BIM and teamwork of civil engineering students: a case study

Rodrigo F. Herrera†‡*, Juan C. Vielma† & Felipe C. Muñoz†

Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile†
Pontificia Universidad Católica de Chile, Santiago, Chile‡
Universitat Politécnica de Valéncia, València, España*

ABSTRACT: The use of building information modelling (BIM) strengthens collaboration and reduces fragmentation in architecture, engineering and construction (AEC) industry projects, improving performance and reducing costs. For this, not only the incorporation of technologies is required, but also a social change in the way in which the professionals of the area work and relate to each other. The teaching traditionally used in universities does not allow students to be trained in collaborative environments or to generate significant learning in this way. In this article, the authors present the implementation of team-based learning (TBL) for teaching BIM in a civil engineering programme and the learning curve required for this methodology. The importance of the planning of the hours of dedication of the students to the course was evidenced, showing long hours of dedication at the beginning of the course, focused mainly on individual work, recording increases in the hours of dedication to collaborative work in the stages for the delivery of projects.

Keywords: learning curve, building information modelling (BIM), engineering, students, teamwork, team-based learning (TBL)

INTRODUCTION

The architecture, engineering and construction (AEC) industry is characterised by being fragmented into several disciplines, which appear at different stages during the life cycle of a product [1][2]. These disciplines interact with an intensity that will depend on the stage of that life cycle. Although fragmentation generates a high level of specialisation in each of the disciplines, their interaction becomes more complex as the number of parts into which the work is broken down increases [3]. Poor interaction in AEC industry work teams can generate unsatisfactory performances, both in the development of each of its stages (design, construction, maintenance, operation and deconstruction) and at the global level in the life cycle of the product [4]. Unsatisfactory performance is due to activities that do not add value and are considered as project waste, such as: rework and waiting time [5].

One technology that can help integrate stakeholders in the AEC industry is the use of building information modelling (BIM) [6]. The use of BIM can strengthen collaboration and reduce fragmentation in AEC industry projects, while improving performance and reducing costs [6]. Building information modelling has significant potential, especially in the design stage. However, greater interaction between the entities involved cannot be fostered solely using appropriate technologies, but requires an understanding of the social phenomena related to the processing of information by an individual, as well as collaboration [7]. Lean tools can allow for greater interaction, because they foster the management of commitments and trust among team members [8-10].

Traditional engineering teaching methodologies are based on the transmission of information with a learning approach centred on the understanding of concepts, where students receive and process information with low levels of participation, and where academics are simply transmitters of knowledge. The traditional methodology is one in which a disciplinary approach is given, focused on conceptual learning, where the teacher is the centre of class development (verbal transmission), and in which the students act only as receivers, the learning propagated by being memorised and the only resources used are the exposition made by the teacher, a book and the blackboard or slide presentation [11-13].

On the other hand, active learning gives rise to a paradigm shift in higher education, clearly explaining that teaching planning is not only oriented toward the contents and goals presented to the student, but also toward students, and their process of acquisition and construction of knowledge [14]. The methodology of active learning is a globalising approach centred on the development of general capacities, through scientific procedures and attitudes. In this methodology, the teacher is the co-ordinator of the class and the students occupy the central role [15].

There are experiences of teaching BIM in schools of architecture [16] and others about the potentialities of linking BIM with education [17]. However, in civil engineering a traditional teaching style still prevails within the teaching-learning process. Such a situation is reported by Molina [18] and in a previous work [19] searching to understand the low performance of students in the first engineering courses, finding that one of the main problems is the need that the students have to adapt their aptitudes to the particular style of each teacher, whose strategy in the classroom can vary widely.

One of the strategies implemented to improve learning in engineering schools is team-based learning (TBL) [20], which allows students to follow a structured collaborative process to improve the participation of all team members by building knowledge from experience, developing cohesion skills and teamwork [21][22]. Here, the student is responsible for a contribution to the joint construction of knowledge, participating in the various activities, being an active and dynamic entity of the process [23]. The development of team-based learning requires small permanent teams, with similar contribution potential from each member. Individual work should be monitored and how it contributes to the group, allowing the development of the team. Development of communication skills and collaborative working techniques will also be required.

Although the potentialities are clear of teaching BIM with an active approach, such as TBL [24], the impact of this type of methodology on the effort required by students to achieve the tasks is not known, nor is the initial effort required to adopt the approach known. In this article, the following questions are addressed:

- How can BIM be taught to civil engineering students with an active methodology?
- How much do students work in teams and individually when such methodologies are used?
- What is the learning curve for students to be able to work this methodology?

The researchers' aim in this study is to answer the questions, as follows:

1. Review of the methodology of TBL.
2. Proposal for the application of the TBL methodology for the teaching of BIM.
3. Case study: measuring the hours students devote to the course.
4. Data analysis and discussion of results: analysis of measures of central trend and the learning curve.

PROPOSAL FOR THE APPLICATION OF TBL TO TEACH BIM

To teach BIM, the TBL methodology was used in the Virtual Design and Construction course, in the civil engineering programme at the Pontificia Universidad Católica de Valparaíso. The case study presented is for the 1/2018 course in which 26 final-year civil engineering students participated. This version of the course had four types of educational and evaluative activities consisting of:

- Six building projects using BIM tools.
- Individual and collaborative research on new technologies in the AEC industry.
- Reading papers and the literature.
- Workshops classes in which students carried out one of the three previous activities and the professor served as a facilitator of learning.

The six projects were based on different topics and use of the BIM methodology in civil engineering. The topics addressed were the following:

- modelling;
- programming (4D models);
- co-ordination of specialties;
- collaborative work;
- structural design;
- documentation for a model.

For the first three projects, the students had to produce an individual deliverable, and for the following three, the deliverables were group efforts. Although the deliverables were both individual and group, throughout the course of 15 weeks a collaborative work environment was created, with work teams of four or five people who shared information and taught each other. The same teams were maintained throughout the course.

Project work always requires both individual and group effort; therefore, during the 15 weeks of the course the students had to report the hours of individual and team work dedicated to each of the activities of the course (classes, research, reading papers and project). In this way, detailed information on the effort of each student was obtained week by week.

The first two weeks were dedicated to the introduction and installation of the necessary software, and the projects started from week three.

DISCUSSION OF RESULTS

The course schedule defines that students should dedicate an average of nine hours per week, including class time and personal study time. With the information collected on the actual dedication of the 26 students to the course, an average was calculated among all participants. In Figure 1 shown in global terms are the hours dedicated to the course versus those planned; the actual hours include all activities.

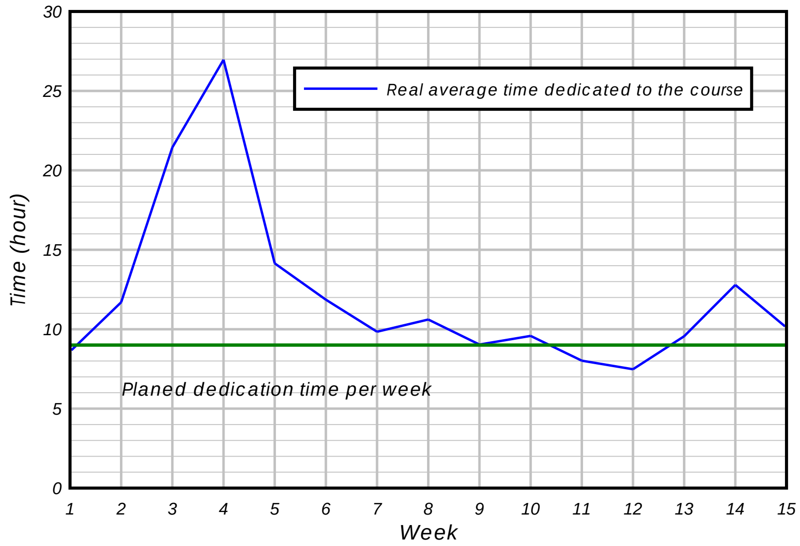

Figure 1: Average hours dedicated to the course vs planned hours per programme.

With the information shown in Figure 1, it is possible to obtain a course dedication index (CDI), which is obtained as the ratio between the average of actual hours dedicated to the course and the planned hours. In Figure 2 is shown how the first five weeks generated a real effort of two or three times what was planned. Then, from week six onwards, an effort was close to that planned, which demonstrates the effect of learning and becoming familiar with collaborative work. This is fundamentally, because at the beginning of the projects (week three onwards), there is an important effort on the part of the students to familiarise themselves with the support tools (software) and to understand the dynamics of collaborative work. It is important to mention that most of the students had never worked in this way with this type of technology.

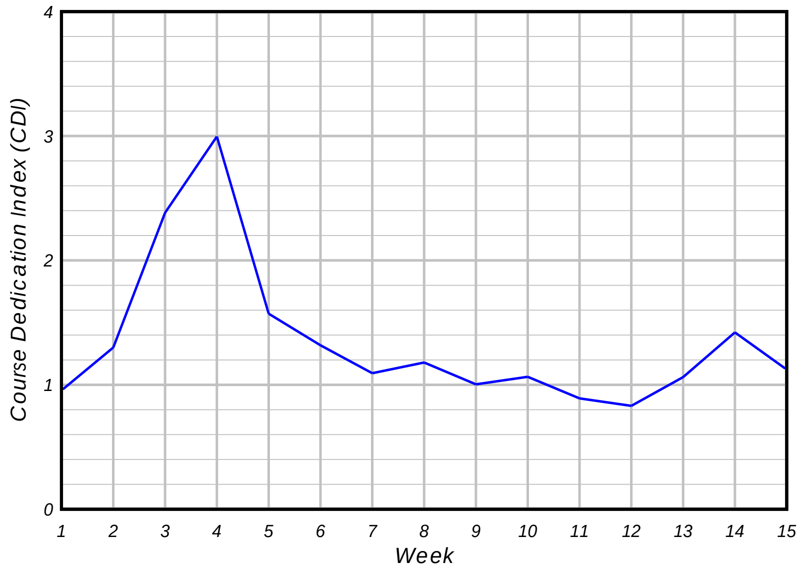

Figure 2: Course dedication index (CDI).

This initial overexertion is reflected by a high individual workload in the first stage of the project during the first four weeks. Shown in Figure 3 is the average percentage dedicated to each activity, with the information divided between individual and team work. It can be observed that most of the effort spent in the first weeks is due to paper study and individual project work. This demonstrates a culture of individual work by students at the beginning of the subject. The important thing is that the students then came to understand that the methodology of work needed in the course should require a collaborative effort among their peers, which is reflected in Figure 4.

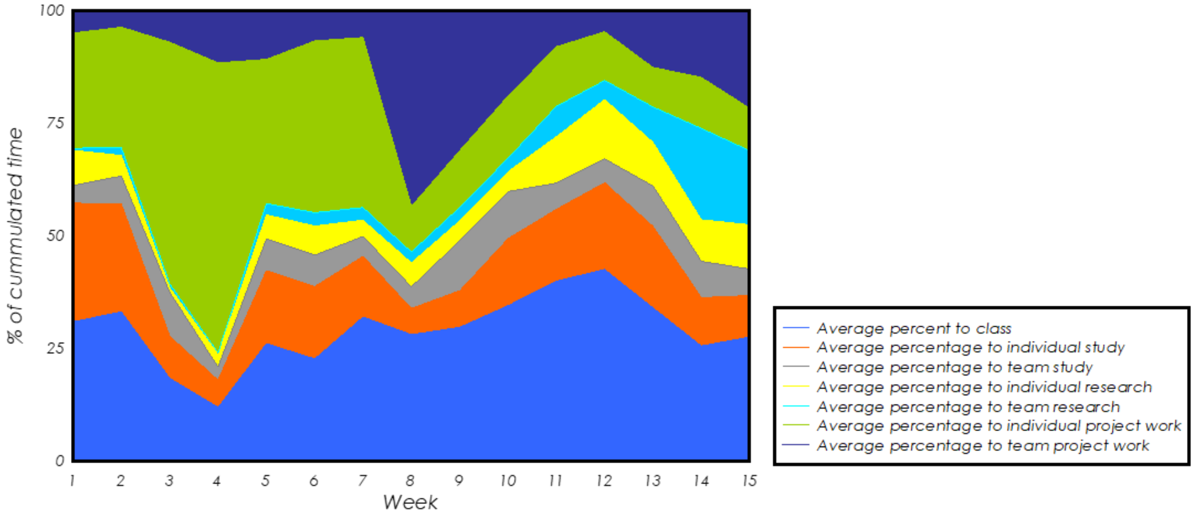

Figure 3: Percentage of time spent weekly on each course activity - individually and in teams.

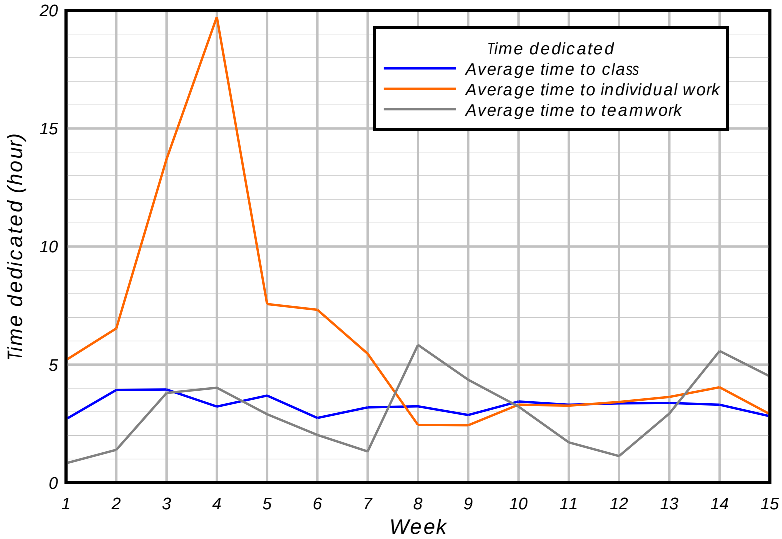

Figure 4: Average hours of individual and group work dedicated weekly to the course.

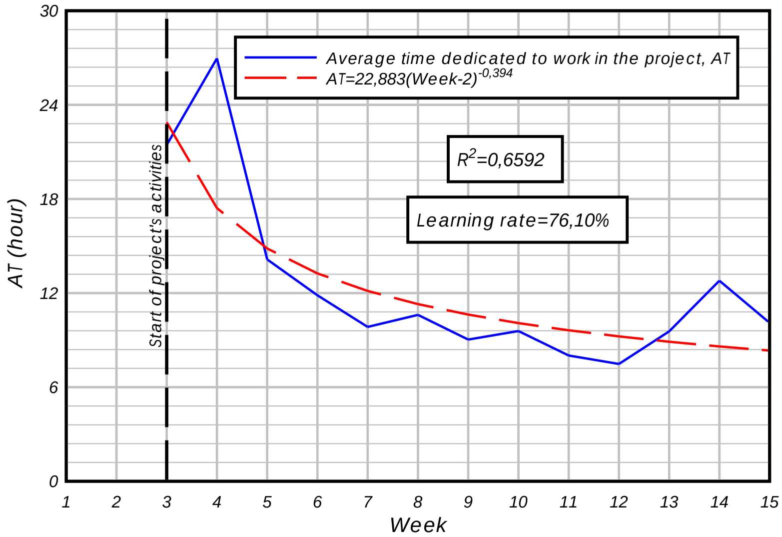

Figure 5: Learning curve - project activity.

The projects had the greatest dedication of time by the students. This was purposely planned by the course faculty, since this teaching methodology is one of those that develops collaborative work to a greater extent [13]. With the information collected as shown in Figure 3, the project activity in the first few weeks involved a number of important hours of individual work and not collaborative work. This effect is generated because, as in all processes, people have a learning period, which can be represented by a learning curve.

Figure 5 shows the average weekly hours dedicated to the course projects, which started in week three and ended in week 15. One of the ways to represent the learning curve is by a potential function. When a potential curve is adjusted to the actual data, it is obtained that the learning curve of the students in this case was 76% with an adjustment coefficient of Pearson $R^2 = 0.6592$. This demonstrates that for a course, the weekly effort dedicated to a project-based methodology using a new technological tool will require an initial effort the first three or four weeks, where students will be in a process of learning the methodology and work tool.

CONCLUSIONS

Presented in this article is the implementation of the strategy of team-based learning to the teaching of building information modelling in a civil engineering programme. When applying the strategy, it is very important to consider the planning of the hours of dedication of the students in the preparation for the strategy. For this purpose, the number of hours dedicated throughout each of the weeks that the course lasted was determined, finding that at the beginning was the largest number of hours dedicated, which adjusted progressively until the final week. It can be stated that the increase in dedication was concentrated in the first five weeks of the course, as evidenced by the CDI. The increase in initial hours of dedication may be interpreted more as the need for an increase in individual work when studying a new subject, rather than reflecting the increase in hours dedicated to collaborative work.

In contrast, an increase in hours dedicated to collaborative work could be detected in the stages of the course in which students were assigned project deliverables, which does highlight collaborative work. The evolution of the time dedicated to collaborative work implies that the group of students took almost half of the course to assimilate the strategy employed. In any case, to establish recommendations for the new application of the strategy in the same course or in similar courses in engineering careers, teachers should consider that students are going to require a significant number of hours in the first four weeks of the course. It is recommended that the same data be monitored in the new edition of the course to assess the improvements made by teachers for the new edition and their influence on students' study time.

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BIOGRAPHIES

Rodrigo F. Herrera is a civil engineer and Bachelor of Science Engineering from the Pontificia Universidad Católica de Valparaíso, has a Master's degree in project management at the University of Viña del Mar, and is currently a PhD student in engineering sciences at the Pontificia Universidad Católica de Chile. He is currently professor of courses: Applied Computer Science, Introduction to Civil Engineering, Planning and Project Control and Project Management in the School of Civil Engineering at the Pontificia Universidad Católica de Valparaíso, Chile. He is the co-ordinator of the Collaborative Group of Engineering Education at the Pontificia Universidad Católica de Valparaíso, Chile. His main research areas are project management and lean construction, besides having a strong interest in defining engineering education.

Juan Carlos Vielma is a civil engineer from the Universidad Centroccidental Lisandro Alvarado. He held his MSc in structural engineering at Universidad de Los Andes, Venezuela, and his PhD in structural dynamics and earthquake engineering at Universidad Politecnica de Cataluña. He has been a Professor at Pontificia Universidad Católica de Valparaíso, since 2016. Areas of interest: seismic vulnerability, numerical methods for non-linear analysis and innovative techniques to improve learning processes.

Felipe C. Muñoz-La Rivera is a civil engineer from the Pontificia Universidad Católica de Valparaíso and has Master's degree in BIM management. He is currently a Professor teaching, such courses as Virtual Design and Construction, Mechanics Dynamics and Project Management at the Pontificia Universidad Católica de Valparaíso. His current research is in AEC technologies, building information modelling (BIM), project management and engineering education.