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Developing BIM Culture in a University – Past and Future Steps

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Abstract. Building information modelling (BIM) still faces adoption barriers in the Architecture, Engineering and Construction industry (AEC). One of the barriers perceived in literature was the lack of professionals with knowledge and BIM competences developed, also due to the fact that BIM is not commonly taught in universities yet, especially in Brazil. Through a case study, this paper analyzed one university that developed a BIM research culture in its curriculum. The study identified a set of three steps to implement a BIM culture in the university: Hiring lecturers and professors with BIM knowledge, creation of a BIM class and the development of a BIM research culture in undergraduate levels. Then, three further steps were suggested to widespread and deepen the use, study and research of BIM in the university: Further capacitation of professors and lecturers, develop BIM research groups and advance post-graduate research and the insertion of BIM concepts in other subjects. A questionnaire sent to the professors and course coordinators involved with the process corroborated the steps perceived through document analysis.

Keywords. BIM, engineering, barriers, university adoption.

Introduction

BIM can be defined as a modeling technology and associated set of processes to produce, communicate, and analyze building models [1]. The design and project processes in the AEC industry have evolved significantly in the last years. Primitive techniques evolved to technical drawings with the use of paper. More recently, the use of computers accelerated the process going from 2D CAD systems to 3D modeling, and nowadays reaching Building Information Modeling systems. This process of technological evolution should be thought in the universities, so students are aware of techniques and understand their differences, since sometimes there is confusion related to what is BIM exactly [2]. This technological evolutionary process, as well as the characteristics of the methods are described in Figure 1.

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New technologies, however, tend to face some adoption barriers [3]. Authors describe the adoption barriers for BIM in two categories: management barriers and training barriers. Among the training barriers, literature highlights that BIM was not often thought in the universities, so young engineers and architects were not aware of the new technologies [4][5].

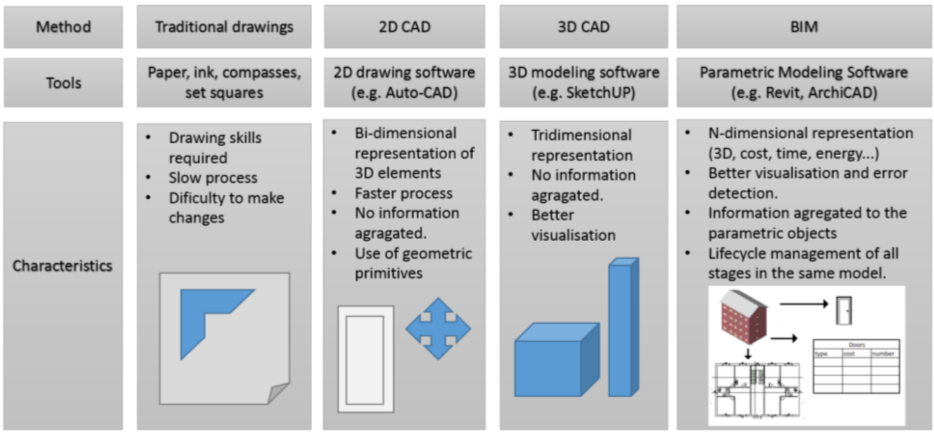

Figure 1. The evolution of design and project methods according to [2].

1. BIM adoption barriers

BIM adoption barriers by companies can be divided in two main categories: project management barriers and training barriers [3]. Most adoption barriers related to project management are related to the lack of knowledge of the technology and to the difficulties of altering the project and design processes in the companies. The main barriers are:

- The choice of the software and platforms is a common problem, since professionals often have difficulties choosing the software or platform that best suits their office [5] [3][6].
- The belief that BIM is only a 3D modelling tool is also a barrier, causing the involved not to understand its potential [3].
- The lack of interoperability is another difficulty faced by AEC industries. The unreliability of interoperability among some systems may lead users to second-guess the advantages of the use of BIM [7].
- The changes in the workflow also cause some challenges, since BIM projects need more personnel allocated in the early phases of the project, in contrast with 2D CAD, which tends to allocate more workers on the detailing stages [3][6].
- Risk management can also be an issue. Excessive worries that the pilot project may not be completed may lead companies to waste too much time on a plan B, leading to a demotivation with the new system [3].

Authors also highlight training barriers. Difficulties in training and capacitation may lead to difficulties in the adoption processes of BIM technologies. The main ones, according to the literature are:

- Traditional CAD use. Traditional CAD users are often more resistant and have bigger difficulties understanding and using BIM than users who have never used CAD before [3].
- The need for differentiated training may become an issue. All employees must receive BIM training, however this training should be specific to the employee's function. Also, when new employees are hired, these too must receive BIM training, in order to keep the team homogeneous [3].
- Few universities teach BIM, especially considering the Brazilian reality, so young professionals reach the market without BIM vision [4][5] .

Literature states the importance of formal training, due to BIM´s complexity [8]. Other authors also observe that software companies usually help in the adoption process by providing free or cheaper software licenses for professors and students [9].

Nine BIM player groups involved in adoption processes were identified: policy makers, construction organizations, individual practitioners, technology developers, technology service providers, industry associations, communities of practice, technology advocates and educational institutions. The main role of educational institutions such as universities and other learning institutions is to develop and deliver educational programs and related material for BIM learners [10].

Along with the actors, literature also identifies nine important actions for BIM diffusion. These actions are: make aware, encourage, observe, educate, incentivize, track, prescribe, enforce and control. Universities can play an important part in these actions. Through teaching, universities can participate in creating awareness and educating. Also, through research, universities may participate by observing and tracking [10].

Some initiatives are being developed to initiate BIM teaching in Brazil, however, scholars highlight that the BIM teaching in Brazil may still be immature, especially if compared to the counterparts in other countries, mainly due to the lack of integration between AEC subjects [4][5].

Another barrier to BIM adoption in Brazil may be related to the difficulties in interoperability for national programs, especially since structural designers in Brazil tend to use software adapted to Brazilian regulations. These barriers in interoperability lie mainly in data and formats, creating difficulties in the entire process for BIM use [7].

2. BIM competences and capacitation

Professionals may acquire a certain set of skills or competences in BIM through three main channels. Competences may be acquired though formal education (usually focused on theoretical knowledge), through on-the-job training (focused on skill improvement) or through professional development (focused on improving personal traits) [11].

Authors also cataloged eight BIM domain competences:

- Managerial: decision-making abilities, to determine or select long-term strategies.

- Functional: non-technical abilities to initiate manage and deliver projects.
- Technical: abilities needed to generate project deliverables such as modelling, model management, drafting, etc.
- Supportive: competencies used to maintain information systems and communication technologies.
- Administrative: skills needed to fulfil and maintain organizational goals.
- Operational: related to the activities required to deliver a project or part of a project such as designing, analyzing, simulating and estimating.
- Implementative: abilities related to the activities necessary to introduce concepts and tools into an organization (component development, library management and standardization).
- Research and Development: competence connected to the activities linked to knowledge engineering, research and coaching.

BIM teaching can't only be seen as an end in itself, but also as a powerful teaching tool. Since BIM is an environment that allows many kinds of simulations, it can be used as a teaching tool to teach project management using real world scenarios. It was shown to be very effective, especially when compared to more traditional methods [12].

Barison and Santos [5], divide BIM functional competences in three levels: BIM Modeler/facilitator, BIM analyst and BIM Manager. The authors recommend that the teaching methodology should be developed for each particular type of BIM professional. Literature also highlights the importance of not only teaching BIM, but promoting BIM in the AEC industry as well.

3. Methodological Approach

Observing this scenario, the research question emerges as: "how can a university implement BIM teaching?" This paper proposes to shed some light in the manner of how to implement BIM teaching in a university.

The object of this study was the adoption of BIM as a teaching and research tool in the Polytechnic School of a Brazilian university. The university studied is located in the South of Brazil, in Curitiba, the capital of the state of Paraná. The Polytechnic school is composed of engineering, informatics and other technology courses, as well as post-graduation and extension courses in these areas.

The case study was conducted in two stages. The first stage was conducted through document analysis. The documents analyzed were: professors' and lecturers' CVs, classes' syllabus, course completion projects developed by students, research papers and classes' diaries. Through this analysis, three first steps for BIM adoption in the university were identified, as well as three future steps were suggested to develop even further BIM adoption in universities. The steps are described in figure 2.

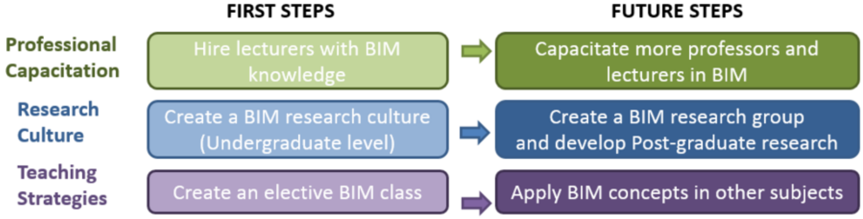

Figure 2. BIM adoption steps in the university.

After the documental analysis, a questionnaire was sent to professors, lecturers and coordinators involved in the adoption process. This was done to validate the past and future steps perceived.

The professors were asked to rate the steps in a Likert scale according to their perception of importance of these steps to the process for BIM adoption (the scale was divided in: not important, somewhat important, important, very important and extremely important). The questionnaire was sent through institutional e-mail, and recorded via Qualtrics. The professors also answered open questions, in which they were asked if they perceived any other important step in the process different from those listed.

4. BIM adoption first steps

In the first stage of document analysis, three main areas were identified in the adoption process of BIM in the university, and in this areas a specific step was perceived. They are:

- Staff capacitation: Hiring professors and lecturers with BIM knowledge ;
- Development of a BIM research culture: Stimulating students to develop undergraduate research in BIM (especially for course completion projects);
- Teaching: Developing a BIM subject for undergraduate students;

The steps perceived showed connection among each other. The development in one area, created momentum for the development in the other two sectors, since we can perceive an increment in the numbers of students taking the courses, staff capacitation and conclusion projects written by undergraduates within the last five years.

These first steps are described in detail in section 4.1 through 4.3.

4.1 Valuing BIM capacitation in professors and lecturers

Hiring staff with BIM knowledge and background is an important step in BIM adoption in a university.

In order to teach a BIM subject and aid the development of a BIM culture in the university studied, lecturers usually have majors in civil engineering or architecture, and some practical experience, especially in the project area.

These lecturers are usually required to have at least a master course, and frequently have already developed research in the area.

In the last five years the university hired three professionals with extensive BIM background. Two of them had developed research in BIM for their master´s dissertations, and the third had used BIM in the professional environment. All of them lectured and worked previously with steel or cast-in-place concrete structures.

The contact with these professors allowed the development of a BIM research culture, as they worked as advisors for course completion projects. These professionals also helped to raise awareness among the students about the existence of new BIM technologies. Finally, they helped to develop and teach a BIM discipline.

4.2 Developing a BIM research culture

In the process of developing a BIM research culture, the university stimulated the development of course completion projects by undergraduate students using BIM as a tool or by having BIM as a subject of study.

In the last five years, students of Civil engineering in the university in question developed at least ten conclusion projects containing the word BIM in their title or summary.

As seen in Table 1, the number of conclusion projects has increased in later years. This is probably due to the growing interest of students in the topic.

Table 1. Course completion projects developed by undergraduate Civil Engineering students.

Year	Conclusion projects developed
2015	BIM Manager characterization BIM interoperability for cast-in-place concrete structures Development of a cast-in-place concrete structural library
2014	Case study of foundation analysis through BIM Project compatibilization through BIM Building planning aided by BIM Comparative of BIM and 2D CAD: uses in construction cost studies
2013	Project information compatibilization through BIM BIM for concrete structures: reinforcing bars
2012	BIM and pre-cast concrete structures
2011	Impact of BIM in the project and planning processes

4.3 Offering BIM subjects

A subject called Building Information Modelling was offered in a post-graduation specialization course in 2013. Based on this subject, a study plan for the regular BIM classes at graduation level was developed (Figure 3).

Observing the course curriculum, it can be perceived that it was structured in four main competences, which contemplate most of Succar et al. (2013) [11] BIM competences:

- Being able to differentiate BIM and other CAD systems - Managerial competences;
- Creating building models using a BIM software - Functional, technical and operational competences;
- Generating and detailing construction documentation - Implementation competences;
- Understanding interoperability and generating IFC files. - Research and development competences.

In the first semester of 2015, the subject was finally offered to students in the regular civil engineering undergraduate course as an elective subject for the fifth period. Six classes were offered, one of them being an international class. This international class was taught in English, which is not the first language in Brazil. In the second semester the scenario repeated itself, almost identically, with one less group being offered.

The number of regular classes probably decreased in the second semester of 2015 due to difference in the number of students that were coursing the semester at the time, probably not meaning a loss of interest or any other factor, since the number of groups rose again in 2016.

The results can be seen in Table 2.

Table 2. Number of groups taking a BIM subject.

Semester	Number of regular groups	Number of international groups
1st Semester 2015	5	1
2nd semester 2015	4	1
1st semester 2016	8	1

PUCPR GRUPO MARISTA	**Pontifícia Universidade Católica do Paraná** **Politechnic School** **Civil Engineering**
COURSE TITLE: Building information modeling	
HOURS: 2 hours/week	**SEMESTER: Elective – suggested: Third semester**
PREREQUISITS: This subject is intended chiefly for Civil engineering e Architecture Students. Electrical and Mechanical engineering students might also profit from the course.	
DESCRIPTION: Building information Modeling, Object modeling, predecessor design technics and interoperability through IFC.	
COMPETENCES	
1. Being able to differentiate BIM and other CAD systems.	
2. Creating building models using a BIM software.	
3. Generating and detail construction documentation.	
4. Understanding interoperability and generating IFC files.	
STUDY TOPICS	**RELATED COMPETENCES**
Introduction on CAD BIM concepts and history, main differences between the software and choosing the right software for each project.	1
Building Modeling.	2
Parametric object modeling.	2
Generation and alteration of tables and drawings.	3
Interoperability and IFC.	4
METHODOLOGY: Practical assignments 50% + Theoretical assignments and presentation 50%	
EVALUATION ACTIVITIES: Practical assignments and/or written tests.	

Figure 3. Course Plan for Building Information Modelling.

5. BIM adoption future steps

The process of technological adoption, in this case BIM, can´t be considered finished simply by teaching students BIM concepts. BIM in the university, just as in the AEC industry, should permeate all different areas and sectors, and this mindset assumes a constant technological evolution. In order to widespread BIM use, some future steps for BIM adoption are suggested in the following sections.

Again, these steps are divided in the three identified BIM areas: Staff capacitation, research and teaching strategies.

5.1 Capacitating more professors and lecturers in BIM

To achieve a wider BIM adoption in the university, it is necessary that other professors and lecturers learn BIM at some extent. Either at a more technical level through workshops and courses or in a more formal environment, through academic means (in doctoral or master courses).

Currently the university offers incentives such as scholarships for many kinds of academic development, however there are no short-term BIM courses or workshops available for professors at the moment.

This step is important for a wider adoption. If more professors receive BIM capacitation, BIM concepts can be applied in integrated projects or in different subjects other then only a specific modeling class.

5.2 Developing a wider research culture in the university

Higher-level research in BIM, especially in post-graduate levels, is essential for the development of a BIM culture. This could bring benefits not only to the university, but also to BIM users in general, considering benefits that specific researches could bring to the community.

Research in BIM is only recently starting to grow in the studied university. Some papers were published or are being developed in the subject along with PPGEPS (Program of Post-graduation in Production Engineering and Systems), mainly in the area of BIM interoperability, like the project "Interoperability Assessment for Building Information Modelling" [7] developed in 2014-2015.

The university could also profit from a BIM research group, to organize and unite researchers in post-graduate and undergraduate levels.

5.3 Applying BIM concepts in other subjects

The idea of BIM itself considers the use of the technology not only as stand-alone programs, but as an integrated process in which many construction disciplines can interact with each other [1]. Considering this view, BIM could be used to integrate disciplines in the curriculum for courses such as civil engineering and architecture.

This was proven advantageous in teaching. Since BIM involves many disciplines, teaching construction project management with BIM support was successful, especially due to the possibility of examining many areas in one single model [12].

6. Validation

Questionnaires were sent to two professors and two coordinators involved in the BIM adoption process. The goal of this stage was to validate the steps perceived in the documental research.

First, professionals were asked about their perception on the importance of each of the first steps: Hiring lecturers and professors with BIM knowledge, development of a BIM research culture in undergraduate levels and hiring lecturers and professors with BIM knowledge.

Then, they were asked about their perception of the importance of each of the future steps: Capacitation of more professors and lecturers in BIM, inclusion of BIM concepts in other disciplines and development of further research in BIM (post-graduate level and study groups).

The questionnaires contained the past and future steps and the folowing scale: 1- Not important, 2– somewhat important, 3 – important, 4 – very important, 5 – Extremely important.

According to the professors, from the first steps, the most important action perceived was the creation of a BIM class, followed by the development of a BIM research culture in undergraduate levels and hiring lecturers and professors with BIM knowledge. All steps were on average evaluated either as important, very important or extremely important. This is shown in table 3.

Table 3. Perception of the importance of the first adoption steps.

Step	Perceived average importance
Creation of a BIM class	Between very important and extremely important
Development of a BIM research culture in undergraduate levels	Between important and very important
Hiring lecturers and professors with BIM knowledge.	Between important and very important

From the future steps, the most important step perceived by the professors was the capacitation of more professors in BIM. Followed by the inclusion of BIM concepts in more disciplines and the development of further research in BIM (post-graduate level and study groups). This is shown in table 4.

These steps are slowly being developed, with some professionals seeking further capacitation and developing research in this area in the university. Some professors who answered the questionnaire even mentioned that the students themselves are applying BIM concepts in different subjects such as hydraulic or electrical projects.

Table 4. Perception of the importance of the future adoption steps.

Step	Perceived average importance
Capacitation of more professors and lecturers in BIM	Between important and very important
Inclusion of BIM concepts in other disciplines	Between important and very important
Development of further research in BIM (post-graduate level and study groups)	Between somewhat important and important

7. Conclusion

The main result of this research was the systematization of steps for BIM adoption in a university, which are summarized in Figure 2. The steps were divided in first steps (which have already happened in the adoption process in this particular institution), and in future steps. Some of the future steps are already in motion for a wider BIM adoption in the university studied.

This research was also able to associate the steps with three areas: professional capacitation for lecturers and professors, research culture and teaching strategies.

The contribution of this paper is the formalization and description of the development of the BIM culture in a university, and can possibly be used as a roadmap for other institutions that perceive the need for BIM adoption and capacitation in-campus.

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