

## BIM TEACHING: CURRENT INTERNATIONAL TRENDS

*Ensino de BIM: tendências atuais no cenário internacional*

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### Resumo

Existem hoje muitas companhias no mundo todo que estão desenvolvendo projetos utilizando processos BIM. Estas companhias estão procurando profissionais que possam efetivamente trabalhar em projetos BIM. Para atender a esta demanda muitas universidades têm implementado uma variedade de cursos para expor os alunos a esse novo paradigma. Contudo, essas experiências acadêmicas são relativamente novas e baseadas em pedagogias ainda não consolidadas. Com base em revisão da literatura internacional focando experiências didáticas sobre BIM, o presente estudo resume as tendências observadas. São apresentados os principais obstáculos enfrentados no ensino de BIM, exemplos de como superá-los e estratégias de implementação. As estratégias são apresentadas para os níveis: introdutório, intermediário e avançado. Sugere-se o estabelecimento de parcerias entre academia e indústria.

**Palavras-chave:** Educação BIM; Pedagogia BIM; Currículo BIM; Modelagem da Informação da Construção; Gerente BIM.

### Abstract

A large number of companies throughout the world are carrying out projects that involve BIM processes. These companies require professional employees who are able to work effectively on projects undertaken with BIM. Several universities have been running a wide range of courses to meet this demand and provide students with experience on this new paradigm. However, this learning experience is relatively new and based on a pedagogical system that has not yet been consolidated. This study draws on a review of the international literature and an investigation of BIM teaching practices to provide a summary of current trends observed in the area. An attempt is made to address the main obstacles encountered with BIM teaching, as well as to give examples of how to overcome them and introduce new strategies at introductory, intermediary and advanced levels. We suggest partnerships between universities and industry..

**Keywords:** BIM Education; BIM Teaching; BIM Curriculum; Building Information Modeling; BIM Manager. .



## 1. INTRODUCTION

A large number of companies throughout the world are carrying out projects that involve Building Information Model(ing) (BIM) processes. These companies require professional employees who are able to work with this new concept. Several universities have been running a wide range of courses to meet this demand and provide students with experience of how to handle the new tools. (Holland et al. 2010). However, this learning experience is relatively new and based on a pedagogical system that has not yet been consolidated.

This study draws on a review of the international literature and an investigation of BIM teaching practices to give a summary of current trends observed in the area. An attempt is made to address the main obstacles encountered with BIM teaching, as well as to give examples of how to overcome them and introduce BIM in the curriculum.

This study is part of a postgraduate research which seeks to build a theoretical model for the introduction of BIM in the curriculum of the Architecture and the Civil Engineering programs in Brazil.

## 2. RESEARCH METHODOLOGY

Initially, an investigation of texts in the field of 'BIM Teaching' was carried out, followed by a textual analysis. Some of the terms, such as 'BIM Education', 'BIM Course', 'BIM Teaching', 'BIM Curricula', have been used in the criteria for the selection of the texts.

In the period 2008-2009, a set of texts was compiled for inclusion in the survey. The selected texts formed a database which allowed the investigation to proceed. A further investigation of texts was carried out in the period 2010-2011 and this supplemented the initial database.

The 'Textual Analysis' method and thus the accompanying 'Content Analysis' (Bardin 2004) were employed because they allowed the 'BIM Teaching' profile to be defined more

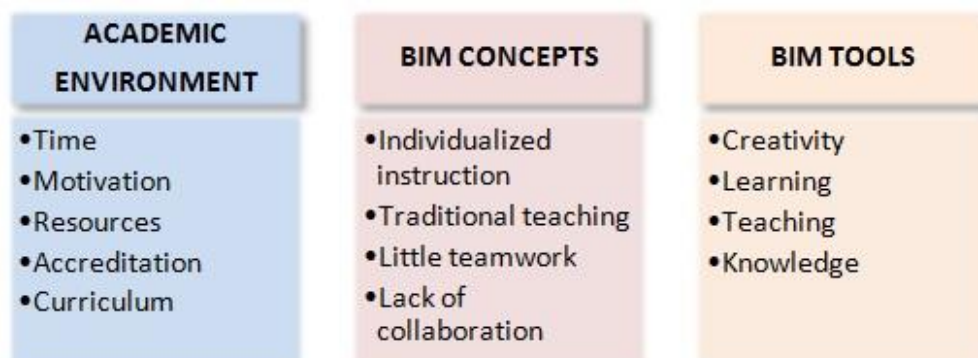
clearly. This method involves arranging qualitative textual data into similar sets of entities or conceptual categories. The purpose of this is to determine the standards and relationships between different themes, and these can either be identified in an a priori way or emerge from the analysis.

Initially, there was an evaluation of what the texts reveal about the 'BIM Teaching' field and this was followed by an attempt to, build up an understanding of four phenomena: (a) schools employ different strategies for teaching BIM; (b) schools introduce BIM into the curriculum in different ways; (c) schools face obstacles when teaching BIM and d) some schools have overcome these obstacles and are prominent in BIM teaching.

## 3. OBSTACLES

The programs that are planning to introduce BIM into the curriculum face a number of obstacles that can be grouped into three types: academic circumstances,

misunderstanding of the BIM concepts and difficulties in learning/using the BIM tools (Kymmell 2008), as shown in Figure 1.



**Figure 1** – Factors and types of obstacles affecting the implementation of BIM in the curriculum

A survey involving 119 building construction schools in the United States found that only 9% of them teach BIM at a degree level (Sabongi 2009). The main obstacles referred to by the respondents are as follows: lack of time or resources to prepare a new curriculum, lack of space in the curriculum to include new courses and a lack of suitable materials to teach BIM.

Another survey involving 101 Architecture, Civil Engineering and Construction Management programs in the U.S. (Becerik-Gerber, Gerber, and Ku 2011) found that, apart from these obstacles, there is a shortage of trained personnel in BIM, that the curriculum is not focused on BIM, that its implementation takes time and that the accrediting bodies for the construction programs have not drawn up clear guidelines for BIM.

Since there is insufficient space in the curriculum to include a new course, the organizers of some programs have decided to teach BIM tools in a Design Studio. However, the teaching of design is still largely concerned with the teaching of architectural form and the teacher usually interacts with students on an individual basis (Scheer 2006).

One of the concepts that BIM introduces is collaboration, which requires integrating different subject-areas. The institutions are traditionally formed of departments which are independent of each other. Some schools have no more than one Architecture, Engineering and Construction (AEC) program. Moreover, it is difficult to coordinate the schedules, classrooms and

laboratories of the whole faculty since this involves a large number of students studying at the same time. Despite these challenges, some studies have shown that it is possible to teach BIM and collaborative practices within a single department but between different institutions or through distance education, but this requires having a particular kind of school infrastructure (Berwald 2008, Hjelseth 2008, Hu 2007, Hedges et al. 2008).

The computer labs are often slow and the students' files are regularly deleted which results in data loss. In addition, the TI schools policy does not usually allow a server to share a central file (Chiple 2010).

The BIM tools are often expensive and the programs experience difficulties in choosing the appropriate tool, which can soon become outdated. Moreover, the prescriptive nature of these tools leads some students to stick to predefined objects in their designs which, undermines their creativity. Although these objects can be created by the student, it is a time-consuming task and there is little time in the course to teach this procedure. One solution is to let the students explore the BIM tool by themselves and in their own way, in pairs or in teams. However, the students sometimes find it difficult, especially when creating curved surfaces and complex geometrical patterns, while others feel discouraged when learning the tool in a team, and think it is too complex to be exploited without any assistance (Horne, Roupé, and Johansson 2005, Sah and Cory 2008, Taylor, Liu, and Hein 2008, Scheer 2006).

#### 4. OVERCOMING OBSTACLES

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Since 2003, several international schools have begun teaching BIM tools, but the vast majority introduced BIM between 2006 and 2009. In exceptional cases, a few engineering schools have been teaching BIM since 2000: the Georgia Institute of Technology, for example, which has carried out research in BIM since the early 90s. The architecture

programs were those that first showed interest in this area. Rapid advances were made and today there are a large number of BIM courses (Barison and Santos 2010a, Becerik-Gerber, Gerber, and Ku 2011, Pavelko and Chasey 2010). The way BIM teaching evolved in the period 1990-2010 can be seen in Figure 2.

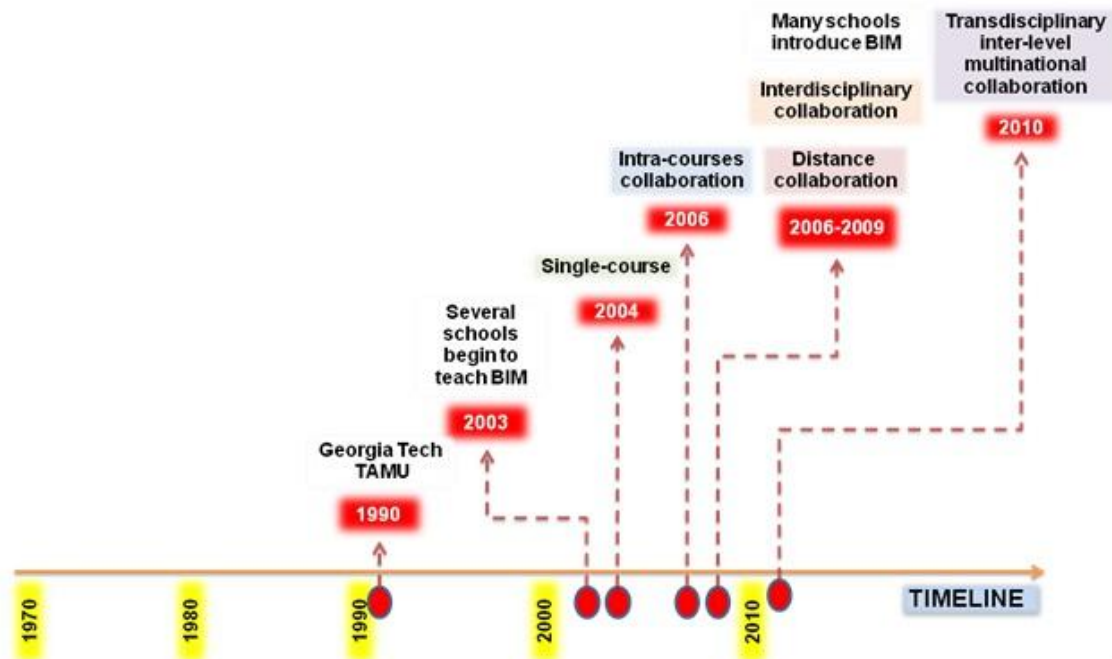


Figure 2 - Evolution of BIM teaching

In or around 2005, some universities began to combine Construction Management and Integrated Design Studio courses in an experimental way. In 2008, BIM began to be taught in the Interdisciplinary Design Studio which brought together students from six different AEC programs (Barison and Santos 2010a, Holland et al. 2010).

The current trend is to implement the Inter-level and/or Transdisciplinary Design Studio. One example is the Integrated Construction Leadership Studio offered by Virginia Tech, which brings together students of all levels from AEC programs. Another project that is being carried out by the same school is called Integrated Real Estate Program (IREP) that will include several courses across the curriculum and will also integrate students from other subject-areas outside the AEC (Taiebat, Ku, and McCoy 2010, Pishdad, Bosorgi, and Belliveau 2010).

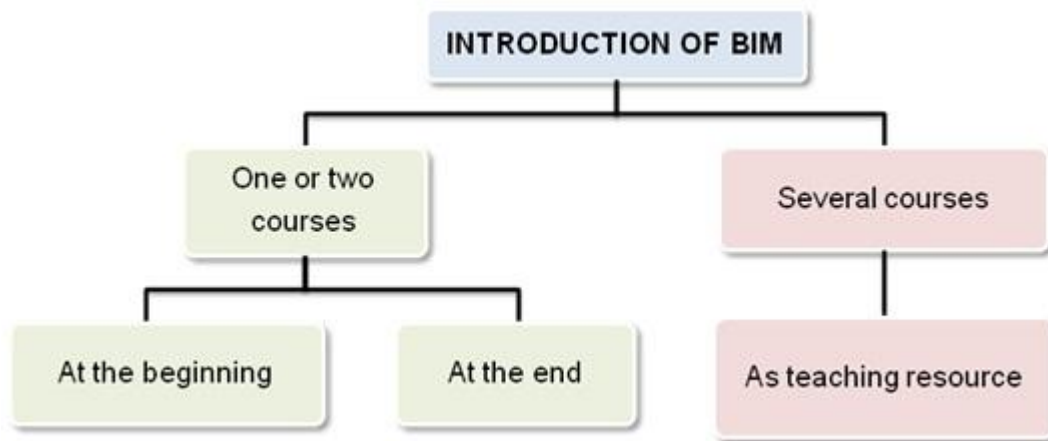
The disadvantage of the Inter-Level and/or Interdisciplinary Design Studio is that the sophomore and junior students who have not yet mastered BIM concepts and BIM tools, lack experience. The models produced by them are, sometimes, faulty in terms of accuracy, level of detail and positioning, which makes it difficult to coordinate them. Although they interact with more experienced students, there is little time for them to learn many BIM tools. The main problem with the Transdisciplinary Design Studio is that it involves various departments, and the students often have different values and goals and lack experience of collaboration and the ability to adopt different forms of evaluation. The students also differ in their cultures, expectations, types and levels of knowledge, perceptions and willingness to engage with technology (Taiebat, Ku, and McCoy 2010, Dossick and Peña 2010; Wu, Issa, and Giel 2010; Dederichs, Karlshoj, and Hertz 2011).

## 5. STRATEGIES USED BY SCHOOLS

The most important aspect of BIM for industry is its cost estimating and scheduling activities. However, most schools use BIM for teaching 3D coordination, visualization and constructability activities (Pavelko and

Chasey 2010, Becerik-Gerber, Gerber, and Ku 2011).

The schools have generally adopted two approaches: teaching BIM in one or two courses or using BIM in several courses, as shown in Figure 3.



**Figure 3** – Strategies used by schools when implementing BIM in the curriculum

In the first approach, the BIM tools are usually taught at the beginning of the programs (freshman or sophomore) and at the end (junior or senior). In the second approach, the BIM model is used as a teaching resource to help students understand certain issues. The teacher can create a tool to check some point in BIM, for example, construction safety or the student can create a tool that involves the BIM process, for example, an automated BIM code compliance checking system (Pavelko and Chasey 2010, Raja et al. 2010, Strelzoff, Sulbaran, and Percy 2010).

Regardless of the approach adopted, schools are introducing BIM in different courses of the curriculum, and these can be grouped into eight categories: Digital Graphic Representation (DGR), Workshop, Design Studio, Specific BIM Course, Building Technology, Construction Management, Thesis Project and Internship. The predominant approach adopted by the schools is to introduce BIM in Design Studios, although there are cases when Design Studios are integrated with other courses. A BIM course may be elective or integrated with the curriculum, either in isolation or integrated with another course, generally the Design Studio. Similarly, the workshops may be independent or integrated with courses and sometime also offer online for students or AEC professionals (Barison and Santos 2010a).

In the architecture programs, BIM is generally taught at a senior and Master's levels. Most architecture programs have introduced BIM into their Design Studio course. The second most common choice is to teach BIM in courses related to DGR and, the

third is to offer a BIM course (elective or compulsory). The other most common options are to teach BIM in Construction Management and to offer a Workshop (Becerik-Gerber, Gerber, and Ku 2011, Barison and Santos 2010a).

In engineering programs, BIM is mainly taught at sophomore, junior, and senior levels. Most of the engineering programs have introduced BIM in a specific BIM Course. However, the other significant choices are to teach BIM in a Design Studio course, to teach BIM in courses related to DGR and, to teach BIM in a Construction Management course (Becerik-Gerber, Gerber, and Ku 2011, Barison and Santos 2010a).

Overall, BIM is more often taught at senior levels, but most programs that aim to introduce BIM, plan to do so at the early stages of the AEC degree programs (Becerik-Gerber, Gerber, and Ku 2011).

The schools have adopted three approaches to teach collaboration strategies: single-courses, intra-courses, interdisciplinary and distance collaboration (Barison and Santos 2010a, Santos and Barison 2011) and, more recently, inter-level and/or transdisciplinary collaboration. However, most schools have introduced BIM in only one subject-area and few attempt to simulate the integrated practices (Barison and Santos 2010a, Santos and Barison 2011).

In 2010, there were no records of multinational academic experiences in BIM (Barison and Santos 2010a). However, in 2011 an experience was recorded involving students from four nationalities studying in four different countries (Brito et al. 2011).

## 6. BIM LEARNING AND TEACHING STRATEGIES

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BIM learning and teaching strategies vary depending on the level at which the skills are being taught. There are basically three skill levels: introductory, intermediary and advanced (Barison and Santos 2010a), which are summarized in Figure 4.

### 6.1 Introductory Level

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At this level, BIM can be taught in courses related to DGR. The purpose is to develop the skills of a BIM Modeler and a BIM Facilitator. When taking this course, it is not necessary to know CAD or have advanced computer skills (Barison and Santos 2010b).

The objectives are to learn the BIM tools, or rather, those that are most commonly used in the field; to obtain a good grounding in BIM concepts; to explore basic concepts of modeling and to understand how to communicate different types of information. The BIM tools can be taught through lectures, workshops and labs. The students do problem-solving exercises and carry out small individual tasks to practice the BIM tool. It is recommended that before the students start the modeling they make modifications to an existing model (Barison and Santos 2010b, Taiebat, Ku, and McCoy 2010, Brown, Peña, and Folan 2009).

After this, the students create the model of a small building (or parts of it), usually with an area of or less than 600 square meters to extract quantities from it, and learn how to manipulate the model, types of basic components and their behavior. It is recommended that a modern single family residence is used as a project. The modeling can be accompanied by analogue methods, sketches and axonometric views, which allow the students make suitable adjustments to the physical proportions (Barison and Santos 2010b, Brown, Peña, and Folan, 2009).

The architecture student can make a volume/mass representation of the house, carry out an investigation of primary components (doors, windows, panels and furniture) and, based on his/her research, develop and refine a new component. The engineering student can do the following: identify a construction component of his/her choice in the Structural and/or Mechanical, Electrical and Plumbing (MEP) areas, make a list of the necessary information required for

the construction of that component, categorize this information throughout the life cycle to show how it can be linked and managed from a life cycle perspective and decide how they should be shared with the other subject-areas (Koch and Hazar 2010, Brown, Peña, and Folan, 2009).

The assessment of the students' performance can be conducted through individual exercises (components or simple models), written exams about BIM concepts and their presentation of models (Barison and Santos 2010b).

### 6.2 Intermediary Level

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At this level, BIM can be taught in Integrated Design Studio and Building Technology courses. The purpose is to develop some of the skills a BIM Analyst possesses while strengthening the skills of a BIM Modeler. As a prerequisite, the student must know about Design Fundamentals, Graphics Representation, and BIM Concepts, and have experience of one BIM tool (Barison and Santos 2010b). The objective is to learn about other BIM tools and advanced techniques in 3D modeling, to know building systems and to explore features of the families in a BIM tool (Barison and Santos 2010b, Brown, Peña, and Folan, 2009).

A Design Studio course that focuses on parametric design can explore more abstract techniques such as creating the parameters and formulas that are needed to process the Generating Design. A studio that focuses on sustainability can explore the analysis, simulation and visualization of the model. A studio that focuses on construction documents can explore the creation of the architectural elements, the 3D detailing, list of materials, establishment of specifications and documentation generation (Brown, Peña, and Folan, 2009, Barison and Santos 2010b, Livingston 2008; Korman and Simonian 2010).

The students construct a BIM model in teams where each of them plays a specific role. A rotation of roles is recommended, because this alternation of roles discourages individual learning and the student can become an expert in a particular subject-area. When 'individual delivery' is also required, there is the risk of the student

falling into a silo and seeing the 'delivery' of his/her project depend on other students, thus destroying the teamwork and reducing the student's familiarity with other subjects (Taiebat, Ku, and McCoy 2010, Holland et al. 2010, Dederichs, Kalshoj, and Hertz 2011, Wu, Issa, and Giel 2010).

The biggest challenge of this approach is the time factor, which must be taken into account when learning some tools, modeling or carrying out analytical activities. A viable solution is for the teacher to provide a model already completed for the students so that they can carry out various types of analysis. If there is time for the student to construct a model, the teacher must provide complete 2D electronic documentation and a description of the project that has to be modeled. The students must learn BIM standards, contracts, how to set up the modeling protocol and how to share the central file, before starting the project (Brown, Peña, and Folan, 2009, Korman and Simonian 2010, Chipley 2010, Taiebat, Ku, and McCoy 2010).

In the experience of Korman and Simonian (2010), the students are accustomed to verify the systems in the follow order structure, HVAC sheet metal, sanitary drainage, process piping, water distribution, electrical control systems and telephone/datacom systems. Each team of students merges the individual models in a common BIM, detects interferences, prepares review reports, resolves conflicts, extracts quantities, plans and schedules and analyzes costs. The teams meet once a week to coordinate the model and update the plan for the BIM implementation. Each student revises his/her project and submits Request For Information (RFI) regarding problems that require an engineering resolution. The instructor of the course, who acts as 'the engineer' for the systems, then answers to the RFI.

The Project that is modeled must be of an existing small building, with a fairly square shape and, modern in style. It should allow the student to explore important design issues; in addition, it should be 1000 to 50000 square meters in size and located within or near the university. The student can prepare sustainable design solutions to improve the physical environment of the building. For buildings with LEED certification, apart from the BIM tool, students can learn concepts of sustainability and what the project would be like if BIM had been used. They can also do the following: visit the building to identify any

discrepancies between the model and the actual project, answer questions about points of detail, talk to the owner and/or person responsible for the design and/or responsible for the project and/or construction, gain access to the operating and maintenance activities, and learn how to be able to compare actual performance with projected performance (Wu, Issa, and Giel 2010, Rashed-Ali et al. 2010, Barison and Santos 2010b, Brown, Peña, and Folan, 2009).

The evaluation may include submission of files in native format, tool integration and Clash detection, CAD, IFC e PDF, as well as demonstrations of the model, checking the process used in the modeling and assessing the lessons learned in the course (Korman and Simonian 2010).

### 6.3 Advanced Level

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At the advanced level, BIM is taught in Management Construction and the Interdisciplinary Design Studio (also called the Professional Collaboration Studio). The purpose of the teaching is to develop some of skills of a BIM Manager. As a prerequisite, the students should have knowledge of Building Technology/Building Science, Professional Practice, Construction Materials, Construction Methods and be experienced in the use of the main BIM tools (Barison and Santos 2010b).

The objective is to learn BIM techniques and related processes such as interoperability, concepts and tools for BIM management, BIM implementation, cases, team process and team dynamics (Barison and Santos 2010b, McCuen and Fithian 2010).

A single project during the course is sufficient. The students construct a BIM model, working in a team, but with students from other programs. The teacher does not allocate the roles in a traditional way but instead, the teams are chosen by the students themselves through a process of self-selection based on individual preferences and skills, but with the assistance of the teacher (Hyatt 2011, Barison and Santos 2010b, McCuen and Fithian 2010, Dederichs, Kalshoj, and Hertz 2011, Starzyk and McDonald 2010).

The project that has to be modeled should be an existing building that has a slightly more complex structure, between 5000 and 15000 square meters in size, preferably still under construction. It should have easy access for

visitors, with information (plans and details) available, and if possible, chosen by the students. Before carrying out this undertaking, it is necessary to contact construction companies and obtain their assistance in acquiring permission to use the projects and also carrying out the monitoring. They can provide unmodified updated construction documents of ongoing projects for the use of the students. The owner of the building plays the role of a client, and together with the designers, provides feedback and takes part in the evaluations (Barison and Santos 2010b, Salazar, Vadney and Eccleston 2010, Holland et al. 2010).

However, there is one drawback in this approach which is that the faculty has less control over the projects and the students' experiences vary depending on the degree of cooperation of the company representative. Another disadvantage is the variable size of the projects, since this requires more work from the head teacher. In view of this, when the institutions invite industrial clients to sponsor capstone projects, they must elaborate on how the sponsorship should operate, the type of projects provided and the benefit to the students of following this process (Arnold 2010).

The students from each program create a model that is relevant to their respective subject-areas. At this stage, the main issue is that of communication because of the differences in the ontologies of the different subjects (Barison and Santos 2010b). The students propose a workflow for the project and update it along the way as needed

(Holland et al. 2010). The final presentation should include an examining panel consisting of the faculty, real project consulting and, if possible, the ownership team along with the contractor, who will carry out a comparative review of the real project contractor (with regard to lines items costs and schedules) and the estimates and schedules of the teams of students (Holland et al. 2010).

The evaluation may be based on the following: how the project has been conducted, in the visual and verbal presentations of BIM, readings, BIM case studies, participation in the classroom, reports about technical visits, integration of team members and 'lessons learned' (Barison and Santos 2010b, Holland et al. 2010). The students may also be graded on the basis of how far they have addressed and integrated pre-construction objectives with the final proposal, such as Work Breakdown Structure (WBS), costing, procurement planning, scheduling, Critical Path Method (CPM) and safety hazard mitigation planning (Taiebat, Ku, and McCoy 2010).

The assessment of the BIM models can be undertaken by taking account of both the degree to which they are able to solve architectural/engineering problems and the level of information content in the BIM/IFC model. The BIM models constructed by the students may be evaluated both in terms of their capacity to solve architectural/engineering problems, regarding the information content level of the BIM/IFC models and their accuracy and organization (Barison and Santos 2010b).



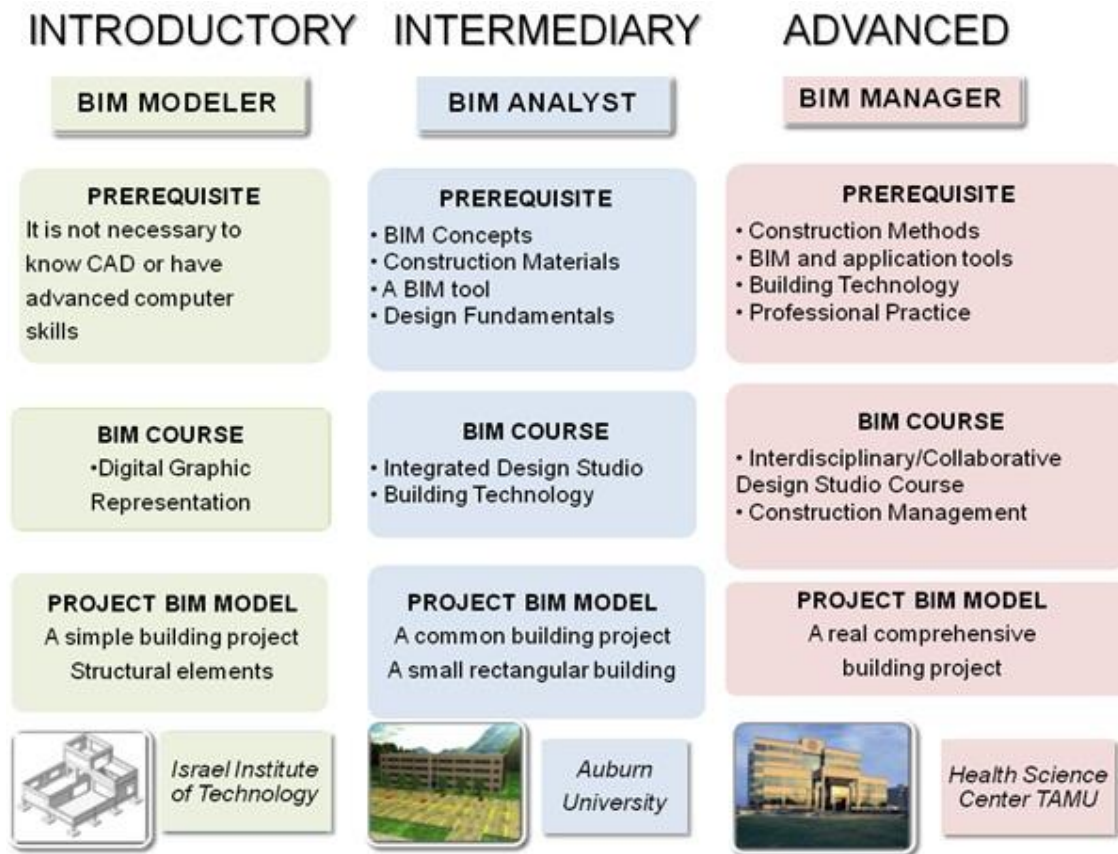


Figure 4 – Levels of BIM proficiency. *Source: Barison and Santos (2010b)*

## 7. CONCLUSIONS

The universities have an important role to play in this transition to the next generation of professionals who understand BIM as a process that supports collaborative work (Lockley 2011).

The first stage in implementing BIM as a part of the curriculum, is to find out what levels of BIM proficiency a student must obtain, in other words, to identify the BIM skills and determine how they should be developed and how much time devoted to them in the curriculum. Barison and Santos (2011) provide a list of skills of a BIM Manager. However, more research into BIM specialist skills is required.

The BIM teaching methodology should be applied to the goals of each level. Laboratory classes and lectures on BIM tools, concepts and industrial issues are recommended in each of the three levels. The lectures must be taught both by the faculty and BIM specialists. It is also important to review case studies, and visit companies and construction sites, since these activities are essential for

the student to understand the sequencing of a project (Barison and Santos 2010b, Hyatt 2011).

Problem Based Learning (PBL) and/or Project Based Learning (PBL) are both suitable for carrying out BIM projects with teams of students where the teacher plays a new role: the Project BIM Manager (Hjelseth 2008, Heintz 2010).

The team responsible for the Integrated Design Studio or Interdisciplinary Design Studio must have a supervisor, an assistant professor, a teacher from each subject-area to give assistance to students and industrial sponsors to act as consultants. The logistical challenges can be partially solved by holding one-hour meetings with all the Design Studios together in the same space. The studio professor does not need to know how to use the BIM tool since the IT professors can give him support and vice versa. Moreover, experienced professors from other universities can be invited to teach virtual courses at the same time and thus help the professors who are at a beginner's stage

(Holland et al. 2010, Brown, Peña, and Folan, 2009, Rashed-Ali et al. 2010, Heintz 2010).

The development of the BIM model should be supported by tutors and completed with self-directed learning. Initially, the students can work with a more experienced colleague to acquire the necessary knowledge and later, be introduced to integrated practices, first with students in the same program and after that, with students from other programs. If the schools do not have other programs to simulate the integrated practice, they should use collaborative distance learning practices. However, before working with students from other programs or universities, the students should be taught about the roles of the members and their professions and also have previous experience of collaboration with BIM (Barison and Santos 2010b).

The teaching resources should support the Industry Foundation Classes (IFC) and include BIM tools appropriate for each subject. They should include games and virtual environment teleconferencing and chat, such as laboratories, studios, public web log, wikis for processing, access, presentation, evaluation, discussions and project presentations. Digital texts with components of self-evaluation are also recommended, together with audio-visual resources including recordings of lectures and workshops, books, reports, papers, webinars and BIM teaching modules containing interactive exercises and produced with the participation of industrial

professionals (Barison and Santos 2010b, Heintz 2010, Wu, Issa, and Giel 2010; Clevenger et al. 2010, Hyatt 2011).

Since the concept of interoperability is a major obstacle to BIM implementation by industry, the teacher should strive to support open standards (Barison and Santos 2010b). To solve the problem of sharing a central file, the use of a single server is recommended (Heintz 2010) and sharing BIM through cloud computing (Puddicombe, Lutz, and Stephenson 2010).

The academic world and industry should form a partnership for knowledge transfer. The students and faculty can both benefit from gaining experience, identifying key research issues and producing significant teaching materials. The companies can benefit by being able to solve design problems in an innovative way (Coates, Arayci, and Koskela 2010, Pollock 2010).

Instead of trying to force through changes in the curriculum, the academic world should first join together with industry to promote BIM or collaborative thinking and setting up a research, teaching and consultancy team (Lockley 2011). On the other hand, industry must be willing to provide funding for the academic world, devote time to visiting the classroom. They must be prepared to discuss with current trends and scenarios with teachers and students, share generic models and provide current materials for students to enable them to practice the knowledge they have learned (Pavelko and Chasey 2010).

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### **Acknowledgement**

The authors would like to express their thanks to CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for supporting this research.

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