A Framework for the Design and Delivery of BIM Curriculum

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Abstract
Building information modeling (BIM) is changing how facility owners approach the design, construction, and operations and maintenance of buildings. Changes in each of these areas have created a need by industry for professionals who are adept at working in the BIM environment. Educators at institutions of higher education have responded and are now introducing BIM into the curriculum for design and construction. However, BIM has frequently emerged in a curriculum through a technology course in which it was a software application to replace traditional CAD software. This ad hoc approach often focuses more on training for skills development and overlooks education for 'learning' objectives. Changing curriculum to include BIM can be a challenge on many levels and is complicated by the fact that BIM is both a tool and a methodology. As a tool BIM is a software solution that extends far beyond traditional graphic software to include detailed facility information. BIM, the tool, supports collaboration as a single repository for information about a project. As a methodology BIM involves collaboration between stakeholders across all phases of a project lifecycle. BIM presents a new approach to doing business in a mature industry, which in turn has made evident the need to revise traditional business processes. The purpose of this paper is to establish a framework for the design and delivery of curriculum that aligns with the concepts of BIM as a tool and methodology. To support the framework for curriculum design, this paper proposes a set of fundamental skills and knowledge necessary to participate in the BIM environment. The set of skills and knowledge presented transcend traditional lines between disciplines of the built environment.

Key Words: *BIM instruction, BIM curriculum, BIM education*

1. INTRODUCTION

There is no doubt that Building Information Modeling (BIM) is changing the way facilities are designed and constructed. As industry evolves from traditional processes, higher education must also evolve it is to meet the needs of students and prepare them for careers in the Architecture/Engineering/Construction (AEC) industry. Rather than a controlled gradual evolution, BIM entered the arena of higher education with a bang. As a result BIM curriculum across university programs vary from the basic software skills to advanced integrated team experiences.

The literature on BIM curriculum is limited and while there is still much research to be done about the state of BIM in education, the studies completed to date have found a common element. The common element is the fact that BIM curriculum is inadequate and is often inconsistent with the needs of industry. (Sabongi, F.J. (2008), Taiebat & Ku, 2010). This finding is important and raises questions about what students should be learning from BIM

course work and how it should be designed to ensure it is adequate and more consistent with industry experiences. Additional findings may provide some insight and guide educators in their design of BIM curriculum. For example, research has also focused on what construction companies are looking for in graduates with regards to their level of BIM skills and knowledge. Results from this area of research reveal that the majority of companies seek to hire university graduates who possess both a broad conceptual knowledge of BIM in addition to relevant software skills. The ability of employees to perform constructability reviews, visualization of alternatives, cost control analysis, and model based estimating were the four areas that ranked highest in the immediate and near future for the companies' utilization of BIM (Taiebat & Ku, 2010). This study provides valuable insight into industry's needs. Converting this data as a needs analysis provides guidance for educators to define learning goals and the design of course work for BIM curriculum. When designing curriculum it is important to keep in mind that training students on BIM software must be supplemented with education. This is critical because training only teaches people how to do, while education teaches people how to think (Smith, D.K. & Tardif M., 2009). Professionals in the 21st century AEC industry must be able to think and solve complex problems. The education component in BIM should be about how to change and improve traditional business processes to accomplish these tasks.

In addition to the conceptual knowledge and skills' development identified by industry as important to BIM curriculum, the National BIM Standard (NBIMS) (National Institute of Building Sciences, 2007) definition of BIM provide additional guidance in its definition of BIM. NBIMS defines BIM as "…a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of a facility to insert, extract, update or modify information in the BIM process to support and reflect the roles of that stakeholder…" (p. 21). Embedded in this definition is the concept that BIM is both a methodology and a tool.

The first steps in designing curriculum are to identify a need along with an analysis of the learner and context for learning (Morrison, Ross, and Kemp, 2007). The research focused on industry needs and the current state of BIM education mentioned previously in this section provides the foundation for the framework proposed in this paper. NBIMS provides a lens through which educators must look at BIM education – methodology and tool. The goal of the framework proposed in this paper is to prepare students for a career in an industry that utilizes BIM for improvements across the lifecycle of a project. The following sections discuss the theories, strategies, and perspectives utilized in the development of the proposed framework for the design and delivery of BIM curriculum. The framework is applicable to all disciplines of study within the AEC domain.

2. BACKGROUND

The framework presented in this paper is theoretical and is considered prescriptive instead descriptive. Prescriptive theories it propose a way of doing something as opposed to just describing why something is a certain way (descriptive theory). The framework proposed in this paper is proposed as an outline for the design of BIM education. The theories and strategies referenced for the framework are found in the literature from the domains of education and business. References included from the education literature specifically focus on instructional

design and curriculum development. The education literature also provided the basis for learning outcomes around technical knowledge in BIM education (Smith & Ragan, 2005; Morrison, Ross, & Kemp 2007). In particular, Gagne′s (1985) theory of learning outcomes guided much of the development in this area. References included from the business literature focus on teamwork and collaboration, basic requirements for working in BIM (Gladstein, 1984; Hoegl & Gemuenden, 2001, NIBS, 2007).

2.1 Declarative Knowledge

Gagné (1985) classified learning outcomes in five categories: declarative knowledge, intellectual skills, cognitive strategies, attitudes, and psychomotor skills. The first two of the five categories are included in the proposed framework – declarative knowledge and intellectual skills. Declarative knowledge is described as "knowing that something is". Declarative knowledge provides the basis from which students can learn higher-order, more complex objectives. Declarative knowledge requires students know the facts about a topic and be able to recall from memory the facts correctly. Although declarative knowledge is a simple learning objective, it is appropriate for learners new to a discipline from which they can build discipline specific intellectual skills.

2.2 Intellectual Skills

According to Gagné (1985) an individual's intellectual skills' set includes four types: concepts, principles, procedures, and problem solving. In general, intellectual skills are typified by the application of rules to previously unencountered examples within an area of study. Following is a description of each type of intellectual skills. The first type is concepts. Concepts may be concrete or defined, but either way they help learners simplify the world. A students' acquisition of concepts allows for categorizing information into groups. The next type of intellectual skill is principles, which are often referred to as relational rules that can be expressed in the form of "if-then" statements. Relational rules help learners predict, explain, or control circumstances in the environment by describing either natural or volitional responses to those circumstances. The fourth type of intellectual skill is procedures and they prescribe certain steps that should be taken to complete a task. Procedural knowledge is "knowing how" to complete a task. The final type of skill is problem solving and it refers to a learned capability involving selection and application of multiple rules. Intellectual skills are hierarchical and build on each other (Smith & Ragan, 2005).

2.3 Integration Skills

Integration skills are the set of skills often referred to as 'soft skills'. Included in this set are interpersonal, teamwork, and collaboration skills. Teams are social systems that collaborate on a common task and are embedded in a particular context. BIM provides a platform for collaboration and is expected to occur between stakeholders (NIBS, 2007). The definition for collaboration used in the framework comes from the small group/team research in the business management domain (Lovelace, Shapiro, & Weingart 2001; Gladstein 1984; Hoegl & Gemuenden 2001). The literature defines collaboration as "a process of decision making among interdependent parties; it involves joint ownership of decisions and collective responsibility for outcomes" (Liedtka 1996). The fact the team takes ownership of the outcomes as a joint effort is the key to interdependence. For collaboration team members must first have interpersonal skills to relate to other team members and identify with the team (Keyton & Beck, 2008). Teamwork

can be evaluated in a number of ways however for the purposes of this paper it is evaluated in terms of six aspects that impact the quality of a team's performance. The six aspects are communication, coordination, balance of member contributions, mutual support, effort, and cohesion. Each aspect is considered tangible and can be measured to evaluate teamwork based on the quality of interactions within the team (Hoegl & Gemuenden, 2001 study is drawn from the small group/team literature in the business domain

3. Framework Design

Figure 1 displays the framework for the design BIM instruction or curriculum. The framework is applicable for course or curriculum design and includes four primary elements:

- temporal
- situation
- outcomes
- approach

The three levels in the framework establish the temporal elements. Across the top of each box is a label for each level of instruction. A level may be at the course level or program level. Each level represents a hierarchical progression either through coursework or curriculum therefore instruction begins at level 1 and progresses through level 3. The framework design assumes BIM is an integrated component of the curriculum or course. For clarification purposes, integration in this context implies that BIM is woven into the core of the students' education and is not relegated to technology courses outside the discipline context.

Below each level label is the situation in which instruction occurs. Here the term situation refers to the context for learning and is designated as either a discipline specific or multidisciplinary context. Following Gagné's work on learning and the small group/team research, the situation boxes list the outcomes. The outcomes are the result of learning and include: 1) declarative knowledge, 2) intellectual skills, and 3) integration skills. Situating the instruction for skills and knowledge within a single discipline or across disciplines facilitates building core technical competencies. Findings from studies about the characteristics of high performing teams reveal the importance of task-related knowledge for team success. In particular, task-related knowledge at the individual level impacts a team's performance (Ericksen & Dyer, 2004; Hackman, 2002).

Below the situation boxes is a box labeled 'Approach' in which two separate boxes reside. The approach represents the delivery component for the framework. Delivery of instruction for learning methods to work in BIM will look much different than the delivery of instruction for learning the tools. As discussed earlier, companies are looking to hire recent graduates that comprehend BIM as both a methodology and as a tool. As such, BIM course work and curriculum should include instruction on both the methodology and the tools at each level. Following the framework then would increase knowledge and build skills about the method of working in BIM and tools for production in BIM. Consequently the methods and tools must be included at each level and this concept is represented with a direct line from the approach box to each level box.

Prescriptive theories are useful for designing instruction and the proposed framework presented in this paper is representative of this type of theory (Reigeluth, 1999). The next section discusses the limitations and need for further research on this subject.

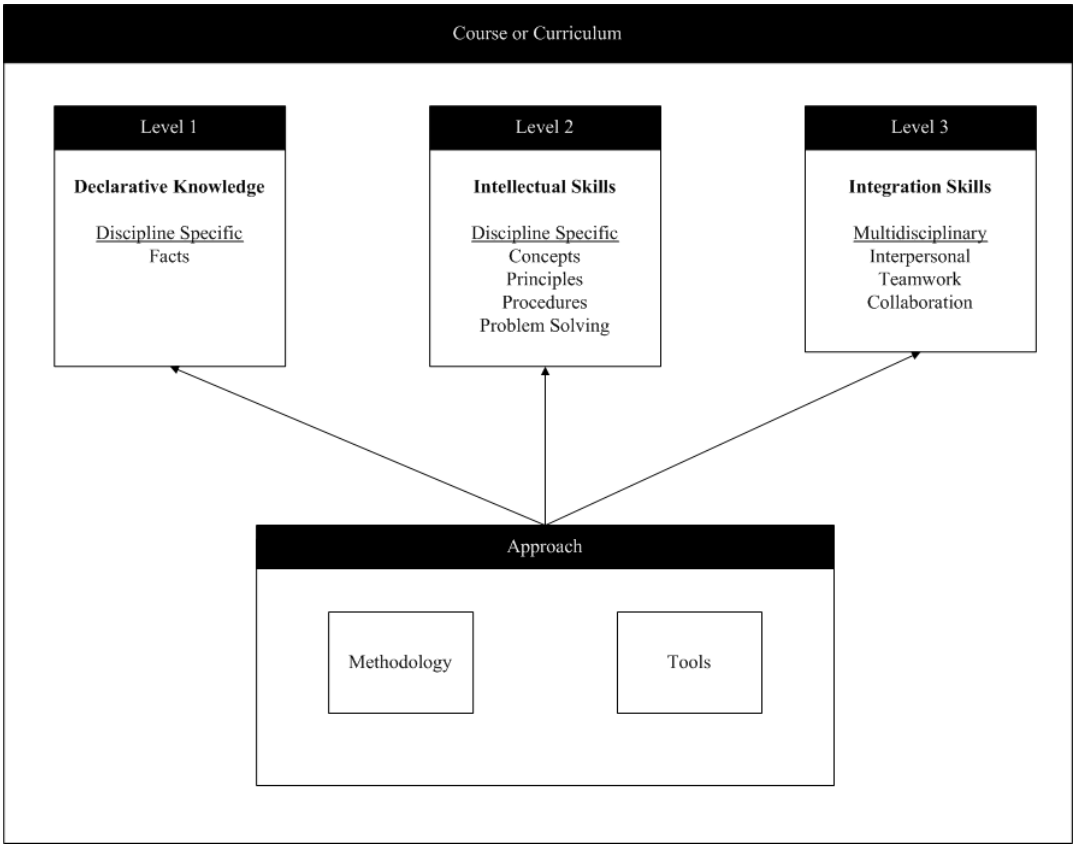

Figure 1 Framework for BIM instruction

4. DISCUSSION AND CONCLUSION

As previously mentioned the framework presented in this paper is in the proposal phase. It has yet to be applied or tested. To do so, future work is needed in the development of metrics to measure the framework's success. First step however is to identify the metrics to assess the learning outcomes for students receiving BIM instruction following this framework. For example, one metric might be to assess the comprehension of methods and tools from results of on-the-job applications. Challenges in furthering the work on this framework include variations in individual epistemology and teaching pedagogy.

While this paper focused on application of the framework to the higher education, it is not limited to higher education. The framework may also be used for organizational training and development as its application extends across disciplines and users within the domain of the built environment. The need for professional architects, engineers, and constructors capable of working in the emerging BIM environment is increasing. It is the job of educators to prepare students to meet this need.

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