ADVANCES IN BUILDING EDUCATION
INNOVACIÓN EDUCATIVA EN EDIFICACIÓN

Problems detected in collaborative construction work

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Recibido: 15/02/2022 | Aceptado: 23/03/2022 | Fecha de publicación: 27/04/2022
DOI:10.20868/abe.2022.1.4812

HIGHLIGHTS

- Architecture and engineering projects have always been examples of collaboration. In the Collaborative Intelligence model proposed, some detected problems are addressed.
- Teaching the knowledge of technical drawing is essential.
- The appearance of many computer applications, particularly in different disciplines, has sometimes turned these disciplines into courses on using that specific software.
- The interactions that occur during the collaboration are analyzed.

ABSTRACT

Engineering is a subject that ranges from extensive collaborations to small individual projects. In our interest in the study of collaboration, we have detected a series of problems in realizing construction and engineering projects that cover different aspects. It is worth highlighting the subject of technical drawing, the different terminology used in the projects, mainly when these are carried out in other locations, the massive use of assisted design software, and the difficulty of carrying out projects collaboratively.
Computer-aided design was a catalyst that has been fully implemented in Spain since the 90s in architecture and engineering. The most widespread application worldwide is AutoCAD. Students learn to carry out small projects with software applications. The basis of any project is the drawing of the object to be made. When teaching technical drawing, instructors have noticed fundamental deficiencies in the correct representation of objects.
Similarly, those responsible for the projects have shown the absence of this knowledge. This significantly impairs the definition of certain essential elements that must be specified later in the execution due to the changes between what is projected and what can be executed. On the other hand, during the construction boom and mainly due to the commercialization of homes, multiple 3D software emerged to facilitate the prospective buyer's vision of their future home. The proliferation of this type of software has posed a series of problems as students master the computer tool but not the transition from 3D to 2D and vice-versa. Although AutoCAD made it easy to carry out projects with excellent efficiency, it has failed, despite its many updates, to become a collaborative tool that allows several individuals to work on the same file at the same time. However, architecture and engineering projects have always been examples of collaboration, as shown in the Collaborative Intelligence model proposed in our research articles. Specifically, this model is based on three fundamental pillars: area of knowledge, collaborative technology, and intellectual cooperation. Of these three pillars of Collaborative Intelligence, we are most affected by the area of knowledge and collaborative technology since this is where more deficiencies have been detected.
This study highlights these difficulties and solves the problems that project managers have detected in their collaborators for students to acquire these skills. We consider that the acquisition of these competencies is based on correct technical drawing learning, although the software is the primary interaction vehicle.

Keywords: *Collaborative Intelligence, Collaborative Planning, Collaborative Working, Technical Drawing Knowledge, 2D & 3D Software.*

1. INTRODUCTION

While scientists try to understand nature, engineers try to do things that do not exist in nature. Engineering is the applied science that consists of acquiring and applying knowledge to analyze the design and construction of works for practical purposes. Technical graphics develop creativity and spatial awareness by having students reason in two and three dimensions. It helps students communicate their ideas graphically and allows them to experiment with shape, shadow, and color [1]. The most important object of technical graphics is technical drawing. According to [2], for Monge, "technical drawing is the graphic language of engineering." Approximately 90% of the projects are based on the graphic part of engineering. In this way, engineering education is based on graphic activity [1].

In our interest in the study of collaboration, we have detected a series of problems in the execution of construction projects that begin with teaching the subject of technical drawing and continue with the interactions that occur during the collaboration.

- The problems that have been detected in terms of technical drawing knowledge are listed below:

- We could consider the different spelling of the symbols that appear in the projects as using a different language.

- The use of new software is very widespread today:
  - It involves a loss of skills in drawing on paper. Although the students applaud this circumstance, it is detrimental to their training, which materializes when freehand sketches must be made.
  - It makes it challenging to represent 3D objects from a 2D support. According to the authors Murad et al. [3]. The main difficulty of technical drawing is representing a 3D object on a 2D support. This restriction imposes on the human mind the need to summarize the spatial properties of objects on paper [3].
  - It makes it challenging to represent, in the 2D plane, any object that has been made from a spatial vision. This last problem arises due to the use of 3D software without previously mastering the plane's design.

Collaboration issues that have been identified are listed below:

- The language used in carrying out engineering and construction projects is based on technical drawing as the only form of communication. In projects carried out in different locations or between a group of companies, using the same language is crucial.
- The most widespread CAD software application in the world is AutoCAD. Despite the numerous updates made to this application, it has not been possible to make it genuinely collaborative software that allows different people to modify the same file.

This article will relate the problems detected with the Collaborative Intelligence (CI) model, which we have raised in other research articles and represented in Figure 1.

Fig. 1: Bases of Collaborative Intelligence
Source: [4]

The model has three pillars on which any project requiring CI is based. Once the problems have been detected, some of them correspond to the field of knowledge of construction and engineering, specifically the graphic representation of the project. Others affect the field of technology and collaborative projects, specifically in the latter with collaborative planning.

For this purpose, a descriptive review has been carried out based on scientific publications in the last 15 years, introducing the search words "technical drawing education" as an advanced search. Specifically, in the Web of Science database, only 27 results have appeared, grouped by date, as shown in Figure 2.

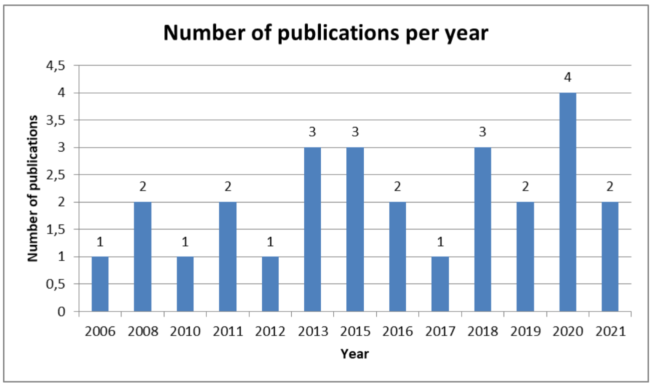

Fig. 2: Number of publications per year
Source: Authors

Figure 3 presents the number of relevant publications by field of knowledge.

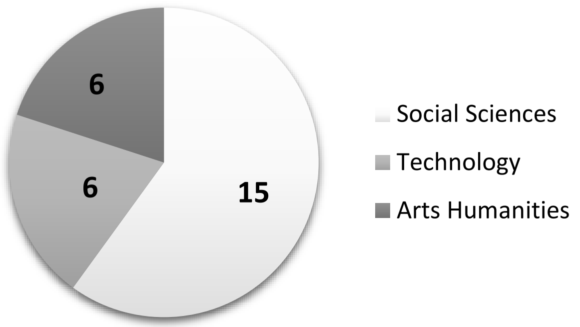

Fig 3: Number of publications by fields of knowledge
Source: Authors

We analyze these studies in the following sections.

2.- PROBLEMS DETECTED IN THE FIELD OF KNOWLEDGE

It has been observed that students who enter engineering and architecture studies have a high level of competence in mathematics and physics and efficiently solve problems based on the use of mathematical formulas or by giving quick answers to an event or event that is presented to them. However, they do not have the same skills to make sketches or pictorial representations [5]. Larkin and Simon [6] explain why diagrams or drawings may be superior to written or verbal descriptions of a problem. Among them is that diagrams preserve the topological and geometric relationships between the components of the problem.

Students present their ideas and solutions in the form of drawings. It is their means to develop and record their ideas and convey them to others. It provides them with the ability to imagine and mentally manipulate spatial forms. It is a unique form of communication [1].

Generally, these preliminary sketches and subsequent design drawings are made according to the principles of technical drawing because it is the most straightforward way of transmitting and recording information. When the engineers sign their approval, these drawings must be checked to send them to manufacturing since they assume responsibility for it. An overlooked mistake can be costly. A lack of quality has been observed in the sketches' design, mainly due to the lack of dimensioning [7]. Ideally, therefore, engineers should be good draftsmen.

These sketches or freehand drawings are among the best activities for developing spatial visualization skills [8,9] and improving the ability to communicate designs effectively [10]. The problem is that the university's time available for its teaching is limited, and it is impossible to achieve the necessary competence [1].

For this reason, different studies have been carried out to improve this visualization ability in students. Specifically, the one carried out by Prieto, and Velasco (2008) aims to analyze the improvement in learning of the mental representation of the internal structure of a piece or the transformation of three-dimensional objects. A battery of computerized exercises is carried out to improve visualization aptitude. The results of this study are that this aptitude has been enhanced through training, and therefore, the performance in learning Technical Drawing is higher. The authors recommend performing this type of test at the beginning of each course to identify possible later learning problems [11]. Current information and communication technologies introduce new educational paradigms in the teaching and learning process. The software has served to detect a deficiency and find a possible solution in this case.

3.-PROBLEMS DETECTED IN INFORMATION AND COMMUNICATION TECHNOLOGIES

The appearance of many computer applications, very specific in different disciplines, has sometimes turned these disciplines into courses on the use of particular software. Table 1 shows the advantages and disadvantages of the implementation of software when carrying out projects:

Table 1: Advantages and disadvantages of software implementation in project realization

Advantages	Disadvantages
Better project storage, in a single file, rather than in drawings on separate sheets.	It is difficult to use without knowing the basic rules of technical drawing.
Possibility to eliminate mistakes in the project faster than in paper-based projects	The application may be challenging to adapt to the current version of the software developed by the company.
Complex drawings which require secondary drawings can be produced more efficiently.	Discrepancies exist among systems with older software versions.
Sending the whole project or parts of it is easier than sending it on paper.	The high cost of licensed software has to be considered.
Both the drawing and its dimensioning are more straightforward.	Drawing files from older versions cannot be opened in the updated version.
	Incompatibility with other applications that complete the final project.

Source: Authors based on [12]

Despite the advantages and disadvantages listed in Table 1, the evidence shows that pre-university students handle new applications with great ease that other generations would never have imagined. The appearance of video games, so widespread in a very short period, provides a highly developed spatial vision. Video games such as Fornite allow the player to move around an island in 3D. Alternatively, Minecraft allows the player to explore and edit the terrain through which the player moves. Will we be able to carry out projects in a video game way in a short time? Could we, at this point, do without Google Maps? Technology provides applications that we could never have imagined a short time ago.

The appearance of the Building Information Modeling (BIM) methodology has been a shock to the profession, although it continues to have detractors. BIM is a new approach to managing engineering work's design, construction, operation, and maintenance, broadly encompassing various technologies, tools, processes, and protocols that transform the architecture, engineering, and construction (AIC) industry [13].

The mandatory use of BIM to carry out engineering and building projects in some European countries began when the British administration demanded that it was necessary to present it in this format to tender any project. Since then, due to the United Kingdom's significant influence, the system has spread throughout Europe, not being mandatory in Spain. However, Spanish companies working in the United Kingdom have implemented it in their procedures. BIM is compulsory in public works that depend on the Ministry of Development and in those of Catalonia. In the Basque Country, projects that depend on the General Directorate of Housing of the Basque Government and residential development companies such as Neinor Homes, Metrovacesa, Vía Celere, or Aedas also use it [14].

The advantages of this system allow reducing costs in projects by between 10-20%. In addition, they substantially improve the processes of rehabilitation of buildings, facilitate control over the economic viability of investments, limit the environmental impact, and significantly facilitate work in strategic fields such as Energy Efficiency and Smart Cities [15].

As for what affects this research work, BIM is the first computer application that allows the collaborative management of a project. According to [15], BIM is the first collaborative application in the engineering and construction sector that enables:

- To collect the information provided by different professionals simultaneously in a single centralized design.
- To use all the data for the different phases of the project life cycle.
- To apply all kinds of methodologies, techniques, and tools that allow structural and energy simulations.
- To simulate the economic exploitation of the building from its initial construction to its demolition.

- Each professional involved in creating a construction project can contribute objects with the attributes developed by himself or by the different suppliers that will become part of the database.

- To store in the database the spaces already built or designed and the materials, means, and resources. All the information is interrelated and allows the building to be created iteratively.

- To recalculate and modify the entire project in real-time with any change made.

- To offer the added advantage of always working in a 3D visual format on a single 2D / 3D plans repository.

4.-COLLABORATION IN PROJECTS

The collaborative intelligence model that we have proposed and are working on is based on the pillars referenced in Figure 1: Bases of the Collaborative Intelligence (CI). The pillars, fields of knowledge of construction and engineering, and collaboration technology have been addressed in previous points. This section will deal with the problems that affect intellectual cooperation in collaborative projects.

The items shown in BIM use allow us, in principle, to favorably relate this application to the Collaborative Intelligence model in terms of two of the three pillars discussed above. However, there are doubts about whether it meets the basic standards of the third of them, in terms of Collaborative Planning, a variable that corresponds to the third pillar of CI. Does BIM comply with the requirements we have established on collaborative planning? The following figure shows these standards:

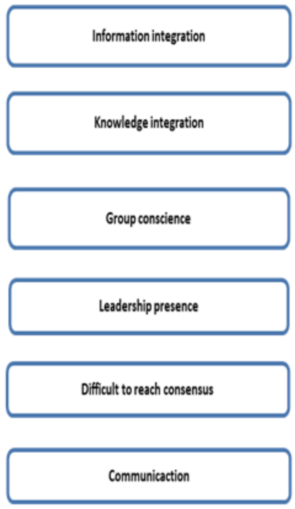

Fig 4: Basic standards of collaborative planning. Source: Authors

Finally, and with all the above, the approach made in this article is discussed.

5.-DISCUSSION

The approach adopted for obtaining CI goes through the three pillars it is based on. Regarding the area of knowledge, the main problem is that the communication language is not unique. In engineering and architecture projects, the language is technical drawing. The loss of specific skills detected, both in students and professionals, in making freehand sketches necessary to define the previous design and the execution of the work has caused an inevitable loss of understanding.

This loss of skills is due to students' lack of prior training before starting university studies, and during these, the excess software does not allow them to go deeper in the development of technical drawing skills. As for professionals, the training received during university studies and depending on the different study plans can be corrected during the company's continuous training. On the other hand, for some researchers, the excess of computer applications represents a loss of knowledge regarding linear drawing, which affects the exhaustive definition of the elements depicted in architecture and engineering projects.

Currently, projects are carried out using different software. These applications are based on drawings previously made in 2D, depending on the quality, definition, and people who enter these data. The projects will be better or worse defined. The applications help a lot, but the individuals who enter the information must know both the design background and the software's commands to use the resources better.

In terms of collaboration technology, the most crucial application that has been developed so far is BIM. Assuming that the professionals who enter the information have carried out a good base project, based on requirements known and accepted by the rest of the participants and that these requirements comply with the standards established by the authorities that will finally approve the project. The information and knowledge base will be correct and integrated since BIM manages to combine this information in a database.

Once the information and knowledge have been collected, the rest of the standards on which good collaborative planning is based no longer depends on the field of knowledge of architecture and engineering or collaborative technology but on Intellectual Collaboration, the third pillar of the IC.

In this sense, is group conscience possible when different stakeholders are involved in a project? A specific group conscience can be reached when there is a shared objective, which is the achievement of a project. During the project's development, there will be disagreements between the different stakeholders that will have to be resolved if the project is to be successful. These differences can be corrected to a greater or lesser extent if there is communication between the members of the project and an expert leader.

6.-CONCLUSION

The appearance of the BIM application has been a shock for CI. Until now, there was no application on the market that would allow collaborative work in an architecture and engineering project capable of allowing several workers to introduce data or modifications at the time. That BIM's first requirement is a database that collects the information and knowledge of those involved in the project, meeting our expectations regarding the pillars on which CI is based.

This database requires that the information entered be carried out by experts in technical drawing, mainly so that the project meets all technical and legal requirements. This implies that in the same way that students nowadays are very skilled in handling new ICT and are very accustomed to using 3D software, a small number of them may acquire technical drawing skills at a specific moment. It will be then when these professionals are more valued.

The problem is the same as in any other collaborative project regarding collaborative planning. Communication is required in all phases of the project. Group conscience and the difficulty of consensus are more achievable since any architectural and engineering project has a tangible common goal. When the objectives are tangible, they are easier to envision and achieve. Problems of another nature that are not typical of architecture and engineering may arise, making the final achievement difficult.

Finally, a leader or coordinator's presence is essential in any project, whether collaborative or not. Planning rarely takes place in the absence of leadership or instruction. The tasks of any project should be structured and subordinated in the hands of an expert team member.

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