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Development of the BIM Body of Knowledge (BOK) Task Definitions and KSAs for Academic Practice

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The BIM BOK project was a catalyst to investigate expectations and perceptions of professional BIM practices and performance outcomes. The project began in 2014 and was developed by the leadership of the Academic Interoperability Coalition (AiC). The AiC operates with the goals of improving communication and discussion concerning how academics around the world have been introducing BIM to their students (McCuen, 2014). The long-term goals of the *BIM BOK* project include the development of comprehensive metrics of BIM competency assessments for both industry/workforce and for academia and assists to delineate the specific tasks to roles, levels of knowledge and project phase. To date, although metrics for assessment for courses and certifications exist, there has not been a unified attempt to collect BIM competencies and requirements in one holistic framework. The AiC *BIM BOK* framework serves the purpose of creating a common curriculum roadmap to bridge the gap between college education outcomes and workplace performance requirements and to advance the understanding of BIM practices. Additionally, for the human resources sector, it will assist to standardize the levels of expectation for hiring practices and establish benchmarks for job task performance for emerging BIM job titles. Academics can then create the baseline performance measurement for BIM education accreditation, professional credentialing and certification. The initial phase of the BIM BOK project is complete and is now entering the next phase which includes a validation process. In an effort to summarize and market the results, the researchers have created a historical account of its development and an update on the future mission and the anticipated benefits for industry.

Key Words: BIM, education, body of knowledge

Introduction

BIM in higher education has evolved through what has been a painstaking process. In the early days, BIM was introduced as technical electives and innovative add-ons to existing college curricula, and there were significant external (e.g., availability of textbooks, industry buy-in, and professional support) and internal barriers (e.g., curriculum redesign, faculty qualification, and time commitment) to its integration in higher education (Sabongi 2009). Because BIM was taking off in the industry between 2007 and 2012, the educational community was incentivized to expand its footprint in higher education with multiple strategies (e.g., vertical and horizontal integration) being adopted to adapt college curricula to prepare students for the rising market demand for BIM talent. BIM education has now become ubiquitous in 2- and 4-year architecture, engineering, construction, and facility management programs, as well as graduate programs (Abdirad & Dossick 2016; Badrinath, Chang, & Hsieh, 2016). However, the delivery of a BIM course is continually evolving due to the need for inclusion of many of the technological capabilities, especially regarding the increasingly collaborative and common data environment in which most capital projects are delivered. The changing nature of digital project delivery and the transforming roles played by the workforce from each industry sector has encouraged educators to take a holistic strategy and interdisciplinary perspective on BIM education. The aim of the efforts for the BIM Body of Knowledge (BIM-BOK) was to first, review all tasks associated with BIM uses to enable a connection to the academic needs and second, to review the same needs as it pertains to the competency gap between workplace performance expectations and actual capacities of recent college graduates that have limited exposure to empirical BIM knowledge (Wu and Issa 2014). This challenge is inherent in the current need for talent acquisition due to the lack of standardization of BIM job titles, descriptions, and qualifications. Most companies do not have established guidelines, benchmarks or instruments to evaluate and validate their candidates' BIM competency declarations (Sacks and Pikas 2013; Wu and Issa 2013, 2014).

BOK Development: Phase I and Phase II

The development of the BOK began in 2015, at a workshop using a Job Task Analysis (JTA) industry-assisted process. It was determined that the development of an overall framework was necessary to capture the multi-dimensional representation of the Knowledge Skills and Abilities (KSAs). The committee reviewed exemplary frameworks established for BIM implementation, application, technical, and research development (Cerovsek 2011; Ding, Zhou, Akinci, 2014; Jung & Joo 2011; Succar 2009) and examined what was believed to be a culmination of all dimensions previously explored. Next, an extensive process (Wu, Mayo, McCuen, Issa, & Smith, 2018b) using the Delphi method aimed to establish a consensus with direct inputs from subject matter experts (SMEs) and focused on two questions:

- What BIM competencies, i.e., knowledge, skills, and abilities (KSAs), do experts consider as important constituents of the proposed BIM BOK?
- How do experts' perception (in terms of consensus) toward specific BIM competencies vary depending on the dimensions (i.e., levels of implementation, roles of users, levels of performance, and types of knowledge) constructed by the BIM BOK framework?

The resulting BIM BOK (Wu, Mayo, McCuen, Issa, & Smith, 2017) was fully explained in two publications (Wu, Mayo, McCuen, Issa, & Smith, 2018a; Wu et al., 2018b). The Delphi work created the knowledge framework (Figure 1) which allowed and facilitated a holistic investigation of the BIM BOK with the broadest stakeholder involvement by addressing the depth and breadth of BIM use cases from a total of *4 (LOI) x 4 (ROU) x 3 (LOP) x 2 (TOK) = 96* different scenarios, each of which provided what was termed a "Task Definition" to assist the respondents. Note: For this discussion regarding the academic perspective, the focus is primarily on the contractor role at the entry level as highlighted in Figure 1.

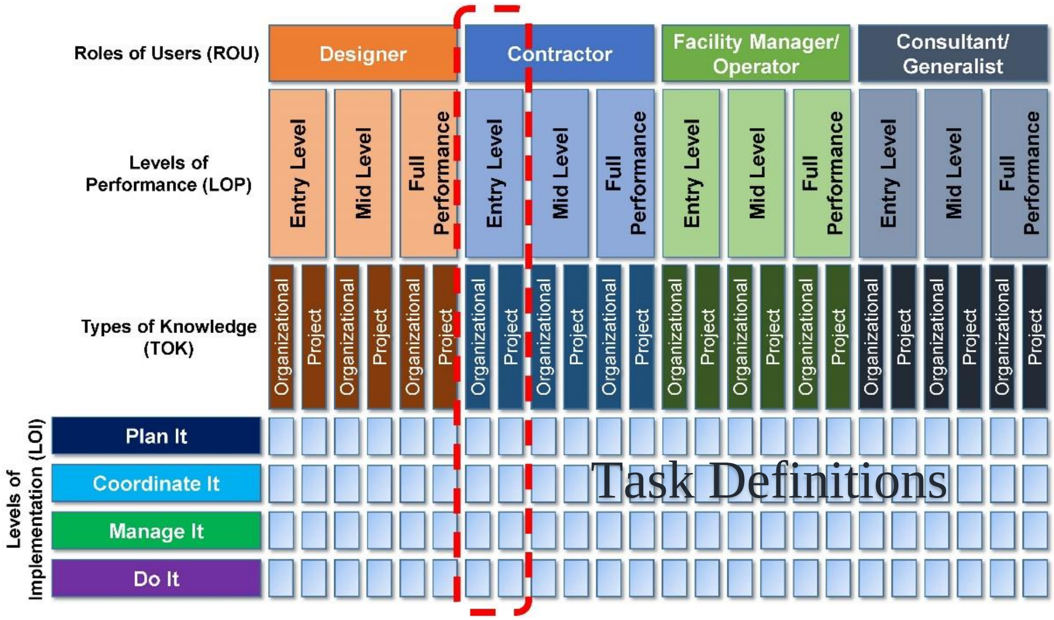

Figure 1. The dimensionality of the BIM BOK classification/categorization

- **Levels of Implementation (LOIs):** The LOIs addressed business decision-making hierarchy on BIM uptake and utilization.
- **Roles of Users (ROUs):** The ROUs acknowledge both commonality and disparity of BIM uses across the AECOO industry sectors in reference to the OmniClass Table 33 – Disciplines (OmiClass, 2006).
- **Levels of Performance (LOPs):** The LOPs indicate the stratification of performance depending on educational background and professional experience, and suggest the progression of performance from *Entry*, *Middle* to *Full Performance* via education and training.
- **Types of Knowledge (TOKs):** The TOKs indicate Knowledge Management (KM) concepts and highlight the project-based nature of the AECOO industry.

The results of the Delphi study revealed that the achieved consensus levels follow a similar trend for the expert and mid-level performances. However, at the entry level, there were high levels of disagreement about those same expectations. A possible interpretation is that the industry holds high expectations on what BIM experts are capable of doing. It is possible that this lack of agreement is due to the discipline specific focus at the entry level where personnel are building technical knowledge through deep-dives into a limited number of tasks. As with any team, individuals bring specific competencies to contribute to a project that are unique to an individual's role. Once the entry level becomes proficient at a task they move to other tasks and so on, until they build to expert level on many tasks. The Delphi effort provided a realistic understanding of the incremental development of BIM KSAs from entry level through full performance. The next step in the BIM BOK (Phase III) is the validation of KSAs by ROU (use roles), which is expected to provide more insight regarding the entry level disagreements.

The assumptions noted previously regarding the reasons for the levels of disagreement showcases the need to further develop curriculum planning and to align competencies to the expectations of industry. Figure 2 shows the phased approach and workflow for the development of the BIM-BOK. Although Figure 2 indicates a single curriculum task, the curriculum development activity will be by role/discipline and not developed for a “one size fits all” approach.

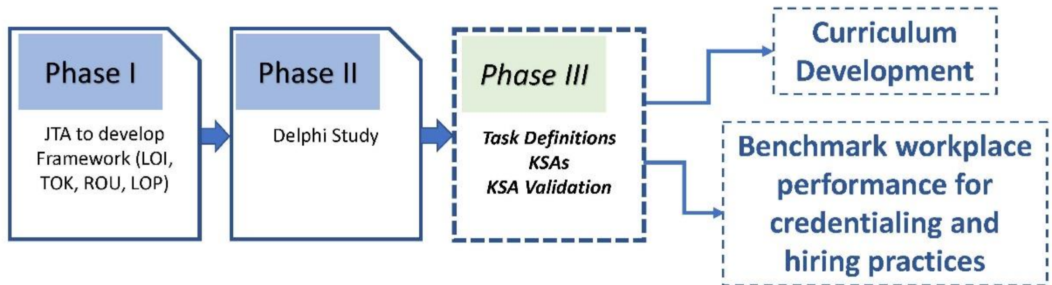

Figure 2. The BIM BOK Workflow Plan

Currently, the research is in Phase III and is using the established task definitions in a validation process for the KSAs to ensure they are correct and align with the original Task Definitions. KSAs are considered special qualifications and personal attributes that one needs to have for a particular job. The KSAs were defined by the researchers as:

- Knowledge refers to the body of information applied directly to the performance of a function (Smith and Ragan, 2005)
- Skills are developed abilities performed in context and transform an individual’s knowledge into use (Webster, 2019). Skills are typified by the application of knowledge to previously unencountered examples (Smith and Ragan, 2005).
- Abilities refer to an individual’s acquired proficiency for the performance of a function and evidenced with activities or products (Webster, 2019).

In conjunction with the validation efforts during Phase III a simultaneous effort is in the early stages of curriculum development and mapping.

Literature Review for Academic Application of the BIM BOK

Industry applications of a BOK to their respective disciplines can be found in literature for various industries. The engineering BOK (National Society of Professional Engineers [NSPE], 2013) was created by dividing their knowledge areas into “capabilities” and then categorized them into basic/foundational, technical, and professional practice (similar to the AiC BOK efforts). In most cases, academia has used their relevant industry BOK to benchmark student outcomes and what is being taught with the needs of an industry. Academia must also rely on a BOK in many cases to ensure that students are graduating with the skills and knowledge required to meet the needs of the workforce. Wadzuk, Dinehart, Glynn, Gross, and Hampton, (2009) recognized the need to meet a changing engineering industry and utilized a methodology consisting of six steps to develop a BOK for any curriculum and its associated learning outcomes. A similar application of an industry BOK was used by DeMers (2009, p.2) whereby he stated that the BOK is a "reflection of the task forces underlying objectives to define the current state of the body of knowledge, reduce the recognized shortage of well-educated personnel, and correct the observed mismatch between the educational process and industry needs" which are identical to the AiC Job Task Analysis objectives. DeMers' (2009) purpose was to explore the ability to translate the BOK for the University Consortium for Geographic Information Science (UCGIS) to the classroom by dividing the BOK into knowledge areas and linking them to learning objectives. Table 1 provides a comparison of these examples to the AiC steps and considerations for the curriculum goals (Figure 2). DeMers' (2009) also used Bloom's Taxonomy to determine the appropriate levels of learning for each of the learning objectives and stated that the connection to the BOK was defined mainly at the comprehensive levels (Bloom's Levels 2 or 3). Using a different methodology, Balreira, Walter, and Fellner (2017) reviewed a course at the introductory level for the computer graphics industry and by using the number of research publications from the top 6 journals of the computer graphics field, compared them to the existing BOK content and course topics. The bolded words represent the comparable next steps for the curriculum development and highlights where the AiC Committee is as compared to the processes undertaken by other BOK authors as identified in Table 1.

Table 1. BOK Curriculum Development Process

AIC		**Wadzuk et al. (2009)**	**DeMers (2009)**
First Meeting 2015	Step 1	Create all-inclusive topic list containing topics traditionally taught	Identify Learning Objectives
Committee Process	Step 2	Development of a mechanism for all stakeholders to provide input	
Delphi Process	Step 3	Synthesis and evaluation of the data collected	**Applied Bloom's Taxonomy to determine levels of learning**
Delphi Process and Industry Review	Step 4	Creation of the prioritized topic list to include in the curriculum	
BOK Task Definitions	Step 5	**Parsing of the BOK into logistical modules**	Divide the BOK into knowledge areas
KSA Validations	Step 6	Development of course format, sequence, and content to best fit the BOK	Link the learning objectives with the BOK knowledge areas

Phase III

Task definitions and KSA development

Upon completion of Phase II, the results were presented at the spring 2017 AiC BIM Symposium in a two-hour brainstorming workshop designed for attendees to start the process of defining tasks and the

KSAs associated with the tasks. Attendees at the workshop were divided into the four roles – designer, contractor, facility manager/operator, consultant - based on their educational preparation and domain expertise. Outcomes from the workshop were used as a baseline for researchers in the initial two steps of Phase III. As shown in Figure 2, the first activity was the development of task definitions. A comprehensive review of national industry standards and recommended practice guides was combined with input from BIM practitioners to define each task. The second activity in Phase III was development of the KSAs by level of performance – entry, middle, full – for each task. Once again, a comprehensive review of the literature was completed, but this time the subjects were learning and instructional design, in the context of BIM practice. Consistent with the BIM BOK, the researchers utilized Bloom's Taxonomy as its framework for writing the KSAs by performance level.

KSA Validation

Methodology

At the time of this paper, task definitions along with the KSAs for each level of performance have been completed and the researchers are early in the process of KSA validation. To validate the KSAs an interpretive framework based on pragmatism was used for the research design. This type of research design was selected because the researchers' focus is on the outcomes of the research and are concerned about its applications and solutions to ensure the KSA are accurate. Two unique characteristics of pragmatist researchers are 1) the need to discover the "what" and "how" of the research subject based on where they want to go with it, and 2) the research always occurs in context (Creswell, 2013). In addition to these ontological beliefs of pragmatism, the methodology selected for the research design to validate the KSAs is a qualitative approach to the data collection and analysis.

Instrument Design

A questionnaire for participant interviews was designed for each role/discipline in the BOK, resulting in the creation of four unique questionnaires. Each questionnaire lists the tasks identified by results from the Delphi panel's early strong agreement, strong agreement, early consensus, or consensus specific to each role. In addition to the task by role/discipline, the level of performance (LOP) – entry, middle, full - was also included in the design, thus resulting in a multi-dimensional questionnaire for interviews. Items were designed first to determine the accuracy of the KSA using a nominal scale of Yes (it is accurate) or No (it is not accurate) based on the task and the LOP for that item. There is also a comment box for participants to contribute recommended additions and/or deletions to the item. Data collected from the item comments will be combined and considered for KSA revisions only if a majority of participants submitted a similar comment. Due to the length and complexity of the questionnaire, the research team chose interviews to collect data.

Participants

A stratified purposeful sampling procedure was used to recruit subject matter experts (SMEs) to participate in interviews for the purpose of illustrating specific ROUs, which will also facilitate comparisons between ROUs in the future (Miles & Huberman, 1994). The researchers determined that a total sample of 20 SMEs, with a distribution of five SMEs for each role, would be used for validation. It is common to work with small samples of participants, nested in their context and studied in-depth, with qualitative research designs such as this validation study (Miles & Huberman, 1994). With the sample size established, the researchers identified participants to recruit based on their experience with BIM implementation for the design, construction, and operations of facilities. Each researcher selected one ROU to recruit participants to the study and will perform interviews in a face-to-face meeting or a virtual meeting space with the SME.

Analysis

The data collected from the Yes or No answers will be counted by item across participant for a simple validation of the KSA. Content analysis by item and role will be used to analyze participants' recommendations for additions and/or deletions to the KSA. Recommendations will be categorized as either *supported by documented practice (SDP)* or *not supported by documented practice (NSDP)*. The first category will contain recommendations grounded in the literature of industry standards and recommended practices. Whereas the second category will contain recommendations without documented practice or are deemed as a company practice. This type categorization will ensure revisions to KSAs are valid and avoid bias from one participant's perspective.

Initial Interviews and Findings

At the time of this paper, participants have been recruited, interviews scheduled, and some interviews are complete. One of the challenges with the process, is the scheduling of interviews given the time commitment required to complete the questionnaire. For example, one researcher scheduled two face-to-face meetings with the contractor SME and reported a total of three hours was needed to complete the questionnaire. While the time required for the interview is excessive, the researcher reported the interview allowed for clarifications and additional discussion with the SME, which would not have occurred if an online survey was used to collect data for the validation. The first interview was conducted with a contractor who allocated 90 minutes for each interview session. During the first interview the researcher was able to validate the accuracy of 30 of the 64 (approximately half) KSAs listed in the questionnaire. In addition to establishing a typical time commitment for future interviews, the researcher stated that the face-to-face process allowed for clarifications and additional discussion. It was also noted that each item in the questionnaire required some back-and-forth communication to document the KSAs. The researcher's notes included a comment by the SME who found *"…value in the BOK."*

Conclusion

The expectation is that the outcomes from Phase III will provide a reliable source for BIM educators and trainers to use in their design and delivery of BIM instruction based on a set of KSAs validated by BIM subject matter experts (SMEs) who practice as professional designers, contractors, facility managers, and consultants for the built environment.

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