Curricular BIM implementation plan: protocol proposal and pilot application in Brazil

Plano de implementação BIM curricular: proposta de protocolo e aplicação piloto no Brasil

Regina Coeli Ruschel
Caroline Kehl

Abstract

Incorporating BIM in the education of professionals has become a demand and a topic of high importance for higher education. Several proposals for a curricular implementation of BIM exist. However, in most cases, they are specific to a single university or domain, do not consider academic policies or simplify practice by segmenting knowledge. This work proposes a protocol for the curricular implementation of BIM similar to the industry, considering aspects of process, technology, and policies aligned with the educational institution's mission and with existing competencies. Action research was the used method. Three actions were conducted: (1) proposition, (2) systematization and (3) application. The actions were executed in cycles incrementally, resulting in (1) guidelines, (2) supporting tools and (3) implementation plans. Two Brazilian universities participated in pilot studies of Project Construa Brasil. The pilot studies inspired a network of BIM cells that have synchronously applied curricular BIM implementation guidelines on a large scale. The guidelines proved to be generic and comprehensive, guiding the transformation with an empirical basis for the academics' decision-making. Leadership of a BIM specialist was confirmed as an essential factor of success. It is observed that even with a timid introduction of BIM competence in a limited scope of engineering solutions, the impact on the BIM maturity curriculum is significant.

Keywords: BIM implementation plan. Construa Brasil. BIM cells.

Resumo

Incorporar o BIM na formação de profissionais tornou-se uma demanda e um tema de grande importância para o ensino superior. Existem várias propostas de implementação curricular do BIM. No entanto, na maioria dos casos, são específicos de uma única universidade ou domínio, não contemplam políticas acadêmicas ou simplificam a prática segmentando o conhecimento. Este trabalho propõe um protocolo para a implementação curricular do BIM semelhante ao da indústria, considerando aspectos de processo, tecnologia e políticas alinhados com a missão da instituição de ensino e com as competências existentes. Pesquisa-ação foi o método utilizado. Três ações foram realizadas: (1) proposição, (2) sistematização e (3) aplicação. As ações foram realizadas em ciclos de forma incremental, resultando em (1) diretrizes, (2) ferramentas de apoio e (3) planos de implementação. Duas universidades brasileiras participaram de estudos-piloto do Projeto Construa Brasil. Os estudos-piloto inspiraram uma rede de células BIM que aplicaram as diretrizes curriculares de implementação BIM em larga escala. As diretrizes mostraram-se genéricas e abrangentes, orientando a transformação com base empírica para a tomada de decisão dos acadêmicos. A facilitação de um especialista BIM foi confirmada como fator essencial de sucesso. Observa-se que, mesmo com uma tímida introdução de competências BIM em um escopo limitado de soluções de engenharia, o impacto na maturidade BIM do currículo é significativo.

***Palavras-chaves**: Plano de implementação BIM curricular. Construa Brasil. Células BIM.*

[1]**Regina Coeli Ruschel**
[1]Universidade Estadual de Campinas
Campinas - SP - Brasil

[2]**Caroline Kehl**
[2]Universidade Estadual de Campinas
Campinas - SP - Brasil

Recebido em 31/03/22
Aceito em 31/08/23

Introduction

Building Information Modeling (BIM) is the current expression of innovation in the construction industry (Succar; Kassem, 2015). Consequently, it is the central digital technology applied in this field. The worldwide adoption of BIM is taking place on a large scale, with the leading countries in adoption levels being the United States, Denmark, Canada, the United Kingdom, and Australia, all with more than 60% adoption rate (Ullah *et al.*, 2019). In Latin America, the macro adoption of BIM was observed by Machado *et al.* (2021), analyzing governments' and associations' efforts for BIM dissemination. Considering this approach, Latin American countries with the most significant movement in BIM adoption are Chile, Brazil, Argentina, and Mexico. Analyzing by continent, at least one country is already nationally and collaboratively adopting BIM by the construction industry (Ullah *et al.*, 2019).

Therefore, incorporating BIM in the education of architects, engineers, and technicians becomes a demand and a topic of high importance for higher education (Zhao, 2021; Wang *et al.* 2020). However, transforming education is a challenging task. Just as there are barriers to adopting BIM in industry, the same is true in academia. Nevertheless, would these barriers be the same and on the same difficulty scale? Comparative studies that list barriers to BIM adoption for industry and academia indicate similarities such as lack of awareness, resistance to cultural change, lack of expertise, inadequate training, BIM models complexity and lack of standardized protocols (Ullah *et al.*, 2019; Underwood *et al.*, 2015). However, the barrier of lack of interest from clients in the industry is the opposite in academia, as the industry demands specific competencies in BIM given the wide adoption by the sector. Barriers intrinsically associated with academia can also be observed, such as hierarchical administrative processes and long-term cycles of change. These practices that aim to guarantee education consistency, as well as pedagogical teaching methods and segmentation of knowledge, are applied to overcome the complexity of learning (Underwood *et al.*, 2015).

Wang *et al.* (2020) characterized BIM education efforts. According to the authors, BIM has been taught in different disciplines[1] (construction, civil engineering, architecture, architectural technology, management, and MEP) in a disaggregated way. However, there are efforts to connect different disciplines through interdisciplinary and collaborative approaches. Developed BIM competencies are technical and managerial. The transformation for BIM education adapts learning outcomes, curriculum development, assessment, specific teaching methods and educational theories – as Bloom's Taxonomy – to specify BIM pedagogical objectives.

Since education transformation is a complex task and transformation cycles are rare, it must be robust and lasting when an effort of this nature is undertaken. Therefore, the technological look must be broad. In the current context, it is required to analyze BIM associated with the fourth industrial revolution. BIM is considered the enabling force of Construction 4.0 (Perrier *et al.*, 2020). Begic and Galic (2021) also include cloud computing and the Internet of Things as core technologies of Construction 4.0. Other technologies of Construction 4.0 are prefabrication, digital fabrication, monitoring, artificial intelligence, data science, visualization, and modeling systems (Perrier *et al.*, 2020). In this way, when introducing BIM in civil engineering or architecture curricula, it must dialogue with these technologies.

This scenario of BIM education indicates demands for incorporating BIM in education that better reflects practice, overcomes intrinsic barriers of academia, and is prepared to cope with the continuous digital transformation of the sector. One way to achieve this goal is holistically planning BIM implementation in curricula. Several proposals for a curricular implementation of BIM exist, however in most cases, they are specific to a single university or a particular domain, do not include academic policies or continue to simplify practice by segmenting knowledge (Zhao, 2021; Solnosky; Parfitt, 2015; Suwal *et al.*, 2014; MacDonald, 2011).

In this way, this work proposes a standardized protocol for the curricular implementation of BIM to high education majors in Brazil based on existing frameworks created for the industry, considering BIM aspects of process, technology and policies in the academy aligned with educational institution bias and with existing competencies. Specific objectives include creating and applying guidelines and tools valid for a broad range of majors for higher education.

[1]In this paper, the words “discipline”, “syllabus” and “course” are used as synonyms.

Theoretical background

Existing BIM academic frameworks

In literature, guidance for incorporating BIM into undergraduate curricula are called academic frameworks of BIM education. BIM academic frameworks seek to identify in which subjects, disciplines or syllabi BIM competencies can be developed or where BIM topics are naturally associated with educational content. This association is driven by BIM alignment with the degrees' focus, their vision of the future, and the constraints of the involved educators. Pedagogical approaches for learning targets are identified, determining whether the competencies delivered will be on knowledge, understanding, application, analysis, synthesis, or evaluation. Bloom's taxonomy (Bloom *et al.*, 1956) is the repeatedly applied approach to specify cognitive complexity. Typical results of this process are original disciplines that include relevant BIM knowledge in teaching content, disciplines that use BIM technology for assisted teaching or disciplines that develop BIM practice. While applying a framework for curriculum transformation, groups of teachers are organized, strategies are developed, school infrastructure is improved, BIM awareness programs among educators are carried out, and pilot projects are developed and monitored. The described characterization of academic BIM frameworks was extracted from a joint analysis of the works of MacDonald (2011), Sacks and Pikas (2013), Pikas *et al.* (2013), Suwal *et al.* (2014), Solnosky and Parfitt (2015), Rodriguez-Rodriguez and Dávila-Perez (2016), Rodriguez *et al.* (2016) and Zhao (2021).

A similar organization for BIM education framework is observed in the industry. An example is buildingSMART Professional Program (BuildingSmart, 2022), developed to support training organizations to deliver internationally standardized and recognized training content. The proposed professional certification organizes skill levels according to Bloom's taxonomy. The curriculum is distributed in modules, and each module comprehends specific learning outcomes (LOs). The LOs define the minimum learning that training must convey. The buildingSMART Professional Certification Foundation curriculum plan comprehends LOs at a level of understanding and recognition following Bloom's taxonomy.

The IMAC framework for collaborative BIM education was developed by MacDonald (2011) to assist educators in benchmarking curricula and developing strategies for improvement. The framework is part of the Australian Learning and Teaching Council (ALTC) grant-funded projects. The framework is structured in four stages related to students' BIM achievement: illustration, manipulation, application, and collaboration (IMAC acronym). BIM achievements are distributed in Bloom's cognitive and affective domains (Table 1). The framework does not dictate in which academic year BIM achievements should be pursued. Instead, it emphasizes that overcoming the challenge of sharing across academic silos is essential to cultivate graduates equipped with the vital skills in collaborative work using BIM. The framework fosters engaging teaching methods in order to promote deeper learning. IMAC framework was demonstrated by introducing BIM into a Construction Management major (MacDonald, 2011). According to Rodriguez *et al.* (2016), it was also applied later by two universities, at the University of South Australia, as a benchmarking tool for two construction disciplines, and at the University of Technology Sydney to develop an Integrated Project Delivery studio class.

In the BIM construction management education framework proposed by Sacks and Pikas (2013), BIM education requirements were listed in terms of process, technology, and application. Education requirements were categorized in terms of levels of achievement. Incremental achievements in BIM were associated with Bloom's cognitive taxonomy domain (Bloom *et al.*, 1956) and suggested to be developed in evolutionary periods of training and practice (Table 2). Interventions in the Technion-Israel Institute of Technology's Engineering and Construction Management curriculum were based on this framework (Pikas *et al.*, 2013). The intervention was conducted on a four-subject set. From this experience, the following steps were proposed for a general curricular BIM implementation plan:

(a) understand industry requirements;

(b) define the objectives of your school;

(c) assess existing curriculum;

(d) select existing courses, or define new courses to fulfil the goals;

(e) compile curriculum and implement courses;

(f) monitor and measure achievements;

(g) review selected courses and determine changes that are needed in the curriculum; and

(h) repeat the process for continuous improvement.

Efforts to expand awareness and competencies in BIM among educators are needed when implementing BIM in academia. These efforts aim to mitigate a significant barrier to BIM adoption. Therefore, the School of Civil Engineering and Building Services (SCEBS) of Metropolia University of Applied Sciences in Finland installed a program named OpeBIM[2] (BIM for teachers) (Suwal *et al.*, 2014). This program's goal was the comprehension by educators of the possible benefits of BIM integration in existing courses and provide theoretical and practical knowledge. The program raised awareness of the present reality of BIM, generated enthusiasm, and inspired application. According to the authors, educating instructors about BIM is at the forefront of implementing BIM in education and should be carried out in close collaboration with the industry.

Table 1 – **Incremental levels of achievements for collaborative BIM education proposed by MacDonald (2011) according to cognitive and affective domains of Bloom's taxonomy (Bloom *et al.*, 1956)**

Bloom's taxonomy cognitive domain	Bloom's taxonomy affective domain	Stage	Description	Developed in
Knowledge/ Comprehension	Receiving/ Responding	Illustration Stage	Building Information Models are used to illustrate key concepts	Separate disciplines
Comprehension/ Application	Receiving/ Responding	Manipulation Stage	Interaction with Building Information Models in order to develop discipline-specific knowledge	Separate disciplines
Application/ Analysis	Valuing/ Organizing	Application Stage	Apply this knowledge to solve discipline-related problems	Separate disciplines
Synthesis/ Evaluation	Characterizing	Collaboration Stage	Development of joint projects	Different disciplines come together

Table 2 – **Incremental levels of achievements in BIM education proposed by Sacks and Pikas (2013) according to Bloom's Taxonomy Cognitive Domain (Bloom *et al.*, 1956)**

Bloom's taxonomy cognitive domain	Level of achievement	BIM competency	Developed in
Know	1	BIM topics	Bachelor's degree
Understand	2	BIM topic or application	
Apply	3	BIM application in new and concrete situation	
Analyze	4	Infer results of BIM application	Master's degree
Synthesize	5	Develop new information from BIM application	
Evaluate	6	Plans of action, suitability, constructability, business processes of BIM application	Work experience

[2]"OpeBIM" (SUWAL *et al.*, 2014) is a pun for "BIM teacher" in Finnish language.

Rodriguez *et al.* (2016) proposed a conceptual BIM education framework with different versions for academia and industry. The study presented initial work into BIM implementation in the Dominican Republic. Three stages of development are established: strategy, implementation, and revision, depending on the target public. For academia, the strategy stage involves the creation of groups to lead the strategy, identifying BIM abilities needed per discipline and categorizing these abilities by themes according to levels of achievement, as proposed by Sacks and Pikas (2013). The implementation stage determines actions and responsible actors to carry them out. Actions comprise preparation of educators, development of learning modules and learning materials, opportunities for students to expand skills on their own (workshops, conferences, seminars, etc.), and the creation/support of graduate programs. Actors include educators, industry practitioners, students, and experts from software companies and associations. Once the offering of BIM renewed disciplines has started, the evaluation of the experiences and the resulting impacts is suggested. Learners, teachers, and industry experts can go through the assessment.

Finally, in order to understand how to incorporate BIM education into a curriculum, Zhao (2021) proposed two concepts and a discipline mapping between these concepts. The first concept consists of BIM technology application capability classification. BIM capability relates to general knowledge, software operation, model production or application, environment establishment, project management or business integration. A curriculum analysis is suggested to identify theoretical courses and practical content where these BIM capabilities can be introduced. The identified courses are then classified in terms of BIM incorporation range, whether the inclusion of concepts, teaching assistance or practical application. The latter measures the impact of courses transformation.

Pedagogic aspects of BIM education

The literature indicates that Bloom's taxonomy has been applied as the pedagogical system that guides BIM education frameworks (Rodriguez-Rodriguez; Dávila-Peres, 2016; Barison; Santos, 2014; Sacks; Pikas, 2013; Succar *et al.*, 2013; MacDonald, 2011). Bloom's taxonomy classifies educational objectives into three domains: cognitive, emotional, and psychomotor (Bloom *et al.*, 1956). The taxonomy is valuable for breaking down a comprehensive system into smaller recognizable parts whose objectives can be enunciated, measurements can be developed, and achievement can be evaluated at the student level.

Regarding teaching methods, problem-based learning is the preferred approach in BIM education (Solnosky, 2018; Badrinath *et al.*, 2016; Underwood *et al.*, 2015; Wu; Issa, 2014), since it promotes the complexity needed to leverage collaboration. Other active methods applied are team-based learning (Herrera *et al.*, 2021), learning-by-doing (Solnosky, 2018; Sacks; Pikas, 2013), teach others (MacDonald, 2011), and gamification (Solnosky, 2018; Yan *et al.*, 2021).

Industry BIM implementation plan guidelines

Propositions of guidelines for BIM Implementation Plans (BIPs) for the industry are lacking. Two studies with this focus are identified in the literature. Coates *et al.* (2010) present a method of adopting BIM extracted from a case study. Gu and London (2010) address the development of BIPs by proposing a decision framework. It is observed that there is partial equivalence between the propositions and that they complete each other. However, the protocol for BIP by Coates *et al.* (2010) encompasses the entire cycle: planning, implantation, and review.

Ma *et al.* (2020) developed a study to identify strategies to improve the implementation of BIM in the AEC projects context. Five latent factors were observed among the strategies: institutional governance, adaptation to change, technical environment, cooperation, and resources. Comparing the main strategies among experts from Nigeria, Singapore and Turkey, the only convergence found was leadership as a driving force. Yet, Smith (2014) indicates the importance of institutional governance and leadership as critical drivers for BIM implementation.

Research method

Action research was the research methodology used. Action research applies to any ongoing, systematic, empirically based attempt to improve practice (Tripp, 2005). According to Hult and Lennung (1980, p. 247), action research:

> *[...] simultaneously assists in practical problem solving and expands scientific knowledge, as well as enhances the competencies of the respective actors, being performed collaboratively in an immediate situation using data feedback in a cyclical process aiming at an increased understanding of a given social situation, primarily applicable for the understanding of change processes in social systems and undertaken within a mutually acceptable ethical framework.*

Three actions were conducted:

(a) proposition;

(b) systematization; and

(c) application.

Each action involved internal sequences of planning, developing, monitoring, and evaluating steps, as presented in Figure 1 (represented using BPMN – Business Process Model and Notation[3]), and detailed in Table 3.

Research cycles comprised two or three actions, within these possible sequences shown in Figure 2: proposition and application; systematization and application; proposition, systematization, and application. The actions were executed in four cycles (Figure 3), incrementally evolving to (1) guidelines for the Curricular BIM Implementation Plan (cBIP), (2) tools to support its application, and (3) documentation of the cBIP.

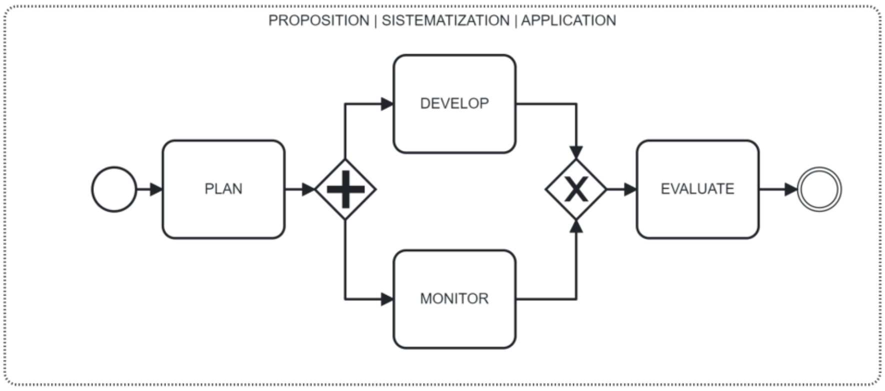
Proposition

The logic supporting the proposition of the guidelines was the combination of existing schemes and adaptation to the higher education requirements of civil engineers and architects in Brazil. When specifying educational objectives in BIM, an attempt was also made to develop a flexible definition scheme not associated with a specific professional domain.

Systematization

Systematization promoted the evolution from the macro view of the curricular transformation to the required corresponding detailing. The systematization aimed to structure criteria that characterizes the incorporation of BIM in each syllabus: the involvement of the responsible teacher, specification of the scope of the built environment (component, system, building, infrastructure, city, region) addressed in the syllabus and the BIM competencies associated with the syllabus content. A survey among involved teachers allowed to scale the effort to renew skills. Characterizing the scope of approaches in the built environment pointed to the breadth of training in BIM being planned for architects, civil engineers, or technicians. BIM competencies fostered the development of educational objectives. Therefore, in the systematization action phase, tools such as spreadsheets and online forms conveying syllabi and characterization criteria were developed to guide and substantiate decision-making, which refers to designing new teaching processes and technology adoption.

Figure 1 – **Breakdown steps of action: proposition, systematization, and application of cBIP**



[3]By Object Management Group Standards Development Organization, available at https://www.bpmn.org/.

Table 3 – **Detailing summary actions, actors and steps developed in cycles**

Steps and actors	Action: Proposition	Action: Systematization	Action: Application
Plan by researcher	Idealize the General structure of the Curricular BIM Implementation Plan. Diagnostics.	Structuring of information manipulated in spreadsheets. Creation of data collection forms to guide and document decision making. Step by step for writing the plan based on charts and graphs of the information collected.	Organization of the group of professors and students. Application of the guideline for the development of the curricular BIM implementation plan.
Develop by researcher with or without participant	Presentation of the structure of the plan to the group of professors and students involved and discussion.	Experimentation of the proposed supporting tools.	Application of tools and decision-making to define Objective. Core of disciplines. Uses of BIM. Educational goals. Transformations in teaching plans. Technological impact. Policy impact. Actions. Final draft of the plan. Plan execution.
Monitor by researcher	Facilitation and tracking of effort.	Facilitation and tracking of effort.	Facilitation and tracking of effort.
Evaluate by researcher	Summary of observed difficulties. Identification of necessary improvements.	Summary of observed difficulties. Identification of necessary improvements.	Analysis of the resulting cBIPs and effort involved.

Figure 2 – **Actions and cycle possibilities**

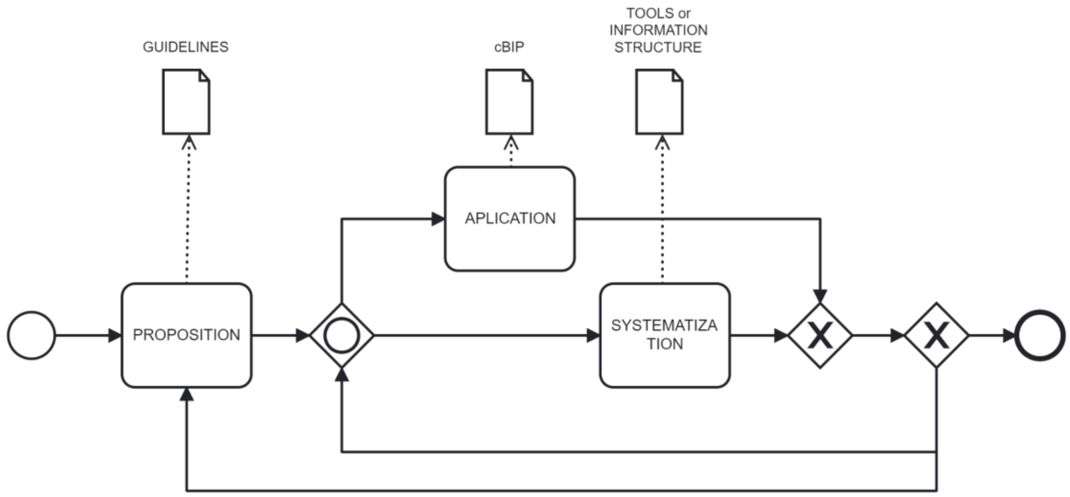
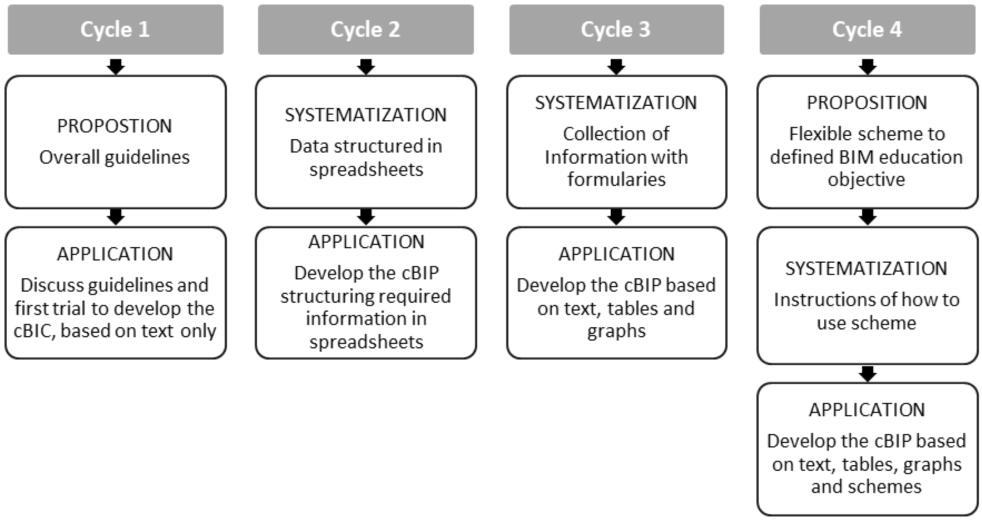


Figure 3 – **Cycles developed in the action research**



Application

The application consisted in the exercise of following and discussing the guidelines as well as using and evaluating supporting tools to generate the cBIP for specific majors by a group of professors and students in high education institutions (HEIs). It includes interactively and incrementally executing all stages of the cBIP guidelines.

Results and discussions

In this section will be presented the resulting guidelines for cBIP, systematization and the application carried out in pilot studies.

Guidelines

The overall implementation flow followed Coates *et al.* (2010) steps for industry BIM implementation. The confirmation of this choice considered the reordering of equivalent steps of Gu and London (2010) and Pikas *et al.* (2013) (Table 4). Figure 4 shows a summary of the developed cBIP.

Coates *et al.* (2010) state to start implementing BIM in companies by reviewing and analyzing current practices. Gu and London (2010) suggest evaluating existing skills, knowledge, and capabilities. Pikas *et al.* (2013) equivalently orient to assess existing curricula. Thus, existing metrics to analyze BIM maturity in majors and BIM potential inclusion were adopted to verify the current insertion of BIM in the undergraduate majors under study.

The adopted metrics were curricular BIM maturity (Böes *et al.*, 2021) and BIM curricular interface (MÉTODO..., 2021). The curricular BIM maturity metric establishes BIM indicators of existing processes, technologies, and policies for an undergraduate course. The BIM curricular interface metric identifies the potential for incorporating BIM into curricular matrices, pointing out disciplines with a vocation for applying BIM in the analyzed undergraduate major. The vocation for BIM in the discipline is characterized by the BIM technology application capability and type of BIM application, similar to Zhao (2021) BIM education framework.

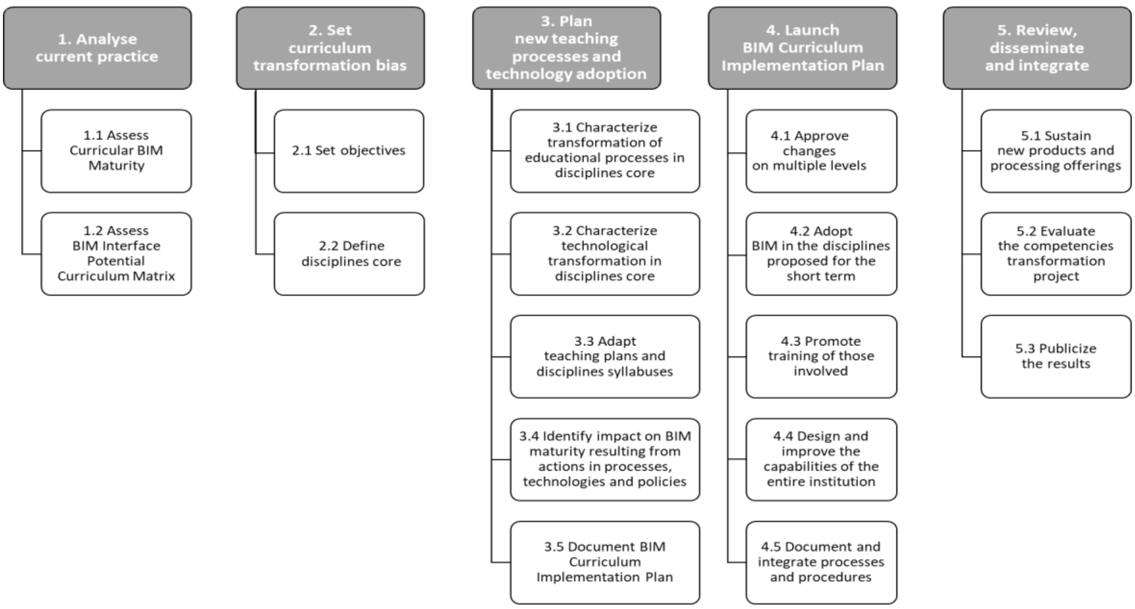
Once an analysis of current practice has been carried out, Coates *et al.* (2010) suggest establishing the objective of implementing BIM in companies considering the efficiency gains intended. From Gu and London (2010), scope and purpose definitions can be extracted. In the case of HEIs, the definition of cBIP purpose must consider BIM competency goals for the major in question, curriculum innovation and consequent impacts. In short, the aim is to improve education.

The scope of the cBIP in academia translates to the core of courses (disciplines or syllabi) that can promote the curricular transformation intended. The core is formed by the subset of courses with vocation for BIM, which guarantees the established objectives, and that are taught by professors involved or open to involvement in the process. Also in this step, the short, medium, or long-term cBIP execution deadlines are defined, setting the execution time of the plan.

Table 4 – **Curricular BIM Implementation Plan (cBIP) references for step sequencing**

Guidelines by Coates *et al.* (2010)	**Guidelines by Gu and London (2010)**	**Guidelines by Pikas *et al.* (2013)**	**cBIP**
Stage 1: Detail Review and Analysis of Current Practice	Key part 4: Customization of the framework and evaluating skills, knowledge, and capabilities	3. Assess existing curricula	1. Analyze current practice
Stage 2: Identification of Efficiency gains from BIM implementation	Key part 1: Defining scope, purpose, roles, relationships, and project phases	1. Understand industry requirements; 2. Define objectives of your school.	2. Set curriculum transformation bias
Stage 3: Design of new business processes and technology adoption path	Key part 2: Developing work process roadmaps	4. Select existing courses, or define new courses to fulfill the goals;	3. Plan new teaching processes and technology adoption
	Key part 3: Identifying technical requirements of BIM	5.1 Compile curriculum.	
Stage 4: Implementation & roll-out of BIM	(No equivalence)	5.2 Implement courses; 6. Monitor and measure achievements.	4. Launch BIM Curriculum Implementation plan
Stage 5: Project review, dissemination, and integration into strategy plan	(No equivalence)	7. Review selected courses and determine changes that are needed in the curriculum; 8. Repeat the process for continuous improvement.	5. Review, disseminate, and integrate

Figure 4 – **Summary of cBIP guidelines**



According to Coates *et al.* (2010), the third stage of implementing BIM in companies comprises designing new business processes and defining a technology adoption path. Once the transformation core of the curriculum has been identified, BIM competencies (Succar *et al.*, 2013) and model uses (Succar *et al.* 2016) for each major, in line with the syllabus content, are identified.

In the third stage, educational objectives are established for the defined students' achievements according to Bloom's cognitive domain revised taxonomy (Anderson *et al.*, 2001). Learning objectives are expressed in remembering, understanding, applying, analyzing, evaluating, or creating the defined BIM competencies or model uses for the discipline. This grading of the cognitive domains with BIM competencies and model uses allows for a broad set of educational objectives that can be applied to any major.

Figure 5 exemplifies the proposed scheme for the teacher's flexible definition of BIM educational objectives based on characterizing parts of the course content. First, the contents that have the potential to incorporate BIM are identified, and the BIM competence category and related topics are evaluated according to Succar *et al.* (2013). The level of the cognitive domain (to remember, understand, apply, analyze, evaluate, or create) that one wants to develop is defined (Anderson *et al.*, 2001). Finally, the educational objective is specified by concatenating the verb that expresses the desired cognitive domain level with a BIM topic aligned with the competence to be developed.

Once the applicable BIM competencies and educational objectives are defined, the technological transformations associated with BIM (Biller *et al.*, 2021) and innovations in the scope of Industry 4.0 (Begic; Galic, 2021; Perrier *et al.*, 2020) are determined. At this stage, the discipline plans are redesigned, seeking new teaching methods and integration or collaboration between other disciplines or majors. This is also the time to define BIM models that can be reused across disciplines.

Once again according to Coates *et al.* (2010), the fourth stage in implementing BIM in companies is the plan's launch. In this stage, pilot projects are carried out, people involved are trained, and support protocols are developed. The equivalent of industry pilot projects would be courses whose transformation is programmed to happen in the short-term. In HEIs, this phase requires political actions to support procedural and technological transformations of BIM and Industry 4.0 innovations incorporation:

(a) administrative and collegiate approvals, acquisitions;

(b) BIM model development;

(c) teacher training and engagement;

(d) institutional vision; and

(e) university extension and scientific initiation (Table 5).

Coates *et al.* (2010) suggest that the final step should evaluate and disseminate the developed and executed plan. In this study, only disseminating was covered, resulting in an Academic BIM Portal (Brazil, 2022a).

Systematization

Four spreadsheets (Table 6) were developed to structure the collection of the necessary information and support decision-making regarding the following:

(a) definition of BIM educational objectives of disciplines;

(b) identification of BIM applications and innovative technologies;

(c) adaptation of teaching plans; and

(d) roadmap for curricular cBIP actions: processes, technologies, and policies.

The competencies developed according to the Brazilian national curriculum guidelines for undergraduate majors are also observed for each discipline. In this way, the relationship between BIM and the general competencies of a major can be evaluated. Furthermore, by including a BIM educational objective, we can assess whether the skills covered in the discipline following national guidelines are expanded. The connection between temporally planned actions (Table 5) in terms of procedural changes in disciplines, consequential support technologies and policies associated with people and the institution determine the impact on curriculum BIM maturity.

Application

Two pilot studies were carried out where the four action research cycles took place. The pilot studies were carried out in the Construa Brasil Project managed by RECEPETI with the Ministry of Development, Industry, Commerce and Services (Brazil, 2022b). Pilot studies were conducted at the Federal University of Paraná and the Federal University of Pernambuco. The guidelines developed were then replicated on a large scale for curricular transformation in ANTAC's BIM Cell Network. Below we present the results of these two applications.

Pilot studies of the Construa Brasil Project

The Construa Brasil Project intends to improve the business environment of the Brazilian construction sector, encouraging modernization. For this scenario to become a reality, the dissemination of Building Information Modeling (BIM) is encouraged. In this context, a strategy for the involvement of higher education was developed. The strategy proposes the formation of university BIM Cells, the development of a cBIP by each cell for a specific major and the execution of the plan. Therefore, the university BIM Cells are organized groups of professors and students from an educational institution involved in proposing and developing a cBIP, in one or more majors, with the aim of carrying out academic digital transformation actions. The work of the BIM Cells in these pilot studies was facilitated by a BIM specialist.

Figure 5 - **Scheme for flexible BIM educational objectives definition**

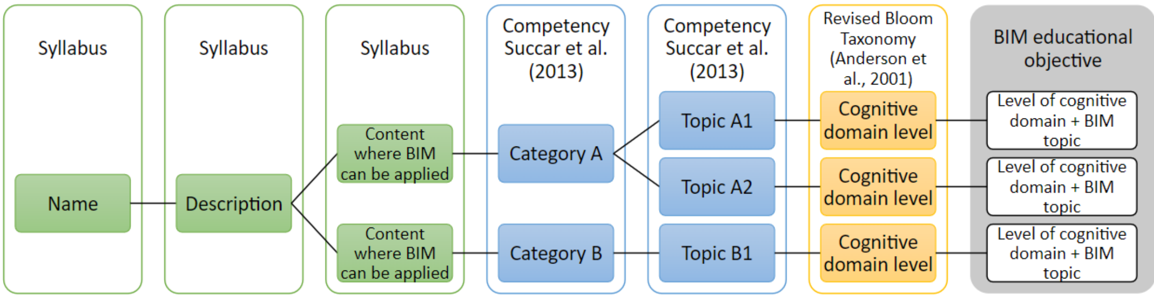


Table 5 - **Types of actions**

Procedural Actions	Technological Actions	Infrastructure Actions
• Send a proposal to update the Pedagogical Project of the major • Approve new subject teaching plan in the required academic instances • Identify existing BIM content available • Prepare theoretical content • Prepare practical content • Identify experts for lecture or collaboration in the discipline • Develop demonstrations • Develop information model • Develop practical activity • Develop or update assessment • Offer up to date discipline • Coordinate joint action of the discipline with other disciplines link to an extension or research project	• Seek software supply agreement for access at the HEI • Seek software supply agreement for individual student access (outside HEI) • Seek agreement for a faculty capacity building and training program • Seek agreements for student body capacity building and training program	• BIM Teaching Spaces, with individualized accommodation and hardware • Space with infrastructure for interaction and information sharing • Active and collaborative learning environment with high student engagement • Network installations suitable for the development of BIM activities • Require financial support or funding

Table 6 – **Summary of collected information in the systematization process for the cBIP**

Educational objectives	Technology	Teaching plan	BIM maturity impact
by syllabus	by syllabus	by syllabus	for the major
+ Major + Name of syllabus + Teacher + Building environment scale + Competency according to National Guidelines + BIM Competency + Cognitive Domain	+ BIM applications supporting new educational objectives + Innovative technologies supporting new educational objectives + Space or equipment where to install + Actions required:(technological and political)	+ Current plan + Updated plan including: new content, review description, teaching method, new competency according to national guidelines, new educational objectives, review assessment, review bibliography. + Actions required (procedural and political)	+Procedural indicator ● current ● goals ● actions ● future + Technological indicator ● current ● goals ● actions ● future + Political indicator ● current ● goals ● actions ● future
Informed in formularies	Informed in formularies	Collected in a spreadsheet	Collected from previous spreadsheets
Resulting spreadsheet with all syllabi allow graphical data visualization	Resulting spreadsheets with all syllabi allow graphical data visualization	Spreadsheet with plans distributed in tabs allowing general compilation of necessary action	Spreadsheet with a summarized view of the plan and estimated impact

Civil Engineering and Architecture and Urbanism majors developed cBIPs by the BIM Cells at the Federal University of Paraná (UFPR) and Pernambuco (UFPE), respectively. The cBIP developed at UFPR considered the interaction between two majors: Civil Engineering and Graphical Expression. Table 7 describes the student workload in terms of mandatory syllabi, optional syllabi, graduation work, professional internship, and complementary activities. It also points equivalence with stages of undergraduates in the European Union. It is noticeable that the Brazilian undergraduation comprises all the incremental levels of achievements in BIM education proposed by Sacks and Pikas (2013) according to the cognitive domain of Bloom's taxonomy. That indicates a difference that demands the adaptation of existing educational frameworks for BIM in Brazil, since Sacks and Pikas (2013) suggest that the abilities of Analysis and Synthesis (according to Bloom's educational domain) would only be applied at the master's level, and the ability of Evaluation only in the professional life, leaving undergraduate education to develop the abilities of Knowledge, Comprehension, and Application. Parallelly, in the IMAC framework (MacDonald *et al.*, 2011), the educational level is not defined, which suggests that all abilities can be developed at every stage of learning.

Table 8 exemplifies the results of the second step of the guidelines, that is, to set curriculum transformation bias (objectives) and transformation core. At the Federal University of Paraná, there was a movement and interest in integrating two majors and thus developing multidisciplinary collaborative skills.

Adding more detail to the pilot study at UFPR, it is observed in the set of disciplines that the BIM competencies introduced a relation of 33% to 56% of the general competencies for engineering courses (Figure 6). The general competence to which BIM is most related is communication, which is a consequence of the quantity and types of disciplines chosen in the implementation plan. Table 9 presents the categories of BIM competencies that will be developed in the major of Civil Engineering at UFPR and in which built environment scale they will be applied. This distribution indicates that the BIM implementation plan is still timid, mostly involving buildings and building systems. However, an initial diversification effort encompassing infrastructure and management is noted. Table 9 also points out which disciplines develop BIM competencies the most, and which categories of BIM competencies (Succar *et al.*, 2013) are present the most in the proposed training. We observed an emphasis on technical and functional competencies in BIM, different from Wang *et al.* (2020), who identified an emphasis on technical and managerial competencies.

Operational competencies are associated with the model uses. Thus, in the Civil Engineering major at the Federal University of Paraná, the uses of the model most taught will be design and planning with the development of models present in most disciplines of the implementation plan (Figure 7). Construction 4.0 technologies planned to be developed with BIM are digital fabrication, data science, and visualization with virtual and augmented reality.

Table 7 – **Types of student workload in the undergraduate courses of the pilot studies**

HEI		**UFPR**		**UFPE**	**Table 1 equivalence**
Majors		**Civil Engineering**	**Graphical Expression**	**Architecture and Urbanism**	
Duration (min)		**5 years (10 semesters)**	**4 years (8 semesters)**	**5 years (10 semesters)**	
Workload (hours)	Mandatory syllabi	3.084	2.112	2.535	Bachelor’s + Master’s degrees
	Optional syllabi	108	240	625	
	Graduation work	108	108	120	
	Professional internship	180	180	120	Work experience
	Complementary activities	120	120	200	
	Total	3.600	2.760	3.600	

Table 8 – **Objective and scope of the cBIP of HEIs in the Construa Brasil Project represented by core disciplines of the implementation plan**

Objective			
Stimulate the development and application of new technologies related to BIM associated with Buildings and Infrastructure in Design, Planning and Budget			
Scope			
Major	**UFPR**	**Major**	**UFPE**
CV	- Building structure - Project management - Building design - Infrastructure design and special works - Architectural design - Planning and budgeting	AU	- Environmental comfort - 2D Graphic Geometry I & II - 3D Graphic Geometry II - Project management - Computing applied to Architecture Urbanism and Landscaping II & III - Educational building design workshop - Tectonics III, IV & V - Special Topics in 2D Geometry III & IV - Special Topics in 3D Graphic Geometry I & II - Special Topics in Computing Applied to Architecture Urbanism and Landscape I, II & III
GE	- Building Information Modeling - Prototyping II - Topic in Prototyping II		

Note:
CV – Civil Engineering;
GE – Graphic Expression; and
AU – Architecture and Urbanism.

Figure 6 – **National curriculum guidelines for engineering majors and the relation to disciplines where BIM competencies are introduced in the major of Civil Engineering at UFPR**

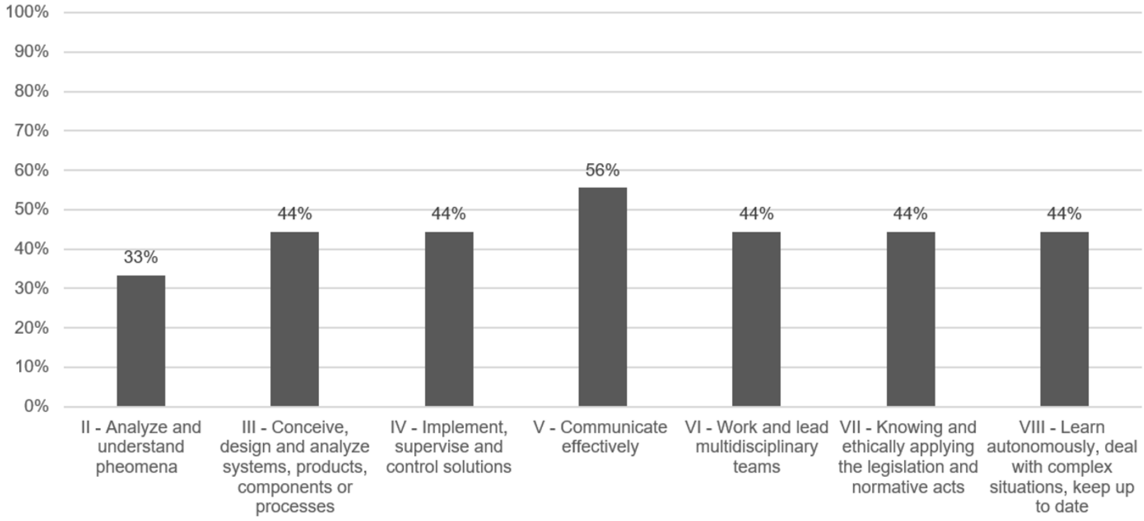


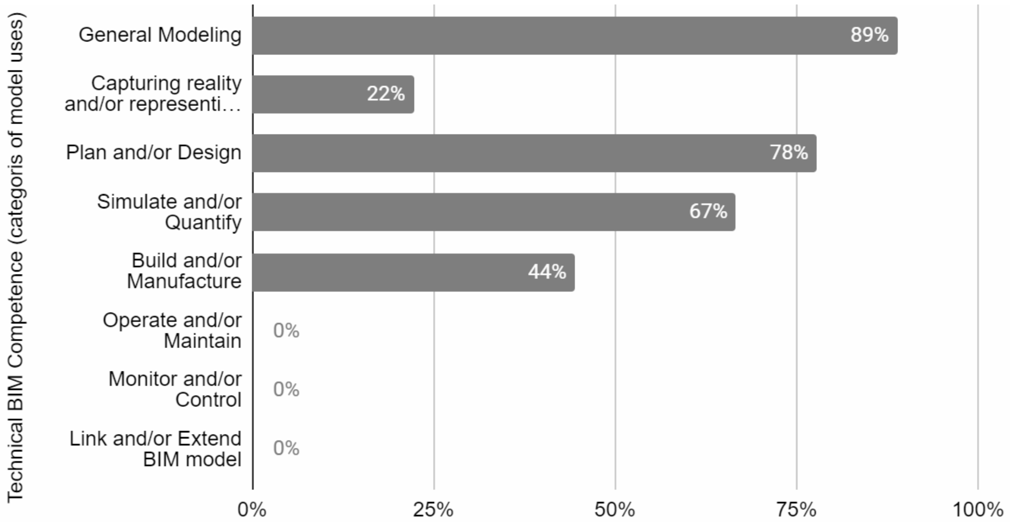
Table 9 – **Distribution of BIM competency types in the disciplines in the major of Civil Engineering at UFPR**

Major	Discipline	Scope of engineering solution	MAN	ADM	FUN	OPE	IMP	SUP	R&D	BIM Competency
CV	Building structure	Building or a building system	0	0	1	3	0	0	0	4
CV	Project management	Building or a building system	0	0	3	4	1	0	1	9
CV	Building design	Building or a building system	0	0	1	3	2	0	1	7
CV	Infrastructure design and special works	Management	1	1	2	0	1	0	1	6
CV	Architectural design	Infrastructure	2	1	3	4	1	0	1	12
CV	Planning and budgeting	Building or a building system	0	0	0	5	0	0	0	5
GE	Building Information Modeling	Building or a building system	2	3	3	3	3	0	1	15
GE	Prototyping II	Building or a building system	1	1	1	2	0	1	2	8
GE	Topic in Prototyping II	Building or a building system	1	2	2	2	1	1	2	11

Note:

CV – Civil Engineering;
GE – Graphic Expression;
MAN – Managerial;
ADM – Administration;
FUN – Functional;
OPE – Operation;
TEC – Technical;
IMP – Implementation;
SUP – Supportive;
R&D – Research and Development (SUCCAR *et al.*, 2013).

Figure 7 – **Operational BIM competencies developed by disciplines in the major of Civil Engineering at UFPR**



Once the competencies are understood for the core disciplines of the cBIP, it evolves to the definition of the BIM educational objectives to be included in the teaching plans. At this moment, the scheme for defining BIM educational objectives (Figure 5) is applied by discipline. Figure 8 shows the result of the Project Management discipline at UFPR. We observed that the idealization of BIM educational objectives requires the assistance of a BIM specialist. It takes envisioning, practice, or knowledge to identify a topic in BIM that represents the desired competency. This reinforces the need for BIM Cells' teachers to carry out minimum training in BIM at the beginning of the cell's work.

The BIM Cell of the Federal University of Paraná has launched the plan. Approvals for the proposed transformations were obtained, and 50% of the syllabi have already been offered at least once with some level of transformation. The development of BIM models is being appointed to be used by professors, and teachers are preparing to continue the planned actions. The expected result in increasing BIM maturity for the major of Civil Engineering at the Federal University of Paraná is shown in Figure 9. It is observed that even with a timid introduction of BIM competence with a limited scope of engineering solutions, the impact on BIM maturity is expressive and will be perceived by the internal academic community and external practice. The BIM Cell at the Federal University of Pernambuco is in the third stage of the implementation plan. In both groups, BIM training was carried out through online training and seminars.

BIM Cell Network

The modernization strategy of Construa Brasil Project for the construction sector through higher education was replicated on a large scale in the BIM Cell Network of the National Association of Technology in the Built Environment (ANTAC). ANTAC held a call to form the network in December 2021, and the network started working in January of the following year. The network comprises 19 higher education institutions, involving the curricular transformation of 32 undergraduate courses, mainly in Civil Engineering, followed by Architecture and Urbanism. The educational institutions are distributed in the south, southeast and northeast regions of Brazil.

All institutions are in the second stage of the guidelines: setting curriculum transformation bias (objectives) and discipline transformation core that will guide the cBIP. The analysis of current undergraduate teaching practice in the network has already been completed, allowing for an initial Brazilian diagnosis of BIM maturity in education and the potential for including BIM in curricular matrices.

The general average BIM curricular maturity observed, according to the metric by Böes *et al.* (2021), is 50.8% for Architecture and Urbanism majors and 43.6% for Civil Engineering majors (Figure 10). It indicates a defined curriculum BIM maturity, by the metric terminology. This means that the incorporation of BIM into undergraduate education is ongoing and that this macro BIM maturity has been achieved through individual faculty efforts. If we've already gone this far with individual efforts, then imagine the impact of a collective effort and on a national scale.

The analysis of curriculum matrices seeking to identify disciplines with a straightforward interface with BIM (Método, 2021) indicates tremendous latent potential for including BIM in the training of Brazilian civil engineers and architects. It is observed that 45.8% of the syllabi in the curricular matrices of undergraduate courses in Architecture and Urbanism in Brazil were classified as having a straightforward interface with BIM (Figure 11). In these disciplines, the content taught is directly related to BIM competencies. As for Civil Engineering courses, this percentage is lower, at 26.8%. Note that the standard deviation is wide, calling attention to the subjectivity of the metric.

Conclusion

The created guidelines for the development and execution of a Curricular BIM Implementation Plan proved to be generic and comprehensive, having been able to guide the transformation of different majors and domains. Systematization tools provide an empirical basis for the decision-making of the academics involved. These two aspects are differentiations of the proposed framework compared to the existing ones.

Figure 8 - **BIM educational objectives defined for the syllabus of Project Management at UFPR**

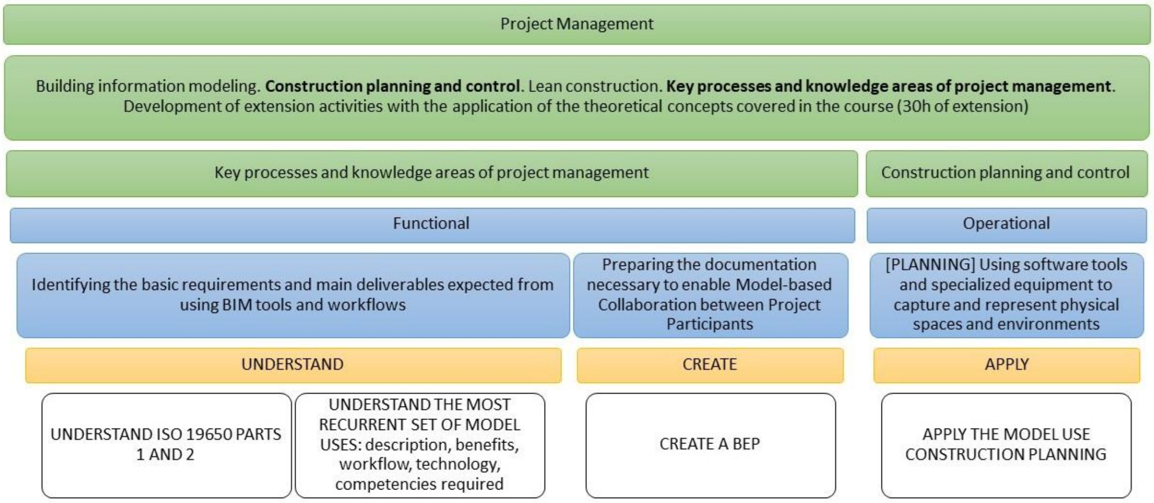


Figure 9 - **Improvements in indicator of the curricular BIM maturity of the major of Civil Engineering at UFPR (dark gray are current values and light gray are expected values)**

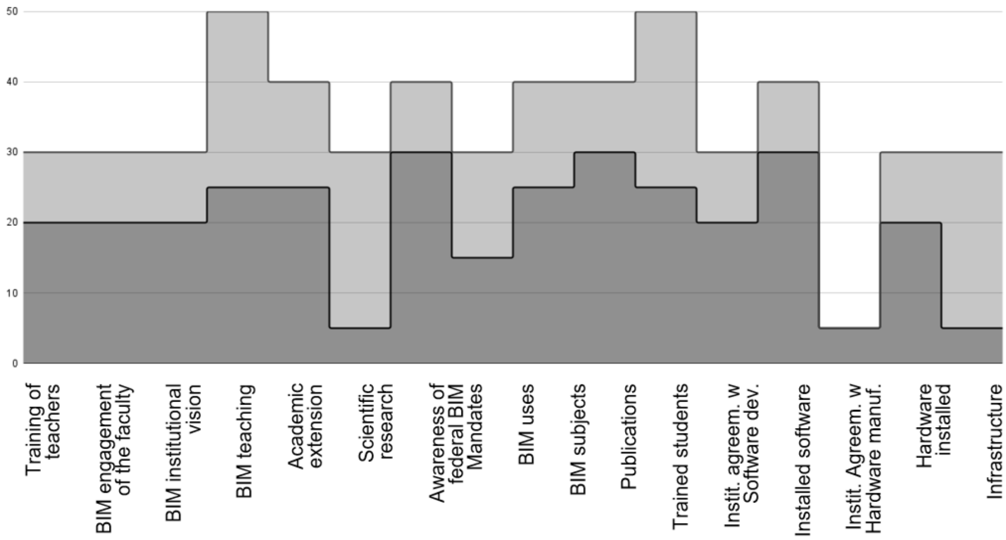
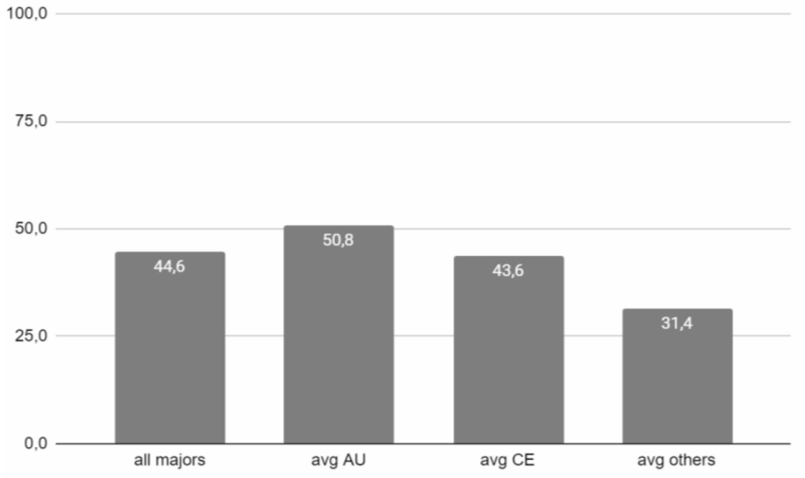


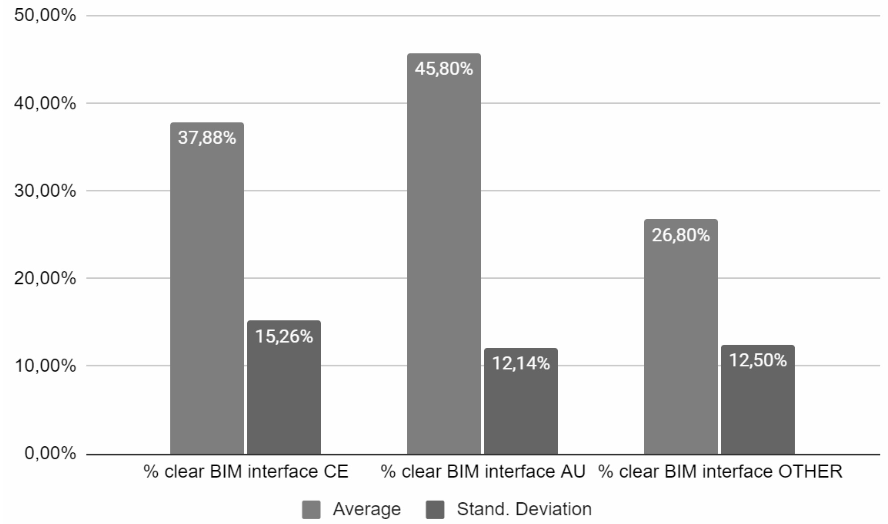
Figure 10 – **Curricular BIM maturity of courses in the ANTAC BIM Cell Network**



Source: Ruschel and Ferreira (2022).

Note: *avg = average.

Figure 11 – **Percentage of disciplines in curricular matrices with interface with BIM in ANTAC's BIM Cell Network majors**



Source: Ruschel and Ferreira (2022).

The implementation plan development acts as a mechanism of awareness of BIM among those involved internally in each BIM Cell. Online training, seminars and discussions with the facilitator promote this awareness. The approval actions of the proposed transformations also work as a BIM awareness mechanism external to the BIM Cell. As such, it can work as a trigger to organize and integrate currently dissociated courses and to address the impact that digital technology would have on the adaptation of designing in a collaborative way, pressured by the evolution of algorithmic methods.

Besides, we confirmed that leadership is an essential factor for the development of the work. This leadership, with significant expertise in BIM, becomes essential in the third stage of the implementation plan. We noted that after the BIM characterization of the disciplines, the necessary transformation of the teaching plan unfolds. If the teachers involved do not have in-depth knowledge of BIM for the topic, the transformation in the teaching plan may be inconsistent.

Bloom's taxonomy for specifying educational goals in the cognitive domain guides the teachers on choosing how to develop the desired competence, whether in a more straightforward way (remember, understand, and apply) or a more complex one (analyze, evaluate, and create). The levels of the cognitive domain in educational objectives can follow the evolution of the major and the students' maturation and ability to face more complex learning experiences.

However, we observed that it could also be adopted as a strategy for the teacher himself to overcome insecurities and lack of knowledge. In the same discipline, the choice of educational objectives within Bloom's taxonomy can evolve with the teacher's gain in BIM competencies. BIM competencies can be initially inserted theoretically through educational objectives associated with remembering and understanding, evolving to apply, or even creating if the discipline admits. This strategy captivates teachers, allowing them to incrementally step out of their comfort zones.

This action research was extended to a network of Brazilian universities. The project is led by the National Association of Technology in the Built Environment (ANTAC), an association of researchers. The project is called ANTAC BIM Cell Network. The collective and scaled effort to incorporate BIM into Brazilian undergraduate education in the network has already shown a significant impact. It was possible to carry out a national diagnosis of curricular BIM maturity in the teaching of civil engineering and architecture and identify the latent spaces in the curricular matrices open for the incorporation of BIM.

References

ANDERSON, L. W. *et. al.* **A taxonomy for learning, teaching, and assessing**: a revision of Bloom's Taxonomy of Educational Objectives. New York: Addison Wesley Longman, 2001.

BADRINATH, A. C. *et al.* A review of tertiary BIM education for advanced engineering communication with visualization. **Visualization in Engineering**, v. 4, n. 1, p. 1-17, 2016.

BARISON, M. B.; SANTOS, E. T. A tool for assisting teachers in planning BIM courses. In: INTERNATIONALCONFERENCE ON COMPUTING IN CIVIL AND BUILDING ENGINEERING, Miami, 2014. **Proceedings […]** Miami: ISCCBE/CIB/ASCE, 2014.

BEGIĆ, H.; GALIĆ, M. A systematic review of construction 4.0 in the context of the BIM 4.0 premise. **Buildings**, v. 11, n. 8, p. 337, 2021.

BILLER, R. R. do N. *et al.* Classificação de plataformas computacionais quanto aos usos do BIM. In: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 3., 2021. **Anais [...]** Porto Alegre, 2021.

BLOOM, B. S. *et al.* **Taxonomy of educational objectives**: the classification of educational goals. In: BOOK I: cognitive domain. New York: David McKay Company, 1956.

BÖES, J. S. *et al.* BIM maturity model for higher education institutions. **Ambiente Construído**, Porto Alegre, v. 21, n. 2 , p. 131-150, apr./jun. 2021.

BRAZIL. Ministério do Desenvolvimento, Indústria, Comércio e Serviços. **Portal BIM Acadêmico.** Brasília: Ministério do Desenvolvimento, Indústria, Comércio e Serviços, 2022a. Disponível em: https://www.gov.br/produtividade-e-comercio-exterior/pt-br/ambiente-de-negocios/competitividade-industrial/construa-brasil. Acesso em: 29 out. 2023.

BRAZIL. Ministério do Desenvolvimento, Indústria, Comércio e Serviços. **Construa Brasil.** Brasília: Ministério do Desenvolvimento, Indústria, Comércio e Serviços, 2022b. Disponível em: https://sites.google.com/antac.org.br/portalbimacademico. Acesso em: 29 out. 2023.

COATES, S. P. *et al.* The key performance indicators of the BIM implementation process. In: INTERNATIONAL CONFERENCE ON COMPUTING IN CIVIL AND BUILDING ENGINEERING, Nottingham, 2010. **Proceedings […]** Nottingham: Nottingham University Press, 2010.

GU, N.; LONDON, K. Understanding and facilitating BIM adoption in the AEC industry. **Automation in Construction**, v. 19, n. 8, 988-999, 2010.

HERRERA, R. F., *et al.* Interaction networks within student teams learning Building Information Modeling (BIM**). Journal of Civil Engineering Education**, v. 147, n. 1, p. 05020008, 2021.

HULT; LENNUNG, S.-A. Towards a definition of action research: a note and bibliography. **Journal of Management Studies**, v. 17, n. 2, p. 241-250, May 1980.

MA, X. *et al.* Critical strategies for enhancing BIM implementation in AEC projects: perspectives from Chinese practitioners. **Journal of Construction Engineering and Management**, v. 146, n. 2, 05019019, 2020.

MACDONALD, J. A. A framework for collaborative BIM education across the AEC disciplines. In: ANNUAL CONFERENCE OF AUSTRALASIAN UNIVERSITY BUILDING EDUCATORS ASSOCIATION, 37., Sydney, 2011. **Proceedings […]** Sydney, 2011.

MACHADO, F. A. *et al.* BIM in Latin American countries: an analysis of regulation evolution. In: INTERNATIONAL CONFERENCE ON COMPUTING IN CIVIL AND BUILDING ENGINEERING, São Paulo, 2020. **Proceedings […]** São Paulo, 2020.

MÉTODO de identificação da interface com BIM na matriz curricular. Érica de Sousa Checcucci. 2021. 1 vídeo (27:58 min). Publicado pelo canal do Youtube GT TIC ANTAC. Playlist Células BIM. 7 mai. 2021. Disponível em: https://www.youtube.com/watch?v=8i32NV4PLjc&list=PLkL20v6GBV3yEjceOKS8WpQd4xxemV6A2&index=2. Acesso em: 31 jul. 2023.

PERRIER, N. *et al.* Construction 4.0: a survey of research trends. **Journal of Information Technology in Construction (ITcon)**, v. 25, p. 416-437, 2020.

PIKAS, E. *et al.* Building information modeling education for construction engineering and management. II: procedures and implementation case study. **Journal of Construction Engineering and Management**, v. 139, n. 11, 05013002, 2013.

RODRIGUEZ, A. K. S. *et al.* BIM education framework for clients and professionals of the construction industry. **International Journal of 3-D Information Modeling**, v. 6, n. 2, p. 57-79, 2016.

RODRÍGUEZ-RODRÍGUEZ, K. Y.; DÁVILA-PEREZ, J. L. Framework development to introduce BIM into the civil engineering undergraduate curriculum at University of Puerto Rico, Mayagüez Campus. In: CONSTRUCTION RESEARCH CONGRESS, San Juan, 2016. **Proceedings […]** San Juan, 2016.

RUSCHEL, R. C.; FERREIRA, S. L. Rede de células BIM ANTAC. In: ENCONTRO NACIONAL SOBRE O ENSINO DE BIM, 4., Porto Alegre, 2022. **Anais [...]** Porto Alegre: ANTAC, 2022.

SACKS, R.; PIKAS, E. Building information modeling education for construction engineering and management. I: industry requirements, state of the art, and gap analysis. **Journal of Construction Engineering and Management**, v. 139, n. 11, 04013016, 2013.

SMITH, P. BIM implementation: global strategies. **Procedia Engineering**, v. 85, p. 482-492, 2014.

SOLNOSKY, R. L. Opportunities for BIM to enhance structural engineering curricula. In: STRUCTURES CONFERENCE, Fort Worth, 2018. **Proceedings […]** Fort Worth, 2018.

SOLNOSKY, R. L.; PARFITT, M. K. A curriculum approach to deploying BIM n architectural engineering. In: RAEBEL, C. H. (ed.). **AEI 2015**: birth and life of the integrated building. Malwaukee: ASCE, 2015.

SUCCAR, B. *et al.* An integrated approach to BIM competency assessment, acquisition and application. **Automation in Construction**, v. 35, p. 174-189, 2013.

SUCCAR, B. *et al.* Model uses: foundations for a modular requirements clarification language. AUSTRALASIAN UNIVERSITIES BUILDING EDUCATION, Cairns, 2016. **Proceedings […]** Cairns, 2016.

SUCCAR, B.; KASSEM, M. Macro-BIM adoption: conceptual structures. **Automation in Construction**, v. 57, p. 64-79, 2015.

SUWAL *et al.* BIM Education: implementing and reviewing OpeBIM, BIM for teachers. **Computing in Civil and Building Engineering**, p. 2151-2158, jun. 2014.

TRIPP, D. Action research: a methodological introduction. **Educação e Pesquisa**, v. 31, n. 3, p. 443-466, 2005.

ULLAH, K. *et al.* An Overview of BIM adoption in the construction industry: benefits and barriers. In: NORDIC CONFERENCE ON CONSTRUCTION ECONOMICS AND ORGANIZATION, 10., Tallinn, 2019. **Proceedings […]** Bingley: Emerald Publishing Limited, 2019.

UNDERWOOD, J. *et al.* **Current position and associated challenges of BIM education in UK higher education**. 2015. Available: https://oliebana.files.wordpress.com/2015/04/baf_bim_education_report_2015.pdf. Access: 06 nov. 2023.

WANG, L. *et al.* Review of BIM adoption in the higher education of AEC disciplines. **Journal of Civil Engineering Education**, v. 146, n. 3, 2020.

WU, W.; ISSA, R. R. BIM education and recruiting: survey-based comparative analysis of issues, perceptions, and collaboration opportunities. **Journal of Professional Issues in Engineering Education and Practice,** v. 140, n. 2, 04013014, 2014.

YAN, W. *et al.* Integrating BIM and gaming for real-time interactive architectural visualization. **Automation in Construction**, v. 20, n. 4, p. 446-458, 2021.

ZHAO, F. Research on the construction of engineering management course system based on BIM technology. In: INTERNATIONAL CONFERENCE ON CONSTRUCTION AND REAL ESTATE MANAGEMENT, Beijing, 2021. **Proceedings [...]** Beijing, 2021.

Acknolegments

We thank then Brazilian Ministry of Development, Industry, Comerce and Services for promoting the *Construa* Brazil Project, the Santa Catarina Innovation Network (RECEPETI), the National Association of Technology in the Built Environment (ANTAC) and the members of the univerties BIM Cells of the *Construa* Brazil Project and the ANTAC Network of BIM Cells.

Regina Coeli Ruschel
Conceitualização. Análise de dados, Pesquisa, Metodologia, Administração do projeto, Supervisão, Validação de dados e experimentos, Redação do manuscrito original, Redação - revisão e edição.

Programa de Pós-Graduação em Arquitetura, Tecnologia e Cidade | Universidade Estadual de Campinas | Rua Saturnino de Brito, 224 | Campinas – SP – Brasil | CEP 13083-889 | Tel.: (19) 3521-2307 | E-mail: ruschel@unicamp.br

Caroline Kehl
Conceitualização. Curadoria de dados, Análise de dados, Pesquisa, Validação de dados e experimentos, Design da apresentação de dados, Redação do manuscrito original, Redação - revisão e edição.

Programa de Pós-Graduação em Arquitetura, Tecnologia e Cidade | Universidade Estadual de Campinas | Tel.: (19) 99828-3259 | E-mail: kehl.caroline@gmail.com

Editora do artigo: **Edna Possan**

Ambiente Construído
Revista da Associação Nacional de Tecnologia do Ambiente Construído
Av. Osvaldo Aranha, 99 - 3º andar, Centro
Porto Alegre – RS - Brasil
CEP 90035-190
Telefone: +55 (51) 3308-4084
www.seer.ufrgs.br/ambienteconstruido
www.scielo.br/ac
E-mail: ambienteconstruido@ufrgs.br