BIM in Integrated Learning Environments for Construction: The Students' Perspectives

Mojtaba Taiebat
Virginia Tech
Blacksburg, VA 24060
mojtaba@vt.edu

Kihong Ku
Virginia Tech
Blacksburg, VA 24060
kku@vt.edu

Andrew McCoy
Virginia Tech
Blacksburg, VA 24060
apmccoy@vt.edu

Abstract

As Building Information Modeling, BIM, has been developed in research and academic centers, the construction industry has also acknowledged its value and become interested in implementing it. Literature shows that BIM's learning curve is one of the top barriers of implementation in construction education, though, followed by a lack of knowledge of BIM concepts for construction. While the knowledge-base of BIM is well developed and a variety of supporting software tools) are available, it is the responsibility of educators to prepare undergraduate students with BIM knowledge, reducing barriers to adoption and preparing them to join industry. The Myers Lawson School of Construction (MLSOC) at Virginia Tech incorporates BIM in a number of courses. One course titled the "Integrated Leadership Studio", integrates four curriculum-level offerings: sophomore-level Construction Principles Lab, junior-level Building Systems Technology Lab, senior-level Construction Practice Lab, and graduate-level Integrated Construction Leadership Studio. The course objective is to simulate the pre-construction process of assembling a bid document, from receiving the plans to submitting the final bid, across multiple levels of construction education and in team-based exercises. We used student feedback as the source for evaluating their perception on BIM learning and developed two online survey instruments to study student viewpoints. Findings suggest certain areas that pose challenges and opportunities for students' learning of BIM.

Keywords

BIM, Pedagogy, Construction Program, Curriculum Design

1. INTRODUCTION

The advent of Building Information Modeling (BIM) in the construction industry has created new opportunity for AEC (Architectural, Engineering, and Construction) professionals to enhance their processes. AEC professionals admit that the basic concept of BIM is sound and is the direction in which the AEC industry needs to move (Jeong Han Woo 2007). Almost fifty percent of the AEC industry is using BIM and twenty percent of non-users are planning to implement it within two years (McGrawHill 2009). BIM deliverables on all major projects by the large owners (e.g. GSA, USACE) encourages AEC to accelerate BIM implementation. There are two recent researches on evaluation of BIM, one on architectural firms and one on the construction jobsites. Becerick-Gerber and Rice (2010) conducted a research on perceived benefits of BIM by US AECO firms at the project level. The research studies primarily US architectural firms, which showed up to 25% cost and schedule reduction. The other research was a study of the construction industry and the impact of BIM on it by Surmann and Issa (2009). They used six key performance indicators (KPIs) to measure jobsite performance. The result showed that BIM can contribute to jobsite performance in terms of quality control (rework), on-time completion, cost, safety (lost man-hours), dollars/unit (square feet) performed, and units (square feet) per man hour.

Other research examines the needs of AEC with the curricula of academic programs. Taiebat and Ku (2010) evaluated construction companies' expectations of graduates of construction programs and redesigned the curriculum of the Building Construction program at Virginia Tech in regard to BIM.

The shift towards an integrated design approach demands all stakeholders to rethink the way they work and structure design agreements (AIA 2007). Considering such changes of the construction business environment, it is important to benchmark the current state of BIM effectiveness for academic stakeholders and to further focus on the needs of individual disciplines to successfully participate in this industry transformation (Taiebat and Ku 2010).

2. BACKGROUND

In addition to research centers and R&D departments of the construction companies, academia could play an effective role in directing this industry toward an effective path for implementing BIM (Taiebat and Ku 2010). There are few recent researches on BIM oriented curriculum developing in the academic construction programs. Johnson and Gunderson (2009) surveyed 126 ASC administrators of member schools. The study considers their course materials relative to BIM, lean construction, jobsite field management, sustainability, and specialty contracting. The survey results did not return an acceptable level of BIM adoption or standardized adoption approaches by many of the construction programs. Another study by Becerik-Gerber et al. (forthcoming) returned the same results regarding BIM in 101 U.S. AEC educational programs. The study showed challenges in each discipline in incorporating BIM, sustainability, and other emerging knowledge areas. Both studies provided a high level view of BIM curriculum structures but did not address the BIM knowledge and skill competence required of students. The research performed by Taylor et al. (2008) studied several discrete courses in which BIM were addressed. The courses cover introductory topics to BIM, CAD, and 3D modeling. They believed integration of BIM into academic construction programs should not be like a silver bullet shot into an already packed curriculum, but rather diffuse the topic to all the related courses in it. Taiebat and Ku (2010) conducted a survey of 50 construction companies, followed by a focus group interview of four construction companies that were earlier adopters of BIM. The main findings of their research revealed the attention of the industry on employing those who have a deep conceptual knowledge of BIM rather than hiring those only skilled on using BIM software. Employers mentioned the learning curve as the first barrier for implementing BIM. Lack of understanding of what BIM is, what it can do, and what its capabilities are, were the other important factors which prevent construction companies to further pursue the implementation of BIM. Sacks and Barak (2009) point out that despite the positive impacts of BIM, lack of adequately trained personnel in BIM is a significant constraint hindering the use and adoption of the technology in industry.

Addressing the lack of studies that examine the perspectives of students, this research studies the students' perspectives of BIM learning in an integrated course ("Integraged Leadership Studio")in the MLSoC at Virginia Tech.

3. RESEARCH METHODOLOGY

The goal of this research is to examine students' perceptions of BIM learning in the integrated studio course. The course brought together students of four different levels and accommodates around 160 students. To validate the students' answers the authors cross checked their profiles. This would give the answer to the question of "who said what" in the survey. To understand the students' concerns and challenges of learning and applying BIM in the integrated studio environment, the authors used an online survey instrument to reach every single student. This allowed to collect data in regard to individual's profile, courses

taken, software skills/awareness, and roles and responsibilities in the lab, of the large student sample.

This survey needed two types of information:

1. Personal backgrounds, and roles of the students in the lab
2. The students' experience of the lab

For the second part, the questions were designed to learn more about two aspects:

a. What happened in the course
b. What the students wish in the future for the course

When it comes to evaluating the lab, group opinion has two advantages over individual opinion, especially when the course was about teamwork. 1. It avoids separation/segregation of the ideas, and makes the results more trustworthy, and 2. Before expressing their opinion, the students dialogue ideas in a small group, and this way they modify their expectations and awareness of the lab. This will end up in less biased and more trustful view of the lab.

The authors decided to conduct two separate surveys; one individual survey which asked the students about their real world construction experience, BIM/VDC/ICT software packages usage, and courses taken in construction. The last essay question asked about their personal thoughts of the course. This question was opened ended to allow them express their thoughts. The second survey, which was conducted the week after the individual survey, was supposed to be filled by each group. In this survey (Appendix 2) they were asked about their roles in the lab, and how they used BIM/VDC/ICT software to fulfill their roles in the lab. It asked what other tools they would like to use, and what were the difficulties for using the current tools. At the end, they were asked to freely talk about challenges and future improvements for the course. Since the students of the course worked in teams, the authors asked each team to sit together, discuss the questions, and answer the questions as a team.

4. COURSE STRUCTURE

The Integrated Leadership Studio (ILS) brings together architecture, engineering and building construction sophomores, juniors, seniors and graduate students (about 160 students) to conduct pre-construction management processes for a real project. Students within each grade level form teams of five members, which are then paired into larger teams of one sophomore team, one junior team and one senior/graduate team each. Sophomore teams act as structural sub-contractors, junior teams act as mechanical sub-contractors, and senior/graduate teams act as general contractors. All sub-teams are required to appoint a project manager, coordinate with other level teams at various stages of work, and work with the same teams throughout the semester. Upper level students lead and mentor lower level teams, to deliver a competitive, formal bid.

ILS students collaborate to create the components of a pre-construction plan based on the plans and specifications for an actual building being put out to bid, with a formal bid document for the construction project representing the major deliverable at the end of the semester. Students are graded based on the extent to which they have addressed and integrated numerous pre-construction objectives into the final proposal, such as work breakdown structure (WBS), costing, procurement planning, scheduling and critical path method (CPM), and safety hazard mitigation planning, among others. In addition, teams react to client-driven changes in the project and re-propose their pre-construction solution for these various objectives.

The ILS course integrates "technical" aspects and "leadership" in a studio learning environment, the major theme of its teaching methodology. The course also aims to address employer interest in students' soft skills while simulating self-directed or team-based

research and learning, similar to the professional environment. As a result, students are subjected to few lectures and primarily interact through team-based work projects throughout the semester. The students are expected to already be familiar with the knowledge needed for performing the tasks. Sub-teams also learn from each other at the inter-team level.

The ILS course puts a teaching philosophy into practice: it draws on past academic and private sector experience to promote better learning through personal growth and classroom interaction.

5. STUDENT GROUP PROFILES AND BIM/TOOLS TOOLS

The previous section explained the course structure and learning objectives. To evaluate the application of BIM/ICT in the ILS course, this section explains how the students understood their roles and responsibilities and which BIM/ICT software they used. Question 1 of the group survey offered eight options to survey takers and asked them about their roles and responsibilities in the lab. Figure 1 shows the role/responsibility distribution perceived by the students.

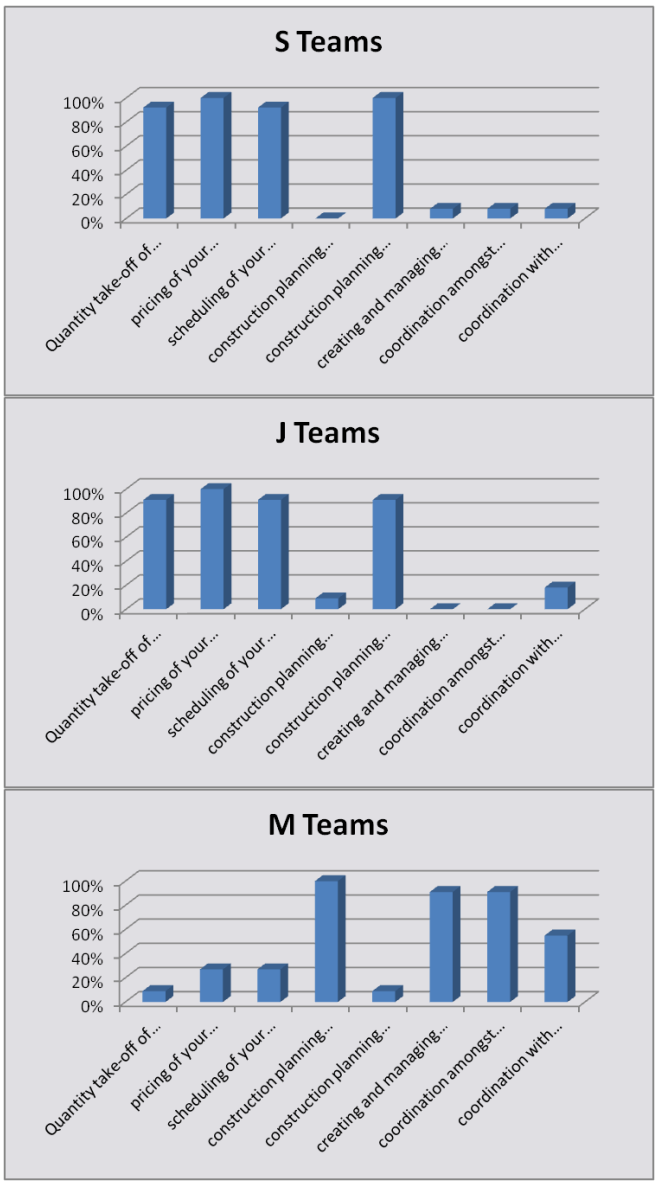

Figure 1 – Roles and responsibilities of the teams.

Both S(Sophomore) and J(Junior) teams who worked as subcontractors selected the same answers. They selected option 1, 2, 3, and 5 as their main roles which were:

- Quantity take-off of your assigned work package (e.g. structure, MEP, etc.)
- Pricing of your assigned work package
- Scheduling of your assigned work package
- Construction planning of assigned package (e.g., structure, MEP, etc.)

The M(senior and graduate) teams who acted as general contractors and mentors defined their roles mostly as options 4, 6, 7, and 8 which were:

- Construction planning of overall building
- Creating and managing master schedule of entire project
- Coordination amongst all subcontractors
- Coordination with selected contractor that had conflicts with our team

The overlapping roles with S and J teams that few of teams mentioned can be interpreted as their mentoring of S and J teams but not their primary responsibility.

Question 3 asked them about the software they used for fulfilling their responsibilities. Figure 3 Excel spreadsheet and MS Project were the pimary tools used across all teams.

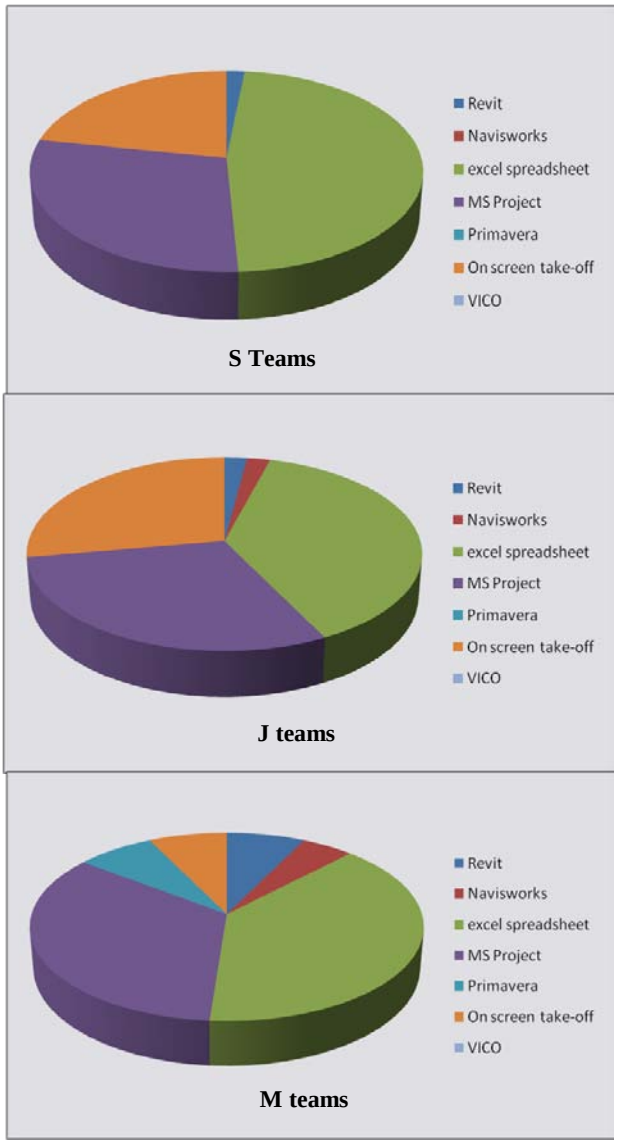

Figure 2 – BIM/ICT software usage.

Responses of S and J teams were similar but slightly different at the M teams level. This attributes to the different roles and responsibilities of each team. Sophomores and Juniors mostly worked with Microsoft Excel, MS Project, and OnScreen Takeoff. They used these software packages for quantity take offs, pricing, and scheduling. Although Microsoft Excel and MS Project were mostly used, M teams also used Revit and Primavera. Just two M teams used Navisworks for trade coordination. The other software they used and their applications (subject of question 4 of group survey) will come in the next section.

6. STUDENTS' FEEDBACK ABOUT BIM/ICT USE IN THE ILS COURSE

In order to understand the use of BIM/ICT in the course, question 4 was asked as an open ended question. It asked if the groups used ICT/BIM software in an innovative way. The answers to this essay-type question showed that the students prefered to use flexible and easy to use the software. Google Sketch-Up is the software that most of the students preferred and used for various purposes. The other software packages they used for the course were GoogleDocuments, GoogleSites, and MicrosoftGroove, which were mostly used by M groups. Studying their responses by team levels, the authors found M teams happier using ICT/BIM software, J teams preferred to use tools like Sketch-Up, while S teams were hesitant to use any applications since they were mostly first time users. But they became comfortable as they worked on the software through the ILS course.

Question 7 offered them six options to select from regarding the difficulty of reaching their goals through using BIM tools. The answer from M and S teams were similar. Both groups pointed out "BIM skill level", "Not required by assignments", and "Time constraints" as the main difficulties. M teams mostly emphasized "BIM skill level" while J teams saw "Time constraints" not as important as "BIM skill level" and "Not required by assignments". When question 8 asked them to assert more barriers M and S teams presented similarly the need for more training.

Question 13 of the individual survey offered more insights into difficulties of BIM/ICT software use and illustrated some common patterns. The frequency of these answers is presented in Table 1. The most common issue was about the "need for training of the software" expressed in different languages.

Table 1 – Difficulty of applying BIM/ICT to assignments

	S teams	J teams	M teams
Need for software training	13 (50%)	16 (60%)	28 (70%)
Why BIM?	2	1	1
Previous Training was less effective	7 (20%)	3 (10%)	11 (25%)
Time constraint	4	2	2
Total responses	25	26	41

The second most often mentioned issue was about the effectiveness of other courses that taught BIM software. While it is difficult to draw conclusions about the students' level of competency in BIM skills from the survey, the results show that it is worth to better understand students' expectations about their BIM skills and their required skills in the ILS course to align both. In addition, there were some discrete comments and suggestions for the BIM use in the course. Lower level students expressed their frustrations while M teams offered constructive feedback. Students who did not like using BIM were mainly sophomore students who had not learned yet what BIM is and why it is useful. Other sophomore students were concerned about learning too many applications but not in depth enough. Some individuals were enthusiastic about learning more applications and others requested for

selective introduction of ICT/BIM software that are used by practitioners. An example of such software was Primavera which is being used in the industry but not available in the department.

Many students felt good to be skillful in software and thought it would strengthen their resume while a study by Taiebat and Ku (2010) found that construction companies do not necessarily look for proficiency of specific BIM skills when hiring BIM competent graduates.

Students offered various suggestions for improving their training of BIM software in the school. Table 2 summarizes them in two groups.

Table 2 – BIM software course suggestions from students

Training Strategies	Workshop Lecture/Seminar Showcasing Elective courses
Training Structure	A class dedicated to just scheduling, estimating, with use of the relevant software Universal use of software between the professors A holistic walk through of a BIM process in construction Offer basic training andreinforce throughassignments Teach software early at the freshman / sophomore level Set up a classes on why and how to use BIM effectively More collaborative use of software

While their training strategy suggestions were about course formats, their training structure suggestions were about the content. Students are looking for a rationale of using BIM and a class in which they learn how useful BIM is and why. The demands from sophomores were mostly around “teach us software”, but seniors’ demands switched towards “give us basic trainings and give us more assignments to practice.” The other type of suggestions addressed the concern of training everybody rather than a group. A raised concern was that in the ILS, each member in the team was assigned a separate task. As a result, one member of the group becomes an expert in take offs, another in modeling, the other in safety, and so on. The one who worked on takeoffs, ended up not handling modeling and vice versa. Another suggestion was toteach one or some aspect(s) of preconstruction planning and focus within the same class on a relevant software before the entering the ILS course. It was also suggested torun the course more collaboratively in a teamwork style rather than a groupwork style that separated individual team member roles.

7. WISH-LIST OF INTEGRATED STUDIO FROM THE STUDENTS’ PERSPECTIVES

Questions 5 and 9 of the group survey and question 12 of the individual survey were designed to let the students freely express their wishes for the ILS course.

Question 5 of the group survey offered them six options and asked level of knowledge. The option “N/A” was provided if they were not interested in answering a specific aspect of BIM. Table 3 illustrates the results.

Table 3 – what students are wishing to use for the future of the ILS course

	Sophomore					Junior					Senior			
Please explain if there were any specific BIM/software knowledge or skills that you think were required for your year level tasks (sophomore vs. junior vs. senior) comparing you to other year groups.	**have skill /knowledge**	**like to have skill/knowledge**	**N/A**	**"agreed" percentage**		**have skill /knowledge**	**like to have skill/knowledge**	**N/A**	**"agreed" percentage**		**have skill /knowledge**	**like to have skill/knowledge**	**N/A**	**"agreed" percentage**
defining adequate level of detail of model	5	4	2	82%		4	6	1	91%		8	2	0	100%
validating the accuracy of the model	2	7	2	82%		3	7	0	100%		7	3	0	100%
defining model submission and approval procedures	1	7	4	67%		0	8	2	80%		9	1	0	100%
incorporating temporary structures and equipment into model for construction planning purposes	3	6	3	75%		1	8	1	90%		10	0	0	100%
modeling architectural and structural components	6	4	2	83%		2	6	2	80%		9	0	1	90%
modeling MEP components	0	6	6	50%		1	8	1	90%		3	6	1	90%

Table 3 shows in the column "agreed" percentage the total percentage of responses that either answered no skill/knowledge or like to have skill/knowledge is mostly over 80%. This illustrates that the students from sophomore through senior level are enthusiastic about learning and implementing BIM/ICT software. Table 3 shows that no S or J team had advanced skill in any aspect, while this number for seniors is not zero. This can be interpreted as the effect of the building construction curriculum specially integrated course on them, because they did not have a strong background on BIM/ICT software (subject of questions 5 & 7 of the individual survey), and they were not happy with the previous IT training as well (subject of question 13 of the individual survey). The authors found that sophomores and juniors consider themselves skillful mostly in "defining adequate level of detail of model" while the seniors had such confidence in all mentioned aspects of the question except "MEP modeling".

Although some of the students did not practice BIM/ICT tools in that semester, they used other communication applications to model, illustrate, and communicate the data and information in order to facilitate the construction planning for the project.

One of the M teams expressed a strong reason (from their point of view) for the necessity of teaching BIM software in the school. They said that since S & J teams' knowledge of BIM is not consistent, the models they develop are not compatible with each other in terms of accuracy, level of detail, and positioning. This makes their coordination through clash detection and 4D simulation difficult for M teams. This indicates that students need to learn how to set up the modeling protocol before startingthe modeling.

Question 9 of the group survey clearly asked them if they have any suggestion for improvement in using BIM/ICT software in the ILS course. Sophomores and juniors mostly restated the same request for the need for teaching BIM software and dedicating a class or a portion of a class to it. The suggestions from S & J teams were mostly around this point explained in different words. When it came to seniors, the language was changed and the demand went towards requesting for mandating the use of BIM/ICT in the ILS course, and increasing the practices and assignments on it. Overall feedback from all levels of students about BIM/ICT applications in the ILS course context indicated a strong interest from the students in BIM and also the desire to learn more effectively relevant tools that can support their required tasks. For example, a sophomore student said "we did not use BIM, but I'm sure in the next couple of years, many others will use it."

8. CONCLUSION

This research studied the student perceptions of BIM/ICT use and needs within the context the ILS course which accommodates different levels of students in an integrated team environment. The survey revealed some specific areas for developing and refining the BIM curriculum in the MLSoC.

A main concern raised by the students were the need for more training in specific software while the current curriculum focuses more on introducing the general principles and concepts of using BIM for construction. Suggestions were made by senior students to set up workshops, walkthrough sessions, showcases, and lectures that can give them a starting point for using software and reinforce their learning with relevant assignments for practice. Since the individual members of teams split the tasks, the walkthrough sessions should be followed by small individual assignments in order to allow all team members to practice the application of specific software tools.

Since most of the students said that they want to be skillful in using software hoping that it would strengthen their resume, it should be explained to them how industry looks for certain competencies in BIM that require rather sound conceptual understanding than specific software skills (Taiebat and Ku 2010). Introduction to the needs and benefits of BIM will address some of the students'concerns of how useful BIM is and how they can benefit from using BIM. In other words, it is important to teach the students the necessity, functionality, and utility of BIM before applying it to specific tasks on projects.

Another concern of the students was about which software to learn as students are expecting to learn tools that are most often used by industry practitioners Further industry research can address this concern.

9. REFERENCES

Woo, J. H. (2007). BIM (Building Information Modeling) and Pedagogical Challenges, *International Proceedings of the 43rd Annual Conference of the Associated Schools of Construction*, Flagstaff, AZ.

McGrawHill. (2009). *SmartMarket Report., The business value of building information modeling: getting building information modeling to the bottom line*.

[WWW Document]. URL http://www.bim.construction.com/research/FreeReport/default.asp

Becerik-Gerber, B., Gerber, D., and Ku, K. (forthcoming). Keeping architecture, engineering, and construction education in line with the needs of industry and the pace of technological innovation, *ITcon*

Becerik-Gerber, B. & Rice, S. (2010). The perceived value of building information modeling in the U.S. building industry, *ITcon 15*, 185-201. [WWW Document]. URL http://www.itcon.org/2010/15

Suermann, P. and Issa, R. (2009). Evaluating Industry Perceptions of Building Information Modeling (BIM) Impact on Construction. *ITCon 14*, 574-594

Taiebat, M. & Ku, K. (2010). Industry's Expectations of Construction School Graduates' BIM Skills, *International Proceedings of the 46th Annual Conference of the Associated Schools of Construction*, Boston, MA.

Taiebat, M. & Ku, K. (2010). Discussion of the Construction Industry's Evaluation Survey, *International Proceedings of the 46th Annual Conference of the Associated Schools of Construction*, Boston, MA.

AIA CC. (2007). Integrated Project Delivery, The American Institute of Architects California Council. [WWW Document]. URL http://www.aia.org/ipdg#ipdguide

Johnson, B. & Gunderson, D. (2009). Educating Students concerning Recent Trends in AEC: A Survey of ASC Member Programs. *Proceedings of the 45th ASC Annual Conference*, Gainesville, Florida, April 1-4, 2009.

Taylor, J., Liu, J., and Hein, M. (2008). Integration of Building Information Modeling (BIM) into an ACCE Accredited Construction Management Curriculum. *Proceedings of the 44th ASC Annual Conference*. Auburn, Alabama, April 2-5, 2008

Sacks, R. and Barak, R. (2009). Teaching building information modeling as an integral part of civil engineering in freshman year. *ASCE Journal of Professional Issues in Engineering Education and Practice, 136 (1)*, 30-38.