Does Learning Building Information Modeling Improve the Plan Reading Skills of Construction Management Students?

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This paper discusses a survey that was conducted in Spring 2006 as part of a curriculum development effort for the Construction Management (CM) Department at California State University, Chico. The purpose of the study was to examine the influence of learning BIM on the plan reading skills of CM students. This exploratory paper takes a first look at using BIM as a teaching tool for construction education. Second and fourth year CM students were given a two part survey that collected data on their educational background and their plan reading skills. Although, the scope of the study was limited, the results showed that BIM appeared to have a small, but positive influence on plan reading skills. The results of this survey are particularly relevant to other CM Departments because of the current interest in BIM and the similar requirement in all CM Departments to teach the fundamentals of plan reading, construction methods, materials, and processes. The author believes that this paper will assist other CM Departments in making better curriculum decisions. The author utilized an evaluation survey of undergraduate CM students and historical documentation to support the positions presented in this paper.

Keywords: Building Information Modeling, Building Information Models, Curriculum Development, Construction Education, Construction Visualization, and Plan Reading Skills

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Introduction

Plan reading skills are fundamental to the success of Construction Management (CM) students' ability to understand basic construction methods, materials, and processes. Historically, it is known that "…visualization is the process of looking at, or thinking about, a structural detail, or a symbol for such a detail, and being able to form a mental picture of how such a detail is constructed or assembled. …the ability to visualize is most important. Without that ability, reading of drawings could never be learned." (Dalzell, 1972).

Building Information Models (BIM), while relatively new, appear to have a positive influence on the plan reading skills of CM students when embedded in the CM curriculum. "BIM is a '4D' model that results from linking 3D graphic images… to the fourth dimension of time." (Clayton, Parker, & Warden, 2001). The building model can also act as a 'smart model' for organizing other information about the construction of the building, such as materials, methods, schedules, costs, and processes. The author believes that exposure to Building Information Modeling within a CM curriculum improves the CM students' ability to read plans and comprehend more fully the construction process because BIM helps them learn to visualize.

To prove this hypothesis, the author examined the qualitative results of this study from several points of view. The educational perspective came from the literature search. The faculty point of view came from interviewing the CM faculty who teach BIM to the CM students. The student perspective was obtained from observing the students using BIM in the classroom and the

literature search. The curriculum development perspective was obtained from working with students learning BIM. The industry perspective was taken from discussions with people who are currently using BIM in the construction industry and from the literature search. To support this investigation the author also undertook a literature search of books, periodicals, and web sites that discuss visualization tools, virtual construction, construction project planning, and building information modeling.

The Impact of Building Information Modeling

It appears from the literature that the main impact of BIM in the construction industry currently is its use as a pre-construction planning tool. "Information about a project can be entered into a model, which is actually a single, dynamic database. The information can then be extracted through any number of forms: plans, schedules… or cost."(Hunt, 2005). The literature search uncovered the fact that little has been studied about BIM's impact on plan reading skills or it's use as a tool to teach construction. This gap was the focus of this study.

BIM is ushering in a new era of examining how design checks, scheduling, and other pre-construction activities can be done more effectively. "It is a time, in which alternatives to these questions may be compared side by side to achieve the best possible solution. This is done through a new technology, coined 'Building Information Modeling (BIM)'," (Gier, Loftin, & Coogan, 2006).

Plan reading skills are necessary for effective collaboration and pre-construction planning. In the past, "project participants involved in the project planning process are expected to visualize in abstract terms the perceived characteristics and spatial relationships among various components of the project, including site-related activities. Due to the interdependence between the different elements and the large amount of information that needs to be manually processed, this approach is difficult to undertake and imposes a heavy burden on the project team to carry out the planning process." (Thabet & Waly, 2002). Any visualization tool like Building Information Modeling that can improve plan reading skills will make an impact on the effectiveness of CM students to do collaboration and pre-construction planning on the job site. The growing complexity and increased competitiveness in the construction industry will drive this need to become more effective in pre-planning activities.

Intelligent modeling capabilities are consistently improving. Through research at Stanford University's Center for Integrated Facility Engineering (CIFE) and the Construction Management Department at CSU, Chico, new impacts of using BIM in the construction industry are being discovered. Interesting studies on the impact of using BIM in the CM classroom are also being conducted at these institutions. Industry is starting to fund BIM Research at these and other universities.

Discovering if BIM Improves Plan Reading Skills

At California State University, Chico, Construction Management Faculty, who are interested in using BIM in the classroom recently focused their attention on the study question, "Does Learning Building Information Modeling improve the plan reading skills of CM students?"

The author organized a study of second and fourth year CM students in the spring of 2006 to see the impact BIM may be having on the students' ability to read plans. The goal was to reveal any improvement in plan reading skills that may be attributed to some students having BIM in their CM curriculum, while others did not. The amount of exposure to BIM varied between the years and between individual students. Second year CM students would most likely have had only one BIM course, whereas fourth year students could have taken up to three BIM courses.

The initial impression of the CM faculty was that BIM was probably helping students visualize the example construction project drawings better, but could the results actually be quantified, i.e. could you see the results in their survey scores. "Even with advances in brain and neuropsychology research, it is often difficult, if not impossible, to observe the actual mental operations an individual performs. For this reason, educational researchers infer how an individual processes information by measuring or observing resulting actions, or responses." (Davidson-Shivers & Rasmussen, 2006).

Students were not asked to give their impressions about using BIM. The students did not know that the survey was about the impact of BIM. They were only told it was a comparative study of plan reading skills for second and fourth year CM students.

The Method

An evaluation survey was prepared by the author to obtain information from second and fourth year CM students regarding their plan reading skills. The intent of this study was to compare internally the mean scores between the peer subgroups, i.e. those students with BIM training vs. those students without in each of the years. The study was not trying to compare results between the second and fourth year students. Second year CM students were chosen because in the current CM curriculum they would have had the potential to have taken at least one BIM course. Fourth year CM students were selected because they would have had the opportunity to have taken up to three BIM courses.

The survey consisted of two parts. The first part had seven questions related to the educational background of the students. The second part had ten questions related to an example construction project. This project is used by second year students in their Contract Documents and Specifications course. The fourth year students use this same project in their Construction Estimating course, their Scheduling course, and their Cost Management course. See Appendix A for the survey. To the students the survey looked like a ten (10) question plan reading quiz about the example project. All students were given the same survey.

By conducting this survey the author wanted to determine what impact, if any, BIM had on the participants' survey scores. Towards the end of the Spring 2006 semester, Fifty five (55) second year students and thirty nine (39) fourth year students were given the survey in their respective classes. Ninety four (94) student surveys were used to compile the following data.

Student Survey Results

The survey was broken into two parts, background information and plan reading questions. It was designed to collect information about the students and test their plan reading skills. The survey was tied to the sample project plans and specs, which they use in several classes, i.e. contract documents and specifications, estimating, scheduling, and cost management.

For the background information questions, students were asked to respond to multiple choice questions about their GPA, BIM training, estimating experience, scheduling experience, etc. The particular question that the author was focusing on was the extent of their BIM training in relationship to their plan reading scores in the second part of the survey.

The results for the 2nd year CM students are shown in Table 1 below.

Table 1
Summary of 2nd Year CM Students' Plan Reading Scores vs. BIM Training

Survey Responses	Total Number of Students	Percent of Total Students	Sub-Group Mean Scores	Group Mean Scores	Percent Difference in Mean Scores
A. Taken a Modeling Course	29	52.7%	5.69	5.62	+1.2 %
B. Currently taking a Modeling Course	5	9.1%	5.2	5.62	-7.5%
C. Not taken a Modeling Course	18	32.7%	5.88	5.62	+4.78%
D. Taken more than one Modeling Course	3	5.5%	6.00	5.62	+6.76%
E. Taken a Modeling Course and worked as a Modeler	0	0%	0.00	0.00	0%
Totals	55	100%			

The 2nd year results are somewhat inconsistent in that the author noticed that subgroup C, those students having no modeling courses have a subgroup mean score of 5.88, which is slightly

higher than the group mean score of 5.62. The author also noticed that subgroup C did better than both subgroup A, those students who have taken a modeling course and subgroup B, those currently taking a modeling course. The author attributed this inconsistency to the fact that one BIM course is probably not sufficient exposure to BIM to have a consistent or significant influence on plan reading skills. The author concluded that one BIM course is not enough to make an impact at the second year level.

The results for the 4th year CM students are shown in Table 2 below.

Table 2
Summary of 4th Year CM Students' Plan Reading Scores vs. BIM Training

Survey Responses	Total Number of Students	Percent of Total Students	Sub-Group Mean Scores	Group Mean Scores	Percent Difference in Mean Scores
A. Taken a Modeling Course	6	15.4%	7.67	7.44	+3.1 %
B. Currently taking a Modeling Course	3	7.7%	7.34	7.44	-1.5%
C. Not taken a Modeling Course	22	56.4%	7.14	7.44	-4.1%
D. Taken more than one Modeling Course	6	15.4%	7.67	7.44	+3.01%
E. Taken a Modeling Course and worked as a Modeler	2	5.1%	5.5	7.44	-16.1%
Totals	39	100%			

The 4th year results are a little more consistent than those from the 2nd year students. The author attributed these results to the fact that by their fourth year CM students have been exposed to more construction topics than 2nd year students and most likely have had an internship, i.e. construction work experience. Under these conditions BIM seems to have more consistent impact. By their fourth year CM students have also had more opportunity to take BIM courses;

some students have taken as many as three BIM courses. For fourth year CM students BIM appears to start acting as a framework to pull all their construction knowledge together.

Overall, from the students' responses in the plan reading part of the survey, it does appear that the students who have BIM experience do slightly better at plan reading than those students without BIM training, particularly in the 4th year group. The mean scores for both groups ranged from 1.2% to 6.76 % better for those students who have had at least one BIM course.

Discussion

Does learning building information modeling improve the plan reading skills of CM students?

The Educational Perspective

From the literature search, Building Information Modeling seemed like it would be most valuable, if it could help students process the abundant amount of information found in a set of construction plans. It is known that "information processing refers to the mental operations that individuals go through as they apply knowledge, skills, and abilities."(Gagne, Briggs, & Wager.1992). If a student can visualize the item being constructed, then it seemed reasonable to think that with practice the student could learn to interpret the plans more accurately, i.e. as demonstrated by scoring higher on the plan reading survey.

BIM facilitates the student's understanding of what is being constructed by drawing on their ability and experience to visualize in 3D. "Experience is the foundation of, and the stimulus for, learning. All learning builds on what has gone before. A new experience is understood in terms of what is already known. The desire to learn emerges from the experience of the learner, either arising from an existing commitment or from the challenge of a new situation."(Boud, Cohen, & Walker, 1993).

The Faculty Perspective

Overall, the faculty felt that BIM could be an effective tool for teaching plan reading because it shows construction concepts and principles visually. From the faculty's standpoint "It is useful to think of construction graphics as a language that participants in the construction process must "speak" fluently, even if with varying "accents." As oral communication varies with the individual using it, so does graphic communication. Consequently, we see considerable variation in how drawing sets are organized, how each sheet is formatted and annotated, and how graphic symbols are used. This lack of consistency adds difficulty to an already complicated process and increases the potential for misunderstandings between builder, owner, and design professional."(Bisharat, 2004).

Using BIM as a teaching tool enhances the ability of the faculty to demonstrate and "show" construction principles and concepts in 3D to the students. It is as close to the benefits of an actual project field trip as an "electronic" field trip can be. The faculty also felt the students benefited most from the visualization and analysis features that are inherent in using BIM. "The importance of visualization as a form of communication derives from our physiological

constitution: much of our internal communication (ideation) and external communication (perceiving externally generated information) is eye-related." (Kalay, 2004).

The faculty learned valuable lessons about making future implementations of BIM in the classroom more effective. The faculty noted the following lessons learned while teaching BIM to CM students:

1. *Treat BIM as an alternate tool for doing existing lab assignments.* Promote BIM's use as an alternative to the usual way of doing things that you as the instructor think are worth trying. Utilize student feedback to improve lab assignments.

2. *Make well-defined instructions for all assignments.* Instructions need to be clear and simple, particularly the parts where BIM might be used. Give students plenty of structure in the lab assignments.

3. *Limit the scope of each assignment.* Don't overload the students with too many activities all at once. Space the assignments out over the term. Less is often more, when it comes to learning and retention. Break big concepts into several small, interrelated assignments.

4. *Build momentum throughout the term by building a term notebook.* Have students document their assignments in a tabbed notebook, which the instructor checks at the mid-term and at the end of the semester.

5. *Ask questions in lab.* Encourage exploration and experimentation by challenging students with leading questions, i.e. not ones that can be answered by a simple yes or no. Encourage self-discovery of the answers. Give them opportunities to report their results to the class.
6. *Demonstrate the assignment in class.* Demonstrate or show the major procedural steps and an example of the expected outcome of the lab assignment. This is one of the most powerful teaching techniques for insuring student success.

7. *Repeat information and instructions.* The use of BIM for doing lab assignments requires plenty of practice. Embed its use in more than one assignment and continue to use it often.

The Student Perspective

From the student perspective BIM appears to work in conjunction with the student's natural abilities. "…we have become very good at processing visual information; it is processed in a parallel manner, not sequentially, as sound and other sensory inputs are processed. We are able to form a comprehensive understanding of a scene practically at a single glance, recognizing relationships, volumes, directions, colors, and movement." (Kalay, 2004). BIM technology helps students visualize complex projects, information, and construction concepts.

The majority of CM students surveyed who had some BIM training did better in plan reading than their counterparts that had no BIM training, particularly in the 4th year group. The author

attributes this improvement to the enhanced learning experience BIM provides. Educational research indicates that quality-learning activities are key. "Learning from experience…is what human beings do all the time throughout their lives. It can be useful, therefore, to examine formal teaching and learning activities from the perspective of what we know about learning from experience." (Stephenson, 2001).

The study team also observed several challenges inherent in using BIM to teach construction topics. While observing students learning BIM in the classroom, faculty noted the following:

1. *High frustration level using BIM software.* The lack of BIM experience slows down the learning process and causes student frustration.

2. *Time commitment to become proficient in BIM software.* The learning curve is steep. BIM's complexity is hard to overcome in one semester or one course.

3. *Insufficient training for faculty and lab assistants.* The BIM software is not easy to learn on a causal basis. No formal training was provided for faculty or lab assistants.

4. *Retention of BIM course material.* The students did not repeat much of what they learned in their BIM courses in other CM courses, so putting it to use was difficult after several months of inactivity. It was also hard for them to keep everything straight when they came back to use the BIM software or to use it in another course.

The Curriculum Development Perspective

The following discussion is a summary of ways that the challenges with integrating BIM into a CM curriculum can be mitigated. They are recommendations concluded from faculty observations made in the classroom. Implementing the following proposed steps will help CM faculty at other institutions make BIM an effective part of their CM Curriculum:

1. *Integrate BIM topics into existing lab assignments and courses.* Embed BIM into your assignments and existing courses, such as Construction Graphics, Plan Reading, Methods and Materials, Methods Analysis, etc. This will encourage BIM enabled learning outcomes and keeps BIM from being its own separate course or topic. Embedding BIM into the CM curriculum is paramount to its successful integration.

2. *Require progress reports from students throughout the term*. This step reinforces incremental improvement and encourages accountability in the student. It also facilitates the instructor checking the student's progress and redirecting their efforts when necessary.
3. *Provided technical "how to" workshops on specific BIM topics.* Do not expect to make students experts in BIM in one semester. Show them how BIM tools might be used as an alternate way to do a common activity. For example, focus on specific BIM tools that relate directly to estimating, i.e. doing quantity take-offs.

4. *Divide "learning BIM" and "applying BIM" into separate exercises.* Separate the assignments where you teach them how to use the tools from the assignments where they apply the tools. This greatly reduces the student's frustration level.

5. *Staff "After Hours" Lab time with trained lab assistants.* Put BIM trained student assistants in the labs after regular class hours to help students overcome any problems they are encountering learning or applying the software tools.

6. *Review completed assignments in class.* Ask students to present to the class the results of their work. Ask peers to confirm or critique these results. Discuss the results. Present the "instructor's solution" as a review for the assignment.

7. *Show example solutions*. Show an example of the expected outcome from the assignment. It does not have to be their exact assignment solution, but one that is similar in type and execution. Post electronic versions of these sample assignment solutions on the department server, so all students have access to them.

8. *Provide formal training for faculty and staff*. Instructors must be trained in the use of BIM. Do not expect faculty, staff, or student assistants to learn BIM "on their own." Successfully integrating BIM into a CM curriculum requires an investment in time and money by the CM department.

The Industry Perspective

The results of a recent survey of the construction industry sponsored by the Construction Employers Association (CEA) were presented at the Associated Schools of Construction's 42nd International Conference. "The [industry] survey showed that CM graduates need to have solid plan reading skills." (Souder & Gier, 2006). Plan reading skills were rated #2 behind estimating skills by industry professionals who were asked to identify the top five skills they expected new CM graduates to possess.

Building Information Modeling is impacting the construction industry in many ways. Leading construction companies like Webcor, DPR, Turner, RQ Construction, and Walt Disney Imagineering have started to implement BIM technology into their various business processes, such as, quantity take-off, estimating, project management, project scheduling, and efforts to increase overall productivity.

Currently, BIM is still seen as a cutting edge planning tool, when it actually may be more of an innovative process. It appears from discussion with industry personnel that enhanced collaboration among the key project players, i.e. the owner, architect, engineer, and constructor, is one of its major benefits. Some construction companies have decided to start investing in this new technology. Others are sure to follow. "The defining moment was the construction of Frank Gehry's Guggenheim Museum in Bilbao-a huge popular and critical success that depended directly upon shrewd use of three-dimensional CAD modeling, CAD/CAM fabrication, and a globalized design, fabrication, and construction process that was coordinated through electronic information transfer." (Kalay, 2004).

Conclusion

The purpose of this study was to assess the influence of learning BIM on plan reading skills by conducting an evaluation of a plan reading survey given to 2nd year and 4th year CM students. The data from this study was supportive of the initial impressions and hypothesis. The survey results were not consistent or conclusive enough to allow the drawing of clear and distinct conclusions. Learning BIM appears to have had some small, but positive influence on the plan reading skills of a group of CM students at California State University, Chico. Other background variables, such as previous construction work experience, individual visual aptitude, etc., may also be having an influence on the CM students' plan reading skills.

The limitations of this study were attributed to the small survey size, the length of the survey, and individual background variables, such as work experience, which were not a part of the study. It appears a more detailed study is needed to make conclusive statements about the actual influence of BIM on plan reading skills. The breadth of each student's previous construction work experience was not considered in this study. This variable, as well as others, and their impacts on plan reading skills deserve further study.

The author concluded that BIM appears to be an effective educational tool for teaching construction because it actualizes a fundamental educational principle, that of learner-centered instruction. "Learner-centered instruction, emphasizes learners as individuals and central to the creation of effective instruction." (Davidson-Shivers & Rasmussen, 2006). The BIM learning experience did seem to reinforce many other valuable educational aspects that were found in the educational literature. For example, "Simulations can be used to challenge learners and involve them in learning activities." (Davidson-Shivers & Rasmussen, 2006). Also, learning outcomes depend on how the learner interprets the experience, "…it is not what is done to the learner, but how the learner interprets what happens." (Mayer, 2003).

The study team surmised that the difficulties experienced while using BIM in the classroom relate to being part of the early adoption phase of this new BIM technology. Continuous incremental improvements to the implementation process will prove that BIM is an effective, untapped resource for improving plan reading skills. Building Information Modeling will transform construction education and the industry in the near future. The merits of using BIM out weigh its disadvantages. BIM technology provides excellent visual aids to use in the classroom. It improves accuracy in quantity take offs and allows the user to improve their project schedule by embedding it in a 3D model.

Although BIM is currently a hot topic within the construction industry, its benefits as a teaching tool are still relatively small compared to the required investment by a CM Department to integrate it into their CM curriculum and the individual student to integrate it into their CM skill set. In the future BIM will get easier to learn and to use, faculty will be better trained, lab exercises will be better developed, and lab facilities will be expanded. All these improvements will eventually see BIM making greater contributions to CM students plan reading skills and to their better understanding of construction methods, materials, and processes. The ultimate curriculum decision facing CM Departments today is whether they want to be an early adopter of

this new technology. Do they want to lead in this area of construction education or do they want to follow.

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Appendix A

Construction Management Department Survey

California State University, Chico

Instructions: Place your answers on a Scantron with a Number #2 Pencil. Place only one answer per question. Put your name, date, and class information on the Scantron and the Survey. Turn in both your survey and completed Scantron to Mary NLT 5 PM May 5th, 2006.

Name: _____ Date: _____
Class: _____ Section: _____

Background Information:

1. What is your accumulative GPA?
    a) 3.50 or higher
    b) 3.00 to 3.49
    c) 2.50 to 2.99
    d) 2.00 to 2.49
    e) 1.99 or below

2. How many semester units do you have completed?
    a) 120 or higher
    b) 110 to 119
    c) 100 to 109
    d) 90 to 99
    e) 89 or lower

3. How many semesters have you been enrolled in the CM Program?
    a) 7 semesters or less
    b) 8 semesters
    c) 9 semesters
    d) 10 semesters
    e) 11 semesters or more

4. What is your estimating experience?
    a) I have taken the estimating course.
    b) I am currently taking the estimating course.
    c) I have not taken the estimating course, yet.
    d) I have taken the estimating course and worked as an estimator at an internship or co-op.
    e) None of the above.

5. What is your scheduling experience?
    a) I have taken the scheduling course.
    b) I am currently taking the scheduling course.
    c) I have not taken the scheduling course, yet.
    d) I have taken the scheduling course and worked as a scheduler at an internship or co-op.
    e) None of the above.
    f)

6. What is your virtual building modeling experience?
    a) I have taken a modeling course.
    b) I am currently taking a modeling course.
    c) I have not taken any modeling courses, yet.
    d) I have taken more than one modeling course.
    e) I have taken a modeling course and worked as a modeler at an internship or co-op.

7. What is your Cost Management experience?
    a) I have taken the Cost Management course.
    b) I am currently taking the Cost Management course.
    c) I have not taken the Cost Management course, yet.
    d) I have taken the Cost Management course and worked with project cost accounting at an internship or co-op.
    e) None of the above.

CHP Project Questions:
Instructions: Refer to your CHP plans and specifications to answer the following ten questions:

8. How many recessed linear fluorescent light fixtures are to be installed in the Men's Locker Room of the New Office Building?
    a) 7
    b) 6
    c) 8
    d) Insufficient information to determine
    e) None of the above

9. You will install the Glu-Lam Beams in the Office Building _____ the HVAC equipment.
    a) before
    b) after
    c) at the same time as
    d) Insufficient information to determine
    e) None of the above

10. The purpose of the nailer shown in Section A/S4.1 is to:
    a) Fasten HVAC Ducts
    b) Provide a pop-out Form Strip for the electrical conduit
    c) Provide a spacer for the bull nose floor tile
    d) Provide backing for attaching sheetrock
    e) None of the above

11. What is the nailing pattern for connecting the two top plates to each other on the wall open framing?
    a) 7 – 16d with a 4'-0" min splice
    b) 16d @ 12' O.C. - TYP
    c) 2 – 16d @ 2 x 4 Studs
    d) 3 – 16d @ 2 x 6 Studs
    e) None of the above

12. What is the thickness of the depressed slab in the Men's Restroom of the Office Building?
    a) 6 inches
    b) 2 and ½ inches
    c) 4 inches
    d) 4 and ½ inches
    e) None of the above

13. The tank hold-down cable anchor is shown on what detail?
    a) 2/S-2
    b) 4/M-7
    c) A2-4
    d) 5/E-8
    e) none of the above

14. Is the New Office Building's finish floor elevation higher or lower than the finish floor elevation of the New Shop Building?

a) Higher
b) Lower
c) The Same Elevation
d) Insufficient information to determine
e) None of the above

15. The Masonry Wall Reinforcing Plan Detail calls for how many bar diameters overlap in the splicing typical?
a) 84
b) 15
c) 48
d) Insufficient information to determine
e) None of the above

16. How many roof drains are there on the New Office Building?
a) 10
b) 12
c) 8
d) Insufficient information to determine
e) None of the above

17. How many roll-up doors are there on the West Elevation of the Shop Building?
a) 4
b) 1
c) 6
d) Insufficient information to determine
e) None of the above