the vehicular project, students must apply the concepts and techniques learned throughout the course in a real environment (Figure 3). They develop personal skills and competencies as leadership and collaboration through the construction process, increased "relatedness" among all the project participants, and thinking projects as holistic production processes.

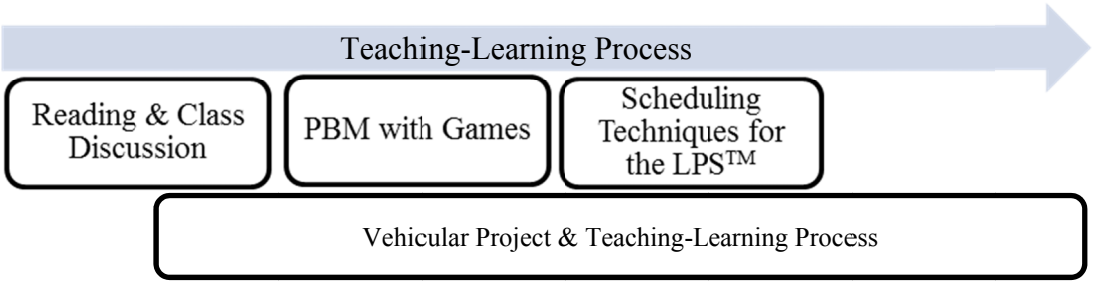

Figure 3: Teaching-Learning Process

The project course is the vehicle of a Project Based Methodology that complements the readings, class discussion, games and problems. The method is based on solving a complex project, with a solution that is not unique or simple, and requires critical thinking to pose and solve it, choosing between different feasible alternatives. The Vehicular Project (Figure 4) is known as the "Napkin Project" by the students; it consists on the full development of a building for residential and commercial use with some volumetric constraints expressed in the statement. Dates for signing the contract, start of the works and deadlines are also set, as well as penalties and bonuses for proposing solutions that alter the established deadline.

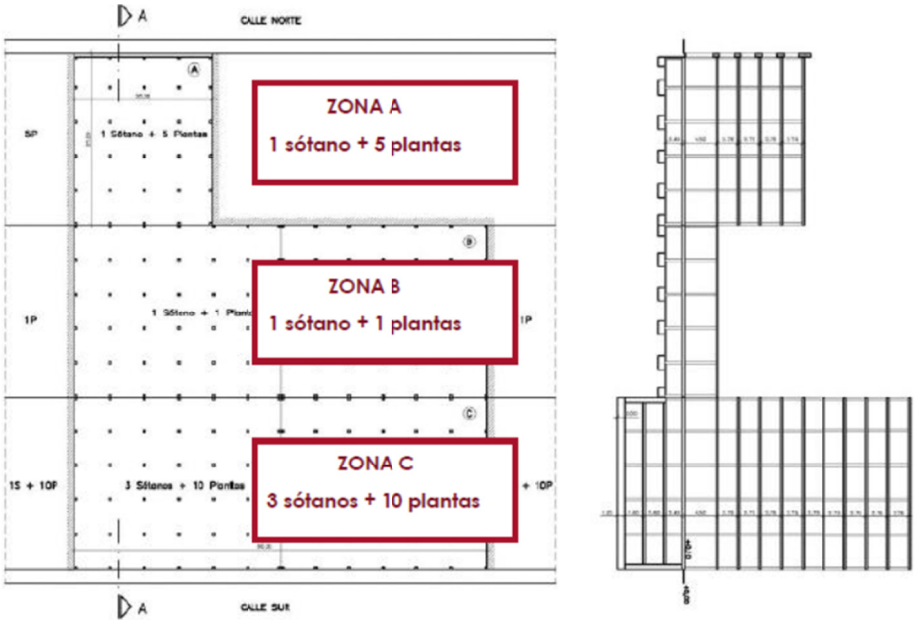

Figure 4: Project course with zones & areas

The teams are composed of five or six members, playing each of them a specific role in the construction process: architect, engineer, earthmoving subcontractor, structure subcontractor, safety and health responsible, and the representative of the owner (Figure 5).

Figure 5: Roles of the Team Work

After establishing the roles of each one of the members of the team-work, students must propose a constructive solution for the project that satisfies the boundary conditions that will be appearing throughout the research process, promoting fair competition to provide sustainable and efficient solutions. Once the initial solution is established, students must schedule the project applying Integrated Project Delivery and LPS of planning and control, proposing a work breakdown structure and a master plan (Figure 6) that usually modifies the initial solution.

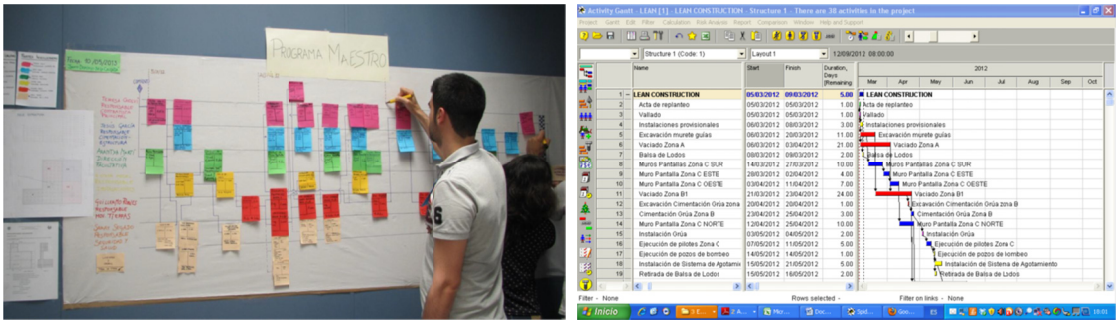

Figure 6. Pull session & master plan

With the ultimate solution, teams propose look-ahead programs for the first six months (Figure 7) and simulate its evolution with the Weekly Work Plan (Figure 8), controlling the production with the application of Plan Percent Complete charts (Figure 9) and the Earned Value Methodology (Figure 10), in an integrated and simultaneous way.

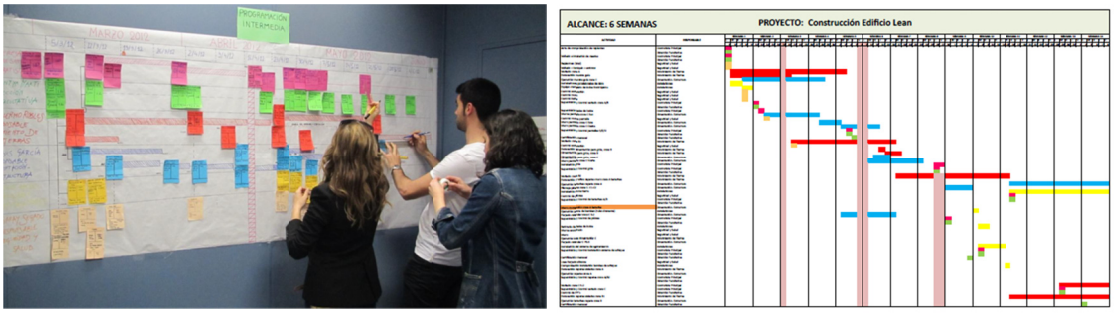

Figure 7. Pull session & look ahead planning implemented with spreadsheets

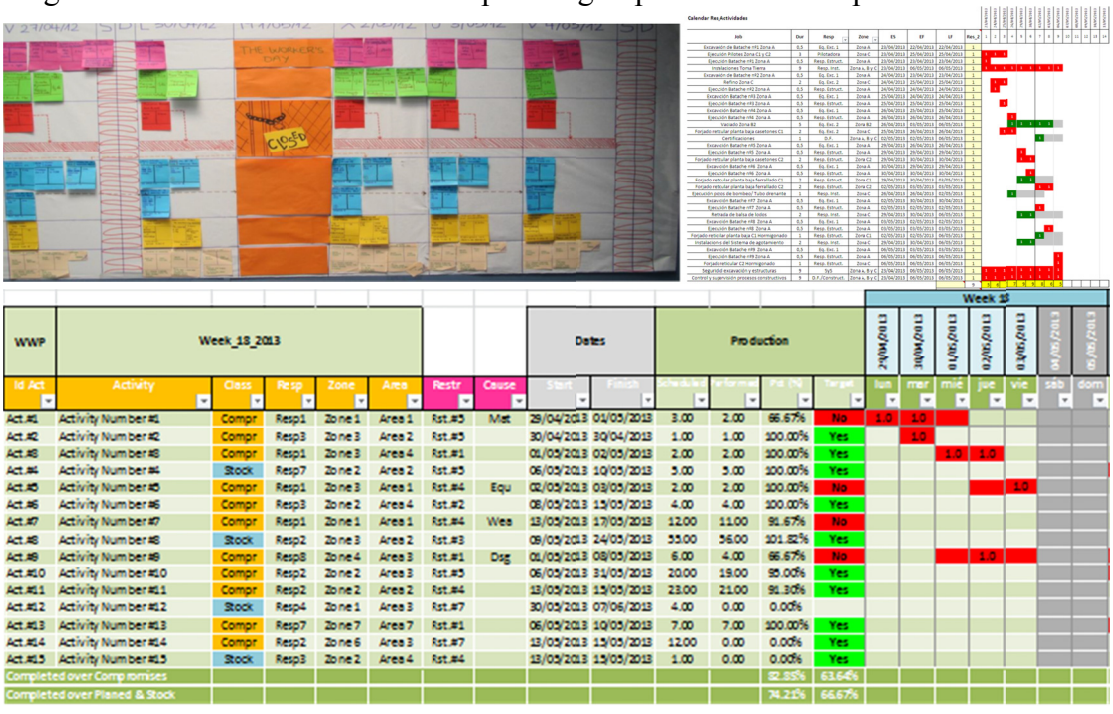

Figure 8. Weekly work plan implemented with spreadsheets

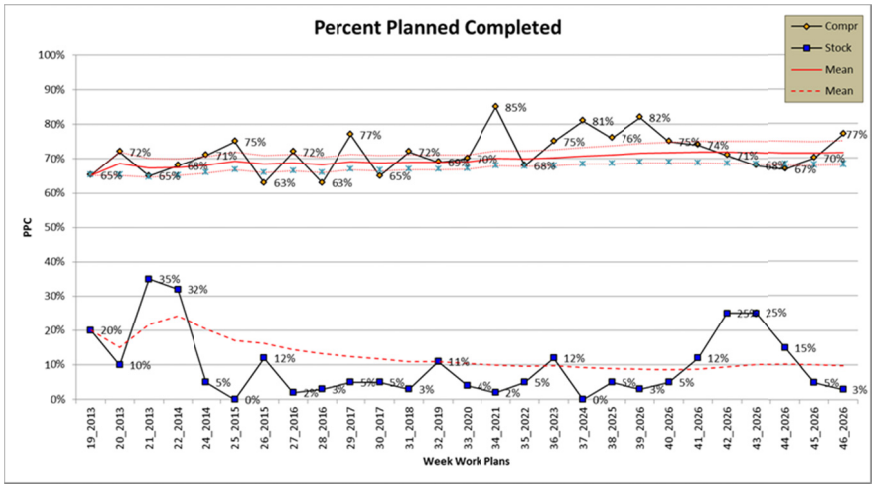

Figure 9. Plan Percent Complete of compromises and stock with means and variances

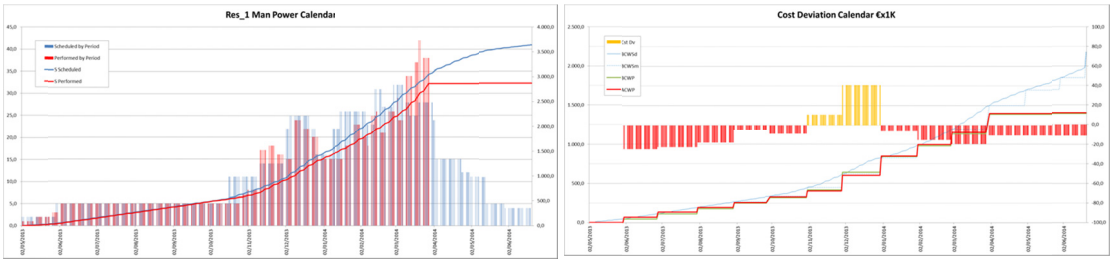

Figure 10. Control applying the earned value method

With the aim of maximizing the academic results through a continuous improvement process, professors involved in the Lean Construction course promote student engagement, commitment, and contribution, applying the Plus-Delta tool at the end of the sessions with a final discussion at the course closure (Fig. 11).

Plus	Delta
Novel, realistic and applicable subject.	The introduction to Lean philosophy is too lengthy.
The course promotes and encourages the collaborative work.	Scheduling tools must go before in the syllabus to face the vehicular project.
A necessary vision to include in the construction industry.	More practical sessions applying lean tools.
Vehicular Project promotes innovation and creativity facilitating the generation of synergies.	

Figure 11. Results of the Plus-Delta at the course closure

CONCLUSIONS

The course of Lean Construction, included in the M.Sc. degree of Planning and Management in Civil Engineering at the Universitat Politècnica de València, is based on a mixed methodology of readings, class discussions, games, simulations, and advanced project scheduling and optimization applied to Last Planner System™ with the application of Earned Value under a production-system point of view. The evaluations of the course, and the high satisfaction achieved by the students, indicates that this mixed methodology as active-based learning, has profound impact on students´ performance and it is an effective method of conveying the main ideas and concepts of Lean Construction techniques to the students and practitioners, even if they have not been previously introduced to them.

ACKNOWLEDGMENTS

The pictures included in figures 2 to 8 are obtained from the project course developed by the team composed by Esther Medel, Jesús García, Guillermo Robles, Saray Segado, Teresa Cholvi, and Arantxa Martí. We want to thank all the students that have participated in the Lean Construction courses throughout the years for their hard work and enthusiasm. We want to recognize the work, passion and insight of part-time professor Fernando Cerveró as well. Finally, we would like to acknowledge the key influence of Professor Luis F. Alarcón who visited Valencia in 2008 and introduced us into the lean construction way of life.

REFERENCES

Alarcón, L., Ashley, D. (1999). Playing games: evaluating the impact of lean production strategies on project cost and schedule. Proceedings IGLC-7, 263-274. University of California, Berkeley, CA, USA.

Ballard, G. (1999). The dice game. Neenan Conference on Lean Construction. Denver, Colorado.

Ballard, G. (2000). The Last Planner System of production control. Ph.D. Thesis. Faculty of Engineering, School of Civil Engineering. University of Birmingham, UK.

Berge, Z. L. (1995). The role of the online instructor/facilitator. Available at http://www.emoderators.com/ (December 2013).

Blank, W. (1997). Authentic instruction. Promising practices for connecting high school to the real world. Tampa, FL: University of South Florida. W.E. Blank.

Bonwell, C., Eison, J. (1991). Active learning: creating excitement in the classroom. AEHE-ERIC Higher Education Report No. 1. Washington, D.C. Jossey-Bass.

Bradley A. Hyatt, P. L. (2011). A case study in integrating lean, green, BIM into an undergraduate construction management scheduling course. 47th ASC Annual International Conference Proceedings. Associated Schools of Construction.

Bucciarelli, L. (1999). Delta design: seeing/seeing as. Proceedings 4th Design Thinking Research Symposium on Design Representation. Massachusetts Institute of Technology, Cambridge, MA.

Dukovska-Popovska, I., Hove-Madsen, V., Nielsen, K.B. (2008). Teaching lean thinking through game: some challenges. 36th European Society for Engineering Education (SEFI) on Quality Assessment, Employability & Innovation.

Ghosh, S., Bhattacharjee, S. (2011). Teaching lean construction with games. Academic Exchange Quarterly, 21-26.

Goldratt, E. (1997). Critical Chain. Great Barrington, MA: North River Press.

Hanzeh, F.R. (2013). Open forum as an active learning method for teaching lean construction. LEAN Educator Conference. Ohio (USA), Fisher College of Business. Ohio State University.

Harwell, S. (1997). Project based learning. Promising practices for connecting High School. S. Harwell.

Howell, G. (1998). The dice game. 6th Ann. Conf. Intl. Group for Lean. Guaruja, Brazil.

Johnson, B., Gunderson, D. (2009). Educating students concerning recent trends in AEC: A survey of ASC member programs. International Proceedings of the 46th Annual Conference. Associated Schools of Construction.

Koskela, L. (2000). An exploration towards a production theory and its application to construction. Espoo, VTT Building Technology, VTT Publications; 408.

Liker, J. (2003). The Toyota way. McGraw-Hill, New York.

Ponz-Tienda, J. (2011). Gestión de proyectos con Excel 2010. Anaya Multimedia, Madrid.

Sacks, R.E. (2007). Simulation of LC management of high-rise apartment buildings. Journal of Construction Engineering and Management, 133(7), 529-539.

Tommelein, I.D. (1998). Pull-driven scheduling for pipe-spool installation: simulation of lean construction technique. Journal of Construction Engineering and Management, 124(4), 279-288.

Tsao, C., Alves, T., Mitropoulos, P. (2012). Different perspectives on teaching lean construction. Proceedings for the 20th Annual Conference of the International Group for Lean Construction. San Diego, California, USA.

Tsao, C., Azambuja, M., Hamzeh, F., Menches, C., Rybkowski, Z. (2013). Teaching lean construction – perspectives on theory and practice. Proceedings IGLC-21, 977-986. Fortaleza, Brazil.