REVIEW AND ANALYSIS OF CURRENT STRATEGIES FOR PLANNING A BIM CURRICULUM

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ABSTRACT

The process of introducing BIM in schools has revealed that it is more complex than just adding a new course to the curriculum, as BIM has the potential to be an intrinsic part of the whole architecture/civil engineering program. Principles of BIM can be taught in the first two years by integrating a *BIM course* with a Digital Graphic Representation Course. In the following years, some related BIM concepts, like teamwork and complexity, can be taught in Design Studio and Building Technology courses. In the final year, BIM practices can be carried out with current construction projects in collaboration with companies by means of BIM content combined with Management. The propose of this study is to review and analyze current strategies for planning a BIM curriculum. The Content Analysis process was used as methodology of research to examine a set of papers and syllabuses that document experiences in schools, mainly those that today are identified as leaders in BIM education. This analysis used as criteria some issues that must be considered when planning a course: prerequisites, goals and objectives, contents, teaching methodologies, evaluation, activities, and teaching resources, among others. Through this study it was possible to identify categories of *BIM courses* based on students activities and to present a basic organization for a BIM-enabled curriculum along with guidelines.

Keywords: *BIM course*, education, curriculum, architecture, civil engineering

1 INTRODUCTION

A large number of schools are using BIM for teaching architecture and civil engineering. Most of them have only introduced BIM in one subject and a few are trying interdisciplinary or distance collaboration. The predominant approach is to introduce BIM in Design Studio courses. However, there have been cases where Design Studios are integrated with other courses. Another approach is to teach tools and BIM concepts in a specific course, which may be integrated with the curriculum, run in isolation or integrated with another course, which is generally Design Studio (Barison and Santos 2010a). This study provides a brief overview of how some *BIM courses* have been planned, introduced, developed and evaluated. The purpose is to understand and to reconstruct this theme in order to discuss how BIM should be taught.

2 METHODOLOGY OF THIS RESEARCH

This study used the Content Analysis process (Krippendorf 2004) to examine a set of papers and syllabuses that document experiences in schools, mainly those that today are identified as leaders in BIM education (Barison and Santos 2010a), which are listed in Table 1. The analysis was initially organized through a process of disintegration of the texts in analysis units. These units were defined by the criteria that must be considered when planning a course: prerequisites, goals and objectives, contents, teaching methodologies and evaluation. During the analysis, other three criteria were added: activities, BIM models and teaching resources. Along of a reflective process about the investigated phenomenon, three emerging categories of *BIM courses* were established: introductory, intermediary and advanced. This categorization is based on students activities and was used to classify courses in Table 1. It will be further detailed in the discussion section.

Table 1: Universities, programs and *BIM courses* included in the review.

	UNIVERSITY	AUTHOR(S)	PROGRAM	*BIM COURSE*
Introductory	U. of North Carolina	Nelson	Architecture	Building Information Modeling
	Montana State University	Berwald	Architecture	Digital Graphics and Design
	U. of Wisconsin-Milwaukee	U. of Wisconsin-Milwakee	Architecture	Computers in Architecture (Arch 382)
	Israel Institute of Technology	Sacks and Barak	Civil Engineering	Communicating Engineering Information
	Auburn University	Taylor, Liu & Hein	Construction Management (CM)	Constr. Info. Tech. , Digital Constr. Graphics
	California State University	Kymmell	Construction Management	Building Information Modeling I, II
Intermediary	Texas Tech University	Rex and Park	Architecture	Digital Media II
	USC	Becerik-Gerber	Engineering and CM	Building Information Management
	University of Utah	Scheer	Architecture	Building Information Modeling, Design Studio
	Queensland U. of Tech.	Nielsen et al.	Architecture	BIM Unit (Architectural Tech. and Science VI)
	NJ Institute of Technology	NJ School of Architecture	Architecture	Design Studio
	Texas State University	Mulva and Tisdel	Architectural Engineering	Design Studio I and II
	George Mason University	George Mason University	Civil, Environ., Infrastructure Eng.	Building Information Modeling (CEIE499/690)
	University of Washington	University of Washington	Construction Management	Advanced Project Management Concepts
	California State University	Kymmell	Construction Management	Building Information Modeling III
	Purdue University	Schmelter and Cory	Computer Graphic Technology	Commercial Construction *BIM Course*
	Norwegian U. of Sc. & Tech.	Hjelseth	Structural Engineering	Design of Buildings and Infrastructure
	Cal Poly	Korman and Simonian	CM and Civil Engineering	MEP Coordination Studio-Laboratory
Advanced	Cal Poly	Dong	Architecture, CE and CM	Int. Design Studio and Int. Bldg. Envelopes
	Virginia Tech	Ku	CM, Building Construction, Arch.	Several *BIM courses*
	Texas A&M University	Texas A&M University	Architecture, CM	Integrated Design Studio
	Penn State University	Poerschke at al.	Architecture, Civil Engineering	Integrated Design Studio (ARCH 497A)
	GeorgiaTech	GeorgiaTech	Graduate curses	Building Information Modeling: Case Studies
	California State University	Kymmell	Construction Management	Building Information Modeling IV
	University of North Texas	Arnold	Construction Engineering Tech.	Senior Design Class

3 PLANNING A BIM-ENABLED CURRICULUM

The principles of BIM can be first introduced into a subject and then into other disciplines, either as an essential part of a subject course or in separate courses (Hietanen and Drogemuller 2008). In the first two years, the focus is on the individual skills of modeling and analyzing the model, while in the following years, it is more on teamwork and dealing with complexity through collaboration. In the final year, the students are expected to work on actual construction projects in collaboration with companies, as suggested by Kymmell (2008). Thus, architecture and engineering programs have to be planned to hold a sequence of BIM contents. The first activities are integrated with Digital Graphic Representation (DGR) disciplines, the second with Design Studio and Building Technology and the third with Management courses (Barison and Santos 2010a). The following subsections detail the steps for planning a BIM-enabled curriculum.

3.1 Prerequisites

The introduction of BIM into the curriculum should be calibrated with the courses and prerequisites in a way that corresponds to the intellectual maturity of the student (Denzer and Hedges 2008).

Design studio, where BIM is taught, usually requires that students have attended courses in engineering graphics and CAD (Western Illinois University 2007). However, according to Sacks and Barack (2010), the students do not need to know CAD to learn BIM. This knowledge may hamper (Graphisoft 2009) or help (Weber and Hedges 2008) the acquisition of BIM skills.

Before creating a comprehensive building design with BIM, students must understand Design Fundamentals (including orthographic drawing) and to know subjects like Building Technology/Building Science and Professional Practice (Denzer and Hedges 2008). It is also recommended that they learn a programming language and data modeling concepts, as this knowledge will help the students to create their own BIM content (Ibrahim 2007).

3.2 Goals and Objectives

In course planning, it is essential to set out the immediate goals (the purpose of teaching a particular subject-area) and overall objectives (what it is hoped will be achieved). The goals may involve knowledge of the subject-area, improved understanding, development of intellectual skills and changing attitudes. Before planning the syllabus of a *BIM Course*, some programs have conducted a research to find out the extent of the demand for professional skills (Taylor, Liu, and Hein 2007; Schmelter and Cory 2009). Mutai and Guidera (2010) have conducted an online survey to find out the ways construction professionals working in large construction firms are utilizing BIM. The purpose was to use the results to provide recommendations to construction engineering faculty interested in integrating BIM technologies into their courses and curricula.

Several institutions such as *George Mason University*, *University of North Carolina*, *Texas Tech University* and *University of Southern California* have defined their *BIM Course* objectives as follows: understand the history, principles and strategies underlying BIM; understand the functions, capabilities, and limitations of BIM tools; being able to develop, handle, manage and coordinate a BIM model; being able to carry out an interdisciplinary design and design review; understand the linking of virtual information; being able to locate the details and amounts required to undertake the estimates bidding and scheduling with the model; conduct an on-site “constructability” analysis in BIM; develop and use the model as if the student were also the contractor; understand contracts and administrative procedures of design and construction and; show a commitment to an attitude of lifelong-learning through technology (George Mason University 2009; Nelson 2008; Rex and Park 2008; Becerik-Gerber 2009; Taylor, Liu, and Hein 2007; University of Washington 2008).

Besides those goals, the most common objectives for BIM related courses include: to promote the interaction of the students with stakeholders from the real world; developing skills for working in teams (Kymmel 2008, Arnold 2010) locally and/or globally; producing drawings from a model (Ku 2009, Sacks and Barak 2010) and, at the same time, developing verbal, written, graphic and electronic communication skills (Arnold 2010).

Construction management students should learn the basic skills required to help them to understand graphical representations of construction projects, organize a 3D simulation model, create a model and handle all the data involved (Kymmell 2008). The emphasis for those students should be on how to use models for construction analysis and improving construction efficiency, and not the creation of BIM content (Mutai and Guidera 2010).

3.3 Contents

A BIM curriculum should start with BIM technical content and guide the students through a technical and conceptual process of learning (what, why and how). This includes concepts derived from BIM tools, BIM management, case studies, potential problems and the implementation of BIM (Kymmell 2006).

According to Sacks and Barak (2010), if freshmen engineering students have a good grounding in BIM concepts and experience with a BIM tool, they will be able use any other tool. These concepts include representing building components with intelligent digital objects, parametric modeling, an inclusion of both 3D geometry and alpha-numerical information for describing objects, the ability to impose constraints and rules that define the behavior of the objects in engineering terms and the maintenance of consistency and integrity across the full representation of a building as a whole.

In the case of the construction management students, Kymmell (2008) recommends the following: teaching how to create and customize objects, detail, models from drawings, drawings from models, project data, presentations, modeling principles, adding information, file structure, model planning strategies, hyperlinked information, model viewing and analysis, reporting and information management.

3.4 Teaching Methodologies

Practical examples and case studies helps making subjects more comprehensible and easier to memorize (Hietanen and Drogemuller 2008). After watching lectures from experts, readings and obtaining a full understanding of what BIM is, the students may work in groups to prepare case studies that focus on the use of BIM (Becerik-Gerber 2009).

The *BIM course* offered by *University of North Carolina* comprise two sessions: one for lectures, readings discussion and BIM workshops and another for students to construct a simple BIM model of a small building (Nelson, 2008). The students involved in the *BIM course* offered by *University of Utah* however, before learning a BIM tool, have to choose a building component and list as much information about it as they can considering its whole lifecycle. They must also document their work in a web log (Scheer 2006).

Some design studios that use BIM and focus on Integrated Practice have adopted the following policies: presentation of papers and discussions in the classroom, consultation with professionals, visits to BIM offices and buildings, and integration with BIM workshop or a *BIM Course*, with independent and under supervision sessions. The *University of Wisconsin-Milwakee* and *Texas Tech University* have adopted these practices (Dicker and Snyder 2008, Rex and Park 2008). Lectures and classes on BIM concepts can be supplemented by audio and video files. Together with individual learning about BIM tools, there should be group projects involving the creation of a model for various construction areas. Each group should work out its own BIM/CAD standards, workflow and project management processes. Once the different models have been completed, the students can assemble them in an "integrator" BIM tool which can carry out a collision detection report and resolve collisions (Sah and Cory 2008, Schmelter and Cory 2009).

In a MEP Coordination Studio-Laboratory at *Cal Poly*, following the resolution of all interferences, separate drawings for fabrication and installation are then produced for each system. Students responsible for different trades submit requests for information (RFI) to each other regarding problems that require an engineering resolution. Deliverables of the project include BIM models, coordinated utility relocation plan, constructability/discrepancy report, and survey/layout points. The student present their results demonstrating the model, the processes, and how it is incorporated into the deliverables (Korman and Simonian 2010).

The building industry shifts towards adopting Integrated Project Delivery (IPD), which means that the educational system should adopt a more collaborative approach to teaching (Becerik-Gerber and Kensek 2009).

According to Fai Ng (2005), the case studio, studio team, studio group and problem scenario are the main components of a *Constructivist* learning environment. Hieltsing (2008) refers to *Constructivism* as a good theoretical basis for learning and *Problem-Based Learning* (PBL) or *Design Based learning* (DBL) as appropriate theories for the development of BIM models with teams of students. In this environment, the students should form components and/or a model from a real project (preferably one that is under construction) and lay stress on factors such as budgeting, scheduling, energy analysis, adaptation, etc. They make use of drawings provided by the constructor to develop the model and present it to real clients which might be the design offices themselves, the construction companies which help them during the development of the project, faculty and other students. They also visit the job site; talking with managers, designers, and workers. Integrated Design Studios of *Penn State*, *Cal Poly* and *Texas A&M University* have adopted some of these practices (Messner 2008, ARCE Cal Poly 2009, Texas A&M University 2010).

3.5 Activities

According to Kymmell (2008), each BIM exercise should contain elements from three categories of skills: software tools (technical skills), management processes (conceptual skills), and project team roles (psychological and social skills). The degree of difficulty and amount of detail included in the subject should increase in accordance with the level of a *BIM course*.

BIM exercises should focus on the construction of a model through the careful analysis of drawings and specifications of current projects (Kymmell 2008). An alternative is to create a 3D model of a building project designed in another course by other students or an existing building on the campus (BIM Journal 2010; Nielsen, Fleming, and Kumarasuriyar 2009; Schmelter and Cory 2009).

Besides constructing the model, students must also solve exercises that involve reading, building a parametric 3D family, generating views, providing presentation models and discussing techniques for creating views (Byrne 2009). After this, other activities should be introduced, such as BIM phasing or scheduling, BIM estimates, and clash detection followed by a presentation (Taylor and Sattinene 2007).

Another activity, especially suitable for graduates, is writing research papers that are relevant to current trends in industry (Sah and Cory 2008, Schmelter and Cory 2009).

3.6 BIM Models

The complexity and size of the building, as well as the tools and computers available, will determine the best approach to the modeling. In architectural practice, there are several kinds of computer models which will each require different methods of tackling problems (Graphisoft 2009). Moreover, there are different types of BIM models: conceptual, design, construction, shop drawing, detailing, as-built, operations and maintenance (Kymmell 2008). The appropriate tool must be used for each model; the modeling must follow particular rules and BIM detailing should follow a series of stages.

BIM Manager (2009) recommends that a good candidate project for a new pilot in BIM should be a small (30,000 to 50,000 square-feet), single storey building, containing all stages (SD, DD, CD); it should be, neither complex or boring, and a building with a single use that is fairly square, modern in style and without excessive ornamentation. This recommendation is applicable to determine the nature of an exercise in a *BIM Course* too.

The architecture and construction students doing an *Introductory BIM Course* at *Auburn University* have used a small rectangular building with little or no complexity as the basis for a simple model. The lecturers asked whether the students recognized the difficulties they had experienced and concluded that they should work on a project of a challenging scope and complexity so that they could have a greater understanding of the implications of developing BIM. In view of this, they decided to use commercial building projects of 20,000 – 30,000 SF as their examples for the BIM class (Taylor, Liu, and Hein 2007). In a *BIM Course* at *Purdue University,* the students worked in groups to form models of existing Purdue buildings; when the model was completed, it was presented to the *Purdue University* Building Faculty to be used as a "*Facility Management Tool*" (Schmelter and Cory 2009). The students at *Queensland University of Technology* developed a BIM of a particular building design based on projects that had been completed in the preceding semester by Senior 5th year students (Nielsen, Fleming, and Kumarasuriyar 2009).

In an Studio BIM based course at Penn State, students worked in teams (architecture, landscape, structural, mechanical, lighting/electrical engineering, and construction management) where each one received a basic BIM model of an actual elementary school. The teams developed the architecture of given general model or develop a new building architecture (Poerschke 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 (Hieltsing 2008), as well as accuracy, which, according to Kymmel (2008), is of the utmost importance in the BIM, and the application of the information to make a successful analysis of the project. The students should also be encouraged to participate in a competition which involves carrying out a project in a group and using BIM. Several institutions, such as *Texas State University* have adopted this approach and found it has helped to stimulate the students (Mulva and Tisdel 2007).

3.7 Teaching resources

The necessary resources for *BIM courses* include computer tools for architecture, engineering, construction, geometric modeling and digital data. These tools should be employed for visualization and simulation, BIM environments, 4D planning, automated estimating packages, automated bill of quantities, code checking and clash detection (Smit, Wall, and Betts 2005). IFC compliant software should be used. A classification and analysis of each category of BIM tool can be found at the *GeorgiaTech* website (GeorgiaTech 2010). However, as each professional discipline has its own set of tools and BIM principles, students must first learn to use the BIM tools that are relevant to their needs. Hence, the task of the lecturer is to identify the BIM principles that are relevant to their discipline and afterwards, choose the appropriate software for the students to use. They can also employ the tools that are available in educational versions (Hietanen and Drogemuller 2008).

A good computing infrastructure and management is crucial (Messner 2008), but even a simple smart board is an effective tool for engaging several students in a BIM discussion at the same time (Kymmell 2008).

The use of BIM manuals can also be a way of stressing the need for a skillful use of software and information content. Like government authorities of several countries, some universities are setting BIM standards, for example *Penn State, Indiana University* and the *LA Community College District.*

3.8 Evaluation

In an academic course, an evaluation can be carried out both by analyzing the ongoing feedback on students' performance (formative) and by identifying larger patterns and trends in performance (summative) with regard to the students' activities. It is of crucial importance to know if the students who are taking an introductory *BIM course* have acquired skills in building modeling. However, according to Sacks and Barak (2010), it is difficult to test these skills in an exam during which they have to operate the tool, especially when the exams include a large number of students. One way to overcome this problem is to ask students to do exercises (modeling) before the test and then, in the exam itself, answer written questions that are based on the exercises that they have each prepared (Sacks and Barak 2010).

Bloom's Taxonomy has been cited as a useful tool for acquiring an awareness of the level of learning in BIM Education (Hjelseth 2008). This has been used by Hedges and Denzer (2007) as a benchmark to evaluate the students performance in a Design Studio Course. They concluded that BIM allows the students to reach the peak of Bloom's Taxonomy in terms of intellectual behavior (the evaluation level).

In Studio Design courses that introduce BIM, the students are assessed by projects and exams on the technologies presented (Rex and Park 2008). Other approach is at the conclusion of the course to require team presentations to Industry representatives, faculty, and other students where each participant give a grade utilizing ABET's Criterion 3 a-k. These evaluations can be used to determine the teams' grades (Arnold 2010).

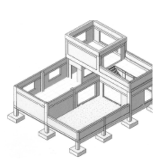
In *BIM courses* the students' performance is generally based on the following: building modeling exercises and the production of a range of outputs from the model (BIM Journal 2010), carrying out projects, visual and verbal presentations of BIM, written exams about the concepts of BIM, reading, analysis of BIM cases, reading tests of texts and exercises, participation in class and reports about visits (George Mason University 2009; Rex and Park 2008, Becerik-Gerber 2009, Nelson 2008,University of Washington 2008, Dicker and Snyder 2008).

A *BIM course* itself can also be evaluated. Hjelseth (2008) set out a classification based on the Program-Process index (P-P index) method that determines if the BIM pedagogy focuses on software or the work process. Additionally, the development of a *BIM course* also can be measured by the "BIM staircase" in terms of its interoperability (Technical, Semantic or Organizational). This tool can also be used to compare a *BIM course* with others.

4 DISCUSSION

The reviewed courses/modules were analyzed and the main inferences emerging from the research were expressed in the framework in Table 2.

Table 2: Framework of categories of *BIM courses*.

Level	**Introductory**	**Intermediary**	**Advanced**
BIM Specialist	BIM Modeler	BIM Analyst	BIM Manager
Prerequisites	Unnecessary to know CAD tools and higher computer skills	BIM Concepts, Construction Materials, a BIM tool and Design Fundamentals	Construction Methods, BIM and application tools Building Technology and Professional Practice
***BIM Course* Categories**	Digital Graphic Representation	Integrated Design Studio Building Technology	Interdisciplinary/Collaborative Design Studio Course Construction Management
Project BIM Model	A simple building project or parts of it  Structural elements of a simple building Israel Institute of Technology	A common building project, Architectural, Structural, MEP designs  Small rectangular building Auburn University	A real comprehensive building project  Complex building Health Science Center -TAMU

Introductory *BIM courses* may be integrated with DGR and each program should provide knowledge and skills of BIM Modelers, on their respective discipline, and of a BIM Facilitator (Barison and Santos 2010b). The students should learn the tools that are most used in their discipline and then develop a BIM model of a small building (or parts of it) to produce a basic quantity take-off from it and to learn how to manipulate the model. The objectives are to obtain a good grounding in BIM concepts and experience with a BIM tool. The evaluation of students' performance can be conducted through both individual exercises (simple models) and written exams about BIM concepts. Bloom's Taxonomy can help the instructor to prepare and evaluate BIM exercises.

An intermediary *BIM course* may be integrated with Design Studio and Building Technology courses. As pre-requisites, the students must know about Design Fundamentals, Engineering Graphics, BIM concepts and have experience in one BIM tool. The students will learn about other BIM tools and advanced techniques in 3D modeling. They will perform analysis of its respective discipline as well as visualization, e.g. LEED Rating/Energy and Daylight/Lighting for architects and structural analysis for engineering students.

The development of the BIM model should be carried out in groups with each person playing a specific role. However, as the division of roles in the team discourages individual learning, the solution is to promote the rotation of roles and to plan both individual learning and group projects. Each group should compile BIM, detect and resolve clashes, perform quantity takeoff, scheduling and cost analysis. The assessment of the student's performance should be based on the building modeling and take into account the degree of communication, accuracy and organization of information. Clash detection could be learned at a junior college or vendor class, however, not all middle school students learn CAD. An intermediary *BIM course* should develop some of the skills a BIM Analyst possess while strengthening the skills of a BIM Modeler.

An advanced *BIM course* could be integrated with a Construction Management course or with an Interdisciplinary-Collaborative Design Studio course. Before taking this course, the students must know about Building Technology/Building Science, Professional Practice, Construction Materials, Construction Methods and be experienced in the use of the main BIM tools. Before using BIM for design, architecture students must master the techniques of construction, design thinking in 3D and dominate BIM tools, so they do not restrict their ability to create and to use the capabilities of parametric software. An advanced course is designed to develop the skills of a BIM Manager and to introduce the students to techniques of BIM and related processes such as interoperability. Students must also learn about BIM managing concepts, case studies, potential problems, how to implement BIM and be trained on the use of processes and tools required for the management of BIM. However, the most essential area of learning concerns being able to understand how a project team functions. In view of this, ideally they should build a BIM model in groups but with students from other programs.

The tackled project should be challenging in scope, complex, real, preferable under construction and chosen by students. For this it is necessary to contact construction companies to gain their assistance in acquiring projects. They can provide unmodified actual construction documents of ongoing projects for student use. However, a disadvantage of this approach is that the faculty has less control over the projects and students' experiences varies with the cooperation of the company representative. Another disadvantage is the variable size of the projects, requiring more work from the lead professor. Therefore, when institutions engage industrial clients to sponsor capstone projects they must elaborate on how sponsors are engaged, the type of projects provided and the benefit to the students in this process (Arnold, 2010).

The students from each program must create a model that is relevant to their respective disciplines, and set out their BIM/CAD standards and workflow. In this stage, the main issue is the communication due to differences in the ontologies of different disciplines.

The assessment of the students' performance should be based on the way the project is carried out, visual and verbal presentations of BIM, reading assignments, analysis of BIM cases, participation in class, and visit reports.

The teaching methodology should be applicable to the goals of each level of *BIM course*. It is recommended that this should involve lab work and lectures on BIM tools, concepts and industrial topics, lectures given by BIM specialists, review of case studies and visits to firms and construction sites. The BIM model should be formed with the assistance of tutors and supplemented with self-directed learning. Initially, the students should work with a more experienced colleague so that they can acquire the necessary knowledge; afterwards, they should be introduced to integrated practices, first with students from the same course and later with students from other programs. If the schools do not have other programs to simulate the integrated practice, they should make use of the collaborative practices of distance learning. Students however, according Hedges et al. (2009), before working in teams with students of other program or university, should be instructed about the roles of each member and the profession. Additionally, the students should have prior collaborative experience in BIM.

Teaching resources should reflect IFC compliance with BIM tools for each discipline, and include games, BIM to standardize the BIM models created by the students and virtual environments (laboratories, public web log and wikis) for processing, submissions, assessment, discussions and presentations. The concept of interoperability is one of the greatest obstacle in the implementation of the integrated BIM industry and therefore the teachers of BIM should be aware of this and strive to support open standards (Camps 2008). The BIM Models constructed by the students should be evaluated in terms of their ability to overcome architectural/engineering problems and the level of information content in the BIM/IFC model, accuracy and organization. Finally, the *BIM Course* should be evaluated either by classification (P-P index) or development (BIM staircase).

5 CONCLUSIONS

An attempt has been made in this brief review to explore some of the trends in BIM Education. Analysing these trends, it was possible to sketch an outline of some of the "best-practices" and guidelines for introducing BIM content in architecture, civil engineering and construction management programs.

A basic organization for a BIM-enabled curriculum was presented, including introductory, intermediary and advanced courses and their basic contents for the most common majors in AEC. Collaboration is one element that cannot be missing on students activities as well as practice in diverse BIM tools.

For planning a BIM curriculum, it is highly recommended to identify what are the responsibilities, functions and competencies of the BIM specialists the course intends to supply and to plan the syllabus according to them. This can be made through literature review (Barison and Santos, 2010b) and developing research with local companies to list what are the skills, knowledge and attitudes demanded from BIM professionals. After that, it is also advisable to find out the obstacles for implementing BIM at the university through local survey with faculty and based on literature review, as they are usually hard to change.

As the time BIM tools and processes will become mainstream in the AEC market approaches, the demand for skilled BIM professionals increases steadily and then dramatically. It is the duty of universities to properly adapt their curricula to turn their graduates into professionals able to perform as those required specialists. Notwithstanding, today this is still a little known and complex task. The guidelines presented in this work may help in that endeavour.

REFERENCES

ARCE Cal Poly (2009) "Crossing Paths: Students benefit from a mix of Architectural Engineering, construction Management and Architecture curriculum", [Online], Available:http://arce.calpoly.edu/alumni/documents/newsletter-09.pdf. Accessed: [May 2010].

Arnold. A. (2010) "Construction Industry Involvement in the Capstone Senior Design Class", *Conference Proceedings of 2010,* American Society for Engineering Education Annual Conference and Exposition.

Barison, M. B. and Santos, E.T. (2010a) "BIM teaching strategies: an overview of current approaches", *Computing in Civil and Building Engineering, Proceedings of the ICCCBE2010*, Nottingham, UK, pp. 577.

Barison, M. B. and Santos, E.T. (2010b) "An overview of BIM specialists", *Computing in Civil and Building Engineering, Proceedings of the ICCCBE2010*, Nottingham, UK, pp. 141.

Becerik-Gerber, B. (2009) "Building Information Management", [Online], Available: http://www.usc.edu/dept/civil_eng/dept/assets/013/59877.pdf. Accessed: [May 2010].

Becerik-Gerber, B. and Kensek, K. (2009) "Building Information Modeling in Architecture, Engineering and Construction: Emerging Research Directions and Trends", *J Prof Iss Eng Ed Pr*, 136(3), 139-147.

Berwald, S. (2008) "From CAD to BIM: The Experience of Architectural Education with Building Information Modeling", *AEI 2008: Building Integration Solutions 2008*, Denver, USA.

BIM Journal (2010) "How Academia has Responded: a Case Study", [Online], Available: http://bimjournal.com/art.asp?art=39&issue=13, Accessed: [May 2010].

BIM Manager (2009) "The REVIT Pilot Project Candidate", [Online], Available: www.bimmanager.com/2009/12/16/the-revit-pilot-project-candidate/, Accessed: [June 2010].

Byrne, P. (2009) "ARCH 498: Special Projects REVIT Workshop", [Online], Available: http://quicksilver.be.washington.edu/courses/Arch498p/ARCH 498 Syllabus.pdf, Accessed: [June 2010].

Camps, H. L. 2008 "BIM: education and the global economy", *JBIM*, Spring, pp.33-37, [Online], Available: www.wbdg.org/pdfs/jbim_spring08.pdf, Accessed: [March 2009].

Denzer, A. S. and Hedges, K. E. (2008) "From CAD to BIM: Educational strategies for the coming paradigm shift", *AEI 2008: Building Integrated Solutions.*

Dicker, J. and Snyder, G. (2008) "IP/BIM comprehensive design studio", [Online], Available: http://www.uwm.edu/SARUP/syllabi/architecture/825-fall2008-bim.pdf, Accessed: [April, 2009].

Fai Ng, F. (2005) "Knowledge Management in Higher Education and Professional Development in the Construction Industry", in Kazi, A. S. *Knowledge Management in the Construction Industry*. Idea Group Publishing.

George Mason University (2009) "Building Information Modeling", [Online], Available: http://mason.gmu.edu/~mcasey4/bim/CEIE499-690BIM_syllabus.pdf, Accessed: [June 2010].

GeorgiaTech (2010) "BIM Tools: entire BIM tools list", [Online], Available: http://bim.arch.gatech.edu/app/bimtools/tools_list.asp?id=521, Accessed: [May 2010].

Graphisoft (2009) "BIM curriculum lecture notes: BIM lecture 2: Computer Modeling", [Online], Available: http://www.graphisoft.com, Accessed: [March 2009].

Hedges, K. E. and Denzer, A. S. (2007) "Visualizing energy: how BIM influences design choices", *Proceedings of the 2007 ASME International Design Engineering Technical Conf.* Las Vegas, Nevada, USA, 4-7 Sept.

Hedges, K. E., Denzer, A. S., Livingston, C. and M. Hoistad (2009) "Making Connections with Design Curricula", *AIA Technology in Practice BIM Awards.* pp. 2-16.

Hietanen, J. and Drogemuller, R. (2008) "Approaches to a university level BIM education", *IABSE Conference*, 2008, Helsinki.

Hjelseth, E. (2008) "A Mixed approach for SMART learning of building SMART", In: *eWork and eBusiness in Architecture, Engineering and Construction*. ECCPM 2008. Org. Alain Zarli and Raimar Scherer. London.

Ibrahim, M. M. (2007) "Teaching BIM, what is missing? The challenge of teaching BIM based CAD in today's architectural curricula" In: *The 3rd International Conference of the Arab Society for Computer Aided Architectural Design ASCAAD 2007: Embodying Virtual Architecture*, 26 - 28 November, 2007 Alexandria, Egypt.

Krippendorf, K. (2004). Content analysis: An introduction to its methodology, 2nd ed., Thousand Oaks, CA: Sage.

Korman, T. and Simonian L. (2010) "Using Building Information Modeling to teach Mechanical, Electrical, and Plumbing Coordination". [Online], Available: http://soa.asee.org/paper/conference/paper-view.cfm?id=22568 Accessed: [Sep. 2010].

Kymmell, W. (2006) "Outline for a BIM Curriculum", Government/Industry Forum, October 31, 2006.

Kymmell, W (2008) "Building information modeling: planning and managing construction projects with 4D CAD and simulations", New York: McGraw Hill.

Messner, J. I. (2008) "The story of BIM adoption at Penn State", *Building SMART alliance™ National Conference:* Engineering, & Construction.

Mulva, S. and Tisdel, R. (2007), "Building Information Modeling: A New Frontier for Construction Engineering Education", *Conference Proceedings of 2007,* ASEE Annual Conference and Exposition.

Mutai, A. and Guidera, S. (2010). "Building Information Modeling in Construction: Current Practices and their Implications for Construction Engineering Education", *Conference Proceedings of 2010*, ASEE Annual Conf.

Nelson, J. (2008), "Building Information Modeling: what is it...why do I care…and how do I do it?", [Online], Available: http://www.soa.uncc.edu/index2.php?option=com_docman&task=doc_view&gid=76&Itemid=234 Accessed: [October 2009].

New Jersey School of Architecture (2007) "Heisman hopeful downtown athletic club redevelopment, Manhattan", [Online], Available: https://kepler.njit.edu/arch463464563564-000f07/Course%20Documents/Arch%20463%20%20Breeden%20Heisman.pdf. Accessed: [December 2009].

Nielsen, D., Fleming, M. and Kumarasuriyar, A. (2009), "An innovative learning model for teaching architectural technology using Building Information Modeling: a Queensland university of technology perspective", *EDU-*

Learn09 International Conference on Educational and New Learning Technologies 2009, Barcelona, Spain. [Online], Available: http://eprints.qut.edu.au/26450/1/26450.pdf. Accessed: [October 2009].

Poerschke, U., Holland, R.J., Messner, J.I. and Pihlak, M. (2010) "BIM collaboration across six disciplines", *Computing in Civil and Building Engineering, Proceedings of the ICCCBE2010*, Nottingham, UK, pp. 575.

Rex, B. and Park, K (2008) "Digital Media 2: Building Modeling", [Online], Available: http://www.arch.ttu.edu/courses/2008/fall/3341/090/3341_090%20Syllabus.pdf. Accessed: [June 2010].

Sacks, R. and Barak, R.. (2010) "Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education", *Journal of Professional Issues in Engineering Education and Practice*. v 136, n 1, January, pp. 30-38.

Sah, V. and Cory, C. (2008) "Building Information Modeling: An Academic Perspective", *The 2008 IAJC-IJME International Conference.* 2008. Nashville. [Online], Available: http://www.ijme.us/cd_08/PDF/196%20IT%20301.pdf. Accessed: [June 2010].

Scheer, D. R. (2006) "From an Educational Perspective: BIM in the Architectural Curriculum", Government/Industry Forum, October 31, 2006, Washington: National Academies' Federal Facilities Council.

Schmelter, S. and Cory, C. (2009) "Commercial Construction *BIM course* created for academia" *JBIM*, Washington, p. 40-41. [Online], Available: http://www.wbdg.org/pdfs/jbim_spring09.pdf. Accessed: [June 2009].

Smit, D., Wall, J. and Betts, M. (2005) "ICT & Curriculum Design to bridge the gap between industry and academy", [Online], Available: http://eprints.qut.edu.au/27345/1/27345.pdf. Accessed: [June 2010].

Taylor, J. M. and Sattinene, A. (2007) "Special topics: building information modeling", [Online], Available: http://www.cadc.auburn.edu/BSCI/FacStaff/files/Syllabii/Sattineni/BSCI%205970-6970/BIM.pdf. Accessed: [March 2009].

Taylor, J. M, Liu, J. and Hein, M.F. (2007) "Integration of building information modeling into an ACCE accredit construction management curriculum", [Online], Available: https://fp.auburn.edu/heinmic/Pubs/ASC 2008-Integration.pdf . Accessed: [March 2009].

Texas A&M University (2010) "Students showcase building information modeling skills to construction executives", *Archone*, [Online], Available: http://archone.tamu.edu/college/news/newsletters/spring2010/stories/BIMpres.html. Accessed: [May 2010].

University of Washington (2008) "Advanced project management concepts", [Online], Available: http://courses.washington.edu/cm515bim/Syllabus.pdf. Accessed: [June 2010].

University of Wisconsin-Milwaukee (2009) "Computers in architecture", [Online], Available: www.uwm.edu/SARUP/syllabi/architecture/382-spring2009.pdf. Accessed: [March 2009].

Weber, D. and Hedges K.E. (2008) "From CAD to BIM: The engineering student perspectives", *AEI 2008: Building integrated solutions*. Reston, VA: ASCE.

Western Illinois University (2007) "Commercial and Residential Architectural Design". [Online], Available: http://www.wiu.edu/engrtech/syllabi/fall07/302Kim%20-%20FL07.pdf. Accessed: [June 2010].