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ACTIVE LEARNING: THE USE AND APPLICATION OF BUILDING INFORMATION MODELING (BIM) IN CIVIL ENGINEERING [1]

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Abstract: This article presents a case study of the application of Building Information Modeling (BIM) in the Civil Engineering course with the aim of guiding the choice of project management practices according to the characteristics of the project and environmental factors. To this end, a work system called Integrator Project was implemented, involving a partial integration between the mandatory subjects of Law and Planning and Construction Management in the Undergraduate Civil Engineering course. The Integrator Project included three general objectives: (i) expand the skills and professional attitudes desirable for the practice of engineering; (ii) develop practical activities to solve complex problems with multidisciplinary teams and (iii) disseminate the application of BIM in Civil Engineering. As a result, the use of active methodologies employed points to a better integration of disciplines in Civil Engineering undergraduate courses and aims to address issues of technological innovation, in line with sustainability, the environment and the market.
Keywords: Project-Based Learning. BIM. Teaching methods. Team work.

INTRODUCTION

Based on the four pillars of UNESCO (DELORS, 2012) that underpin 21st century learning – knowing how to be, knowing how to live together, knowing how to know and knowing how to do – this article deals with the Integrator Project, involving partial integration between the mandatory subjects of Law and Construction Management, as well as the application of learning based on Problem-Based Learning (PBL) using the concept of Building Information Modeling (BIM) in the Civil Engineering course.

There is an increasing demand for new skills and abilities from engineering professionals (KRUEGER, CARSRUD,1993; CASALE, 2011, 2013). According to Boahin and Hofman (2014), companies and organizations seek professionals who are capable of combining skills and competencies in an innovative way to deal with the challenges of the 21st century. The regulation itself, instituted in 2019, of the National Curricular Guidelines (DCNs) for engineering courses points to a graduate with humanist, critical and reflective training, which allows professionals to adapt to rapid social, technological, economic and environmental transformations. It is based on this context that the experience of the integrative project is inserted, that is, the recognition of the role of higher education institutions (HEIs) in creating an academic environment that is capable of contributing to innovation and entrepreneurship in teaching engineering (BITTENCOURT, 2019). This study is aimed at those interested in exploring transdisciplinarity, innovation in teaching and educational entrepreneurship (FAYOLLE, 2007).

Another point that has intensified in civil engineering education is the application of digital tools for data management and integration systems, as well as the need to develop management solutions capable of combining creativity and flexibility to adapt to changes, along with adequate documents and levels of control. Wortmann (2016) explains that "the concept of using digital models and specifications for simulations is firmly rooted in several industries that require measurable and repeatable methodologies". Aghion, Dewatripont and Stein (2008) emphasize the difficulty of managing projects that involve researchers from different areas of knowledge, working as a team, with autonomy and at the same time creativity. To this extent, managers are faced with the need for multidisciplinary teams to create project control and reporting systems to meet the various stakeholders and

the demands of research funding agencies.

In this context, Building Information Modeling (BIM), proposed by G.A van Nederveen and F. Tolman (1992), became the option for the teachers involved to coordinate the needs of the integrative project defined for the academic semester. Firstly, because BIM allows you to gather information about the project, including physical and functional information about the building, which is stored in the same digital space, as a database of information on the construction life cycle. Furthermore, it brings the 3D concept, being an excellent planning and projection tool for the civil construction market. According to Eastman et al. (2008, p.13), BIM is "a modeling technology and an associated group of processes for production, communication and analysis of the construction model".

According to the researchers involved, information technologies can provide support, transparency and quality for process management, as well as for better systematization of information on engineering works and services as well as for other stages of the existence of buildings and infrastructure. In fact, the use of modeling such as BIM must be understood as the set of protocols, standards and methodology developed for the application of information technology in civil construction. This modeling allows for an integrated treatment of information in construction, as it consolidates the information on each aspect/information of the project that is provided by each agent involved independently, allowing the management and control of political interactions, processes and technologies involved in the projects. of construction.

This article presents a case study of the application of BIM for integrated project management in the Civil Engineering course with the aim of guiding the choice of project management practices according to the characteristics of the project and environmental factors. The present study reports the use of this modeling, whose approach allows the management of a project, structuring a proposal for a project management model, in order to contribute and help professionals in the field to improve the management process of their projects. In this context, a work system was implemented, called Integrator Project, involving a partial integration between the mandatory subjects of Law and Planning and Construction Management in the Undergraduate Civil Engineering course.

The Integrator Project included three general objectives: (i) expand the skills and professional attitudes desirable for the practice of engineering; (ii) develop practical activities to solve complex problems with multidisciplinary teams and (iii) disseminate the application of BIM in Civil Engineering. The specific objectives of the Integrator Project were: i. bring a vision of context, that is, expose the perception of the environment in which the building or enterprise will be located, including social and cultural issues, considering the project's vision in the real estate market and ii. explore solutions in construction, understanding the integrative project as a bridge to think about solutions that satisfy the issues of technological innovation, in line with sustainability, the environment and the market. Therefore, this article presents the results of applying the Problem-Based Learning (PBL) methodology with the application of BIM with the aim of proposing solutions to challenges in the Civil Engineering course. The aim was to ensure that at the end of the project, students would be able to identify and validate correlations between the class of the building and the legal parameters of urban law, operational costs, management and sustainability, taking into consideration, the technology used, based on

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more sustainable solutions to be incorporated into the execution of the project.

METHODOLOGY

PRESENTATION OF THE INTEGRATIVE PROJECT

The Integrator Project introduced, in the second semester of 2021, the teaching method known as "Project-Based Learning" (PBL) with the application of Building Information Modeling (BIM) in the teaching of Engineering for the second semester class of the 5th year of Civil-Aeronautical Engineering course. The introduced PBL method provided students with the understanding of contextualized scenarios to face situations that are part of everyday life and their future professional career (ESCRIVÃO FILHO, RIBEIRO, Luis Roberto, 2009; BOULD, FELETTI, 1999) and addressed the following challenge: "Incorporate technological and sustainable innovations in construction management and reduce the burden of civil construction imposed on the environment". Table 1 presents a description of the stages of the learning cycle expected in the Integrator Project, in which students learned about and defined the problem, moving on to research and present solutions.

The Integrating Project incorporated concepts from the disciplines Notions of Law (HUM-20) and Construction Planning and Management (EDI-48), whose objective was to integrate knowledge from different areas in resolving a problem situation related to civil construction in a work in group. The guiding theme for the preparation of the project was Social Interest Housing (HIS) in the municipality of São José dos Campos/SP (SJC). Figure 1 presents the HIS architectural plan (a) and an isometric view of the model (b). HIS has a built area of 63 m², comprising a living room combined with a dining room, an open-plan kitchen, two bedrooms, a bathroom and a laundry area. The models studied in the Integrator Project were architectural, structural, electrical and sanitary. The solutions adopted by the groups incorporated technological innovations in the execution of civil construction works, within the scope of resource management and monitoring of the work, using the BIM concept and with a sustainable character, in which they verified compliance with the Master Plan and zoning of the area. municipality of SJC.

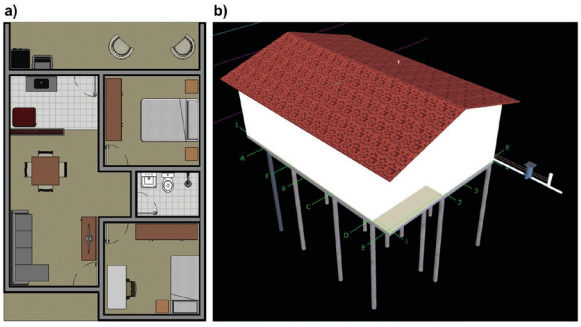

Figure 1 - HIS architectural plan (a) and isometric view of the compatible models of architecture, structure, electrical and sanitary installations (b)

Source: Authors

The integrative project involved two teachers, a mentor, four speakers and ten students and was structured as follows: (1) two groups of five people were organized; (2) the challenge focused on the theme of Sustainability was presented and (3) the groups were enrolled in the same subjects with partial integration of content. Table 1 shows the scope of the Integrator Project, which resulted in ten students working on two projects, with each project involving five students.

Class	Number of students involved	Number of Projects
Civil	10	02

Table 1 – Quantitative information about the scope of the Project.

Source: Authors

Steps	Goals	Activity	Requirement
1ª step	Know the problem	Presentation of the challenge by teachers and division of groups	Map the context and carrying out preliminary secondary data research
2ª step	Define the problem	Guidance guided by mentors and teachers about the scenario (stakeholders)	Identify active and passive stakeholders and study scenarios
3ª step	Search for solutions	Integration of components of the disciplines involved	Define legal requirements, functions and limitations
4ª step	Present the solution	Integration of components guided by teachers and mentors	Bring technical and/or business solution

Table 1 – Description of the stages of the expected learning cycle

Source: Authors

RESPONSIBILITIES OF THE HUM-20 AND EDI-48 DISCIPLINES IN THE INTEGRATOR PROJECT

Each discipline defined specific objectives and learning within the Integrator Project. The discipline "HUM-20: Notions of Law" was responsible for bringing the legal and regulatory frameworks for the viability of the project, as well as the concepts of zoning and master plan of the municipality of SJC, in addition to the skills and attitudes desirable for project management (AJZEN, 1987; 1991). The subject "EDI-48: Construction Planning and Management" aimed to study and develop planning, design, budgeting and building management practices. During the course, students worked from identifying the activities of a project to generating the physical schedule, within the issue of planning and building design; moving on to the budgeting part, in which students collected cost information and calculated the sales price of a building; and finishing with the construction management content, where students studied techniques and tools to correctly manage the construction of the building. The BIM methodology has acted as one of the modernization processes in civil construction. Therefore, using this concept and applying it in the EDI-48 discipline is an important step towards updating the tools taught in the classroom and which will be used in the student's professional career. The work sought to integrate building planning, management and budgeting software so that the student worked with project compatibility and the physical-financial schedule of a project in order to apply these concepts in one of the most modern concepts in civil construction. To this extent, software for application in BIM provides support and resources for the execution of the different technical disciplines that make up the set of documents necessary for a project in a collaborative and simultaneous way, so each group adjusted its project simultaneously with each exchange of information during development. with other disciplines and project information. Therefore, the EDI-48 discipline was responsible for evaluating the students' solutions regarding the management of the work studied.

ACTIVITIES CARRIED OUT IN THE INTEGRATIVE PROJECT

This section presents a description of the integrative project, its objectives, methodologies, and, mainly, the challenges regarding adaptation to the virtual format in 2021, highlighting the stages of development of the work.

The activities were carried out by the groups and divided into three work stages:

i) Socio-territorial context of the municipality of SJC and legal and technical mapping for the viability of the project: the group of students identified the legal restrictions of urban law and the technical standards applicable to the

project. At this stage, the architectural, structural, electrical and sanitary models of a social housing (HIS) were presented; compatibility of the models to check interference between disciplines (architecture, structure, electrical and sanitary) using project analysis software and theoretical content and its application based on the models in the planning and design software for works to generate the physical schedule using the concept BIM. Furthermore, integration with HUM-20 began to define the scope of the solution within the scope of construction management for HIS with fortnightly monitoring. The groups presented Social Housing projects in São José dos Campos - São Paulo, highlighting the legal aspects for choosing the location with analysis of the master plan and local zoning definitions. The location of the project was defined using geoprocessing and feasibility analysis with medium and long-term aspects of the project.

ii) Minimum detail of solutions within the scope of the EDI-48 and HUM-20 discipline: Students presented details of solutions within the scope of resource management (sustainable use of materials, etc.) and monitoring of the work (sustainable monitoring). At this stage, the theoretical budgeting content and its application in the budget using the BIM concept were presented; theoretical content of construction management; detailing the integration with HUM-20 with the solution within the scope of construction management for HIS with weekly mentoring;

iii) Presentation of results through oral presentation and writing of an Academic Article. The assessments consisted of delivering a physical schedule and budget; partial and final presentations; article and Solid Waste Management Plan. In the final presentation, the students explained the legal and technical analyzes for implementing HIS in the city of São José dos Campos/SP and presented the details of a sustainable solution in the context of construction management, whether resource management or monitoring of the work. The BIM models developed during the course were used to support and assist in proposing solutions.

BIM CONTENT AND INFORMATION MANAGEMENT

The HIS models used by the students were composed of architecture, structure, electrical and sanitary. In these models, the elements contained relevant information for the planning and construction management stage, such as linear measurements (height, width and length), areas, volume, specific mass, among others. These models were exported to planning and project software with this information. Furthermore, new information was added to this software, such as the compositions of elements and activities of the work. Using this software and with this information, it was possible to survey activities, extract quantities, calculate activity durations, precedence to generate the HIS physical schedule. By surveying prices in databases, the students produced the HIS budget, using the information obtained from the physical schedule. With the information obtained from the HIS models, with the incorporation of composition and price databases, the students were able to work with the physical schedule and budget of the work to carry out simulations in accordance with the solutions adopted by the students in the integrative project.

RESULTS AND DISCUSSION

PRESENTATION OF STUDENT SOLUTIONS

The students' presentation was divided into two parts: i) legal and technical analysis for implementing HIS; and ii) presentation of a sustainable solution in the context of construction management. In relation to the analyzes for implementing the HIS, the students sought information within the legal context regarding territorial planning, special zones of social interest and macro-zoning established based on current laws and mainly using the São José dos Campos Master Plan. In addition to these legal guidelines, students also used some technical criteria, such as proximity to public environments (schools, restaurants, etc.), access to public transport (bus stops) and financial criteria (value per m² of land). As a result, students arrived at different locations for HIS implementation. Figure 2 shows the location of the HIS for Group 1 (Fig. 2a) and Group 2 (Fig. 2b). Within the criteria chosen by the students, Group 1 chose the address: Rua do Serrote (Recanto do Vale) as the location for implementing the HIS, while Group 2 considered the address: Rua Kenkiti Shimomoto (Vila Zizinha) as a suitable location for the HIS. These locations meet both the legal criteria regarding zoning and the technical criteria of points of interest close to the chosen location and land value.

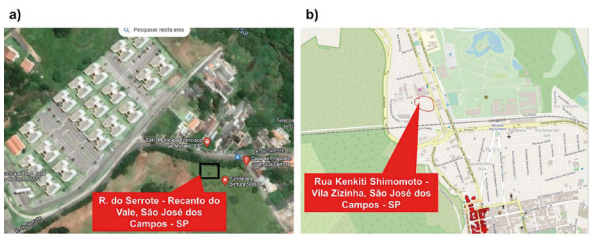

Figure 2 - Location of the HIS chosen by Group 1 (a) and Group 2 (b)

Source: Authors

In the second part, students presented sustainable solutions for resource management (Group 1) and construction monitoring (Group 2). Regarding the first topic, resource management, Group 1 carried out a bibliography survey and concluded that adequate resource management for the HIS reality aims to reduce material losses and increase labor productivity. Therefore, the group developed a training procedure for specific employees on the site in order to achieve these objectives. As a result, the group reported that there was a long-term cost reduction and improved human resource training. With regard to the second theme, monitoring of works, Group 2 proposed a SCRUM methodology, in which this methodology involves dividing the main project into short-term activities with the aim of managing them in a more agile and efficient way. Using this methodology, it is possible to divide the stages of the work into smaller activities in order to improve monitoring capacity. By employing the methodology in specific stages of the work, students reported the possibility of increasing productivity and motivation of the workforce.

The BIM concept helped students' solutions because construction planning and budget information was easily accessible and interconnected. With these advantages, it was possible to present simulations of the solutions presented by the students with an adequate basis. Therefore, there was better use of the study of solutions and better presentation by students due to this methodology.

IMPACT ON STUDENT TRAINING

Of the 10 students who participated in the implementation of the integrative project, 08 gave feedback via email or at the end of the course about the semester's experience. Of these, 4 pointed out problems such as: (i) planning and concentration of content in the second two months; (ii) reduced time for

presenting solutions, as well as workload and extra-class dedication time.

The questions presented by the students were grouped into didactic-pedagogical organization and digital tools used.

The challenges of didactic-pedagogical organization required a transdisciplinary approach, in order to awaken students' interest in connecting curricular components, contextualizing them. This dynamic encouraged teams to access multidisciplinary content, digital tools linked to project management and experience real-world problems. Teachers played the role of facilitators of the work carried out by the groups, creating learning environments and emphasizing group interaction, active listening and introducing questioning techniques, in order to establish informal communication and stimulate skills related to attitudes as a protagonist. and commitment to users.

The first challenge was the alignment, among teachers, of what would be possible to integrate, taking into consideration, the respective syllabi and the time interval of one semester to make the project viable in the COVID scenario. It was decided that the integration would be partial and would take place in the middle of the semester, after the introduction of the fundamental components of each area. The decision resulted from two aspects raised: (i) the need to introduce minimally the curricular components of the disciplines involved and (ii) the dimensioning of the complexity of applying BIM modeling within the established deadline.

The point of greatest complaint from students was the load of proposed activities and content organization, with, for example, one student putting forward as a suggestion "the distribution of content throughout the semester and not concentration in the second two months". It is worth noting that during the 2nd semester of 2021, due to the pandemic scenario, teachers and students were inserted into Google Workspace for Education, with access to a set of tools and services adapted to remote teaching.

The second challenge was the choice of using digital tools in the development of hands-on activities through group dynamics, with the aim of promoting engagement and the good development of the project. In this environment, teachers and mentors presented the necessary theoretical concepts, always in accessible language, and, subsequently, guided students to carry out an experiment in which the concepts studied were applied. Studies (RIBEIRO, 2009; ESCRIVÃO and RIBEIRO, 2008) indicate that this type of learning is improved by social interaction.

Despite the problems described, the students' general assessment of the adaptation to remote teaching and the implementation of mentoring, in the second two months, was positive. Of those who spoke, 7 liked the learning experience through PBL and reported that BIM modeling was an important differentiator for optimizing the team's work and for the enterprise's knowledge management; They also highlighted the importance of guidance guided by real problems. Below are the main impacts indicated by the students:

Positive Impacts	Negative Impacts
1. better understanding of project, planning, budget and construction management; 2. importance of the BIM concept in civil construction; integration with other disciplines and understanding the role of integration.	1. load adjustment and work administration; 2. definition of themes; interoperability

Table 2: Description of impacts

Source: Authors

It can be seen from the table above that the implemented proposal boosted not only the understanding of technical problems, but

also the legal restrictions of the project. The feedback to the teachers involved was positive, with emphasis on the ability to make decisions with a greater understanding of the risks and scenarios. To this extent, the proposal appears to have provided students with an experience close to the reality of more complex areas of construction management.

FINAL CONSIDERATIONS

This article dealt with the application of active learning applying BIM in the Civil Engineering course and its challenges, among them: (i) planning of activities with the need for teachers to take ownership of the syllabi of the disciplines involved and above all, the methodologies used in each discipline; (ii) design of challenges with the dimensioning of complexity within the established deadline and (iii) the adaptation of dynamics and in-person teaching to remote teaching. The application experience brought significant learning to teachers and drove a new modeling of the design of challenges for a medium and long-term scenario (post-pandemic), involving regional and local development strategies based on the concept of sustainable development.

The students involved were heard and the perceptions recorded showed the high degree of interest in active learning, especially in the development of hands-on activities through group dynamics, with the purpose of promoting engagement and access to new technologies available for learning. area. The results obtained pointed to the positive effect of applying BIM. To this extent, learning through PBL, made possible by the partial integration of Law and Construction Management disciplines, can be one of the paths to be adopted by the universities to insert the innovation trail into its curricular proposals and comply with the requirements of the DCNs for courses of engineering.

It must be noted, however, that the results cannot be generalized, since they were obtained through application restricted to an engineering class, in addition to having occurred in a period that is outside of normality, that is, the year 2021 affected by the coronavirus pandemic. COVID. With the purpose of expanding the database collected, the teachers chose to continue with the project in 2022, involving new challenges associated with the 2030 Agenda and Sustainable Development.

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