Integrating Building Information Modeling (BIM) into Core Courses within a Curriculum: A Case Study

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Abstract: This paper discusses a case study of a teaching and learning approach for integrating Building Information Modeling (BIM) into a core course within a Construction Management (CM) curriculum. The paper presents a detailed study of the experience and lessons learned from introducing a project model into a Methods Analysis course in the curriculum of the Construction Management Department at California State University, Chico. The author illustrates how the introduction of BIM helped Faculty deliver more realistic project-based courses. In particular, the author analyzes a new model-based Methods Analysis course that allowed students to learn how to use BIM software, while applying construction concepts to real-world, project-based assignments. The paper presents evidence that integrating BIM allowed the instructor to design and implement a course that utilized more realistic assignments to simulate real-world project planning activities and helped students to improve their BIM skills.

Keywords: Building Information Modeling, BIM, Virtual Design and Construction, Construction Management, Construction Methods, Constructability, Curriculum Development, Construction Education, Information technology (IT), Three-dimensional models

INTRODUCTION

Understanding Virtual Design and Construction (VDC) technologies and processes along with BIM skills is becoming more important for CM students to participate effectively in the construction industry upon graduation. This importance stems from industry's ever increasing adoption of BIM into their construction delivery workflow (Ahn et al. 2013). Construction companies are starting to demand that CM graduates have BIM skills and an understanding of VDC processes (Souder and Gier 2006). CM educators generally agree that the knowledge of VDC and BIM is now required to adequately prepare students for work in the industry. They also recognize that there are inherent barriers to implementation (Lee and Hollar 2013; Lee and Dossick 2012). And, in fact, "Only slightly over half of all programs offer BIM courses and almost one fifth of all programs still do not have any plans to offer BIM courses" (Becerik-Gerber et al. 2012).

What is not agreed upon is how best to teach these topics and how to integrate VDC technologies, processes, and BIM tools into the CM curriculum (Glick et al. 2011). Most CM faculty agree that teaching and learning practical, real-world VDC and BIM skills in the classroom is important, but also difficult to implement. One problem is due in part because acquiring proficiency in the use of BIM tools, both for students and faculty, takes repetition and practice, which are difficult due to the time constraints in the traditional lecture-lab CM course. Another difficulty in teaching in the traditional format is that it takes so much time to cover the technical course material there is very little time remaining to apply what the student has learned to a real-world project (Glick et al. 2011). Overcoming these barriers requires a new teaching and learning approach. Integrating VDC technologies within a virtual framework of a real-world construction project contributes to student learning because the model becomes the learning environment (Richards and Clevenger 2011; Clevenger et al. 2010; Lu et al. 2013).

This exploratory case study presents the analysis and documentation of the process to integrate VDC technologies into a CM curriculum at California State University (CSU), Chico. The author selected a Methods Analysis course to analyze during this case study mainly because of past and current experience with the course and the first-hand knowledge gained during the course re-design and subsequent migration to a model-based format. The author spent the last eighteen months designing, developing, and delivering this course with an instructional team comprised of two CM faculty, as co-instructors, two industry representatives, as subject material experts, and two undergraduate students, as lab assistants. All course development work was funded by an external grant from the California Contractor's State License Board. The author served as the team leader of the instructional team and managed the design and development of this model-based Methods Analysis course, which would eventually integrate VDC technologies.

LITERATURE REVIEW

Historically, students learned practical construction methods and processes during summer internships or through simple stand alone, topic-based assignments, due to the time constraints of the typical classroom. To reach beyond these types of assignments instructors often enhanced them with "war stories" from the field, typically discussing, isolated solutions and methods found on past projects from their own experience. Listening to the instructor tell a story about the application of a certain construction method, while it may sound interesting, does little to help the student know what to do when they are confronted with a problem on an actual project or on a course assignment based on a real project (Thomas and Mengel 2008; Weber 2003; Terenzini et al. 2001).

Pre-construction planning activities and methods analysis really depends on an understanding of the project (Thabet and Waly 2002). The transformation of project information into useable, practical planning and construction methods depends extensively on the knowledge and experience of the individual members of the project's management team (Becerik-Gerber et al. 2012). Knowing when and how to apply a specific method or processes is as much an art as it is a science. It is heavily dependent on the experiential knowledge of the Project Manager. Teaching without project specific details falls short in accounting for the degree of complexity, the diversity of situations, and sheer numbers of situations, variables, and conditions on a typical construction project. Construction project case studies and stories cannot begin to cover all the interconnected variables and factors that an experienced Project Manager brings to the understanding of a specific construction project. What is missing is the specific project context, in which decisions are made about construction methods and processes (Hunt 2005; Boud et al. 1993; Andresen 2000).

As BIM becomes an industry standard, the educational paradigm must evolve towards an interactive learning environment, where student's gain experience interacting with dynamic project models. Developing integrated project-based assignments however, has been challenging, particularly, prior to the introduction of BIM (Kunz et al. 2003). BIM can also be difficult to teach to students because of their limited construction experience, novice skills with software tools, and lack of educational materials (Lee and Dossick 2012). There have also been several other obstacles to integrating VDC technologies into undergraduate CM courses, such as, lack of course development funds, lack of experienced instructors, lack of software tools, and lack of project models. But, now that the industry has been using BIM for a number of years, models of real-world projects exist that can be used in the classroom, thus the labor-intensive task needed to create these integrated assignments has become more manageable. Students still need to learn about contract documents, specifications, quantity take-offs, productivity analysis, methods, and construction processes, however now they can learn them in the context of a real-world project. The possibility of model-based methods analysis has diminished the negative impact of many of the practical barriers that instructors have encountered in the past (Lee and Dossick 2012). The advancement of computer applications, particularly BIM, has helped to support project-based education (Fruchter 2001).

Several improvements to VDC technologies have enabled instructors to teach students with off-the-shelf software, such as, Sketch-up, Autodesk Revit, Navisworks, and Solibri in a structured and integrated manner that was previously difficult or not possible (Teicholz and Fischer 1994). First, BIM tools speed up the time it takes to do time-intensive tasks, such as, quantity take-offs. Second, a proliferation of BIM project models in industry means students do not need to take the time to build a model to study it. Third, BIM models introduce a realistic level of project complexity, but at the same time, make it easier to manage all the project-specific details. Fourth, BIM tools allow students to learn more construction concepts, such as, site layout, methods analysis, productivity analysis, cost analysis, sequencing, schedule analysis, and clash detection all in an integrated fashion within a real-world project context (Richards and Clevenger 2011).

As noted by Barham et al. (2011) improvements in student performance were observed when 3D models were used. Integrated, model-based project assignments have several features that make them naturally effective for the CM classroom. First, a building information model presents to the student project-specific information and details from a real-world project in a very comprehensive, visually enhanced, 3D manner. The student can see and manipulate this project detail in such a way that it increases their understanding of the project, while they are using the model (Glick et al. 2011; Vygotski 1978). Second, by definition, the model is a database of project-related information, easily accessible to students as they work to apply construction concepts, like methods analysis, and to solve problems on their project-based assignments. Third, the model facilitates the automation of tedious and repetitive project tasks, such as, quantity take-offs, when analyzed by model checking software, like Solibri. These aspects of BIM combine in a synergistic way to give instructors the capability to design a course that comes closer to delivering actual project-specific details, in such a way, as to give the student a more realistic learning environment.

Based on the literature review the author hypothesized that the integration of VDC technologies, processes, and BIM tools would give instructors the ability to develop and teach model-based Methods Analysis courses that:

1. Utilize real-world projects to effectively teach VDC technologies and processes.
2. Increase opportunities to use BIM tools to improve students' BIM skills.
3. Utilize a learning management system, such as, Blackboard Learn to increase course effectiveness.

RESEARCH METHODOLOGY

To find evidence for the above listed hypotheses, the author embarked on a exploratory case study analysis of the people, courses, events, activities, and resources involved in integrating VDC technologies, processes, and BIM tools in the CMGT 332 Construction Methods Analysis at CSU, Chico. In particular, this case study focuses on the evolution of a non-model based Methods Analysis course taught by the author in 2005-2006, which was re-designed as a model-based course and implemented by the author in 2013-2014. This case study provides a comparison of the two courses and an analysis of how integrating VDC technologies can enhance CM curriculum, improve course learning outcomes, and cause a paradigm shift in the learning environment (Lee and Hollar 2013).

Studying these two Methods Analysis courses allowed for observations of students and experience with students in a consistent course environment, even to the point of being taught in the same classroom. Fortunately, the author was also able to reference accreditation course records kept in the CM Department archives for the 2005-2006 Methods Analysis course, so that the syllabi, lecture notes, Power Points, assignments, quizzes, exams, keys, grades, and student evaluation comments could be compared with the new 2013-2014 model-based course materials and results. All this archival data provided a degree of consistent and historical context and allowed a detailed comparison of the courses. Using several different data sources permitted the author to cross-triangulate the data, thus increasing the reliability of the research results (Yin 2003; Miles and Huberman 1994).

Jorgensen (1989) explains that being a participant observer can provide valuable insight into unsystematic and irregular data collection. Being participant observers helped the instructional team to collect data, observe student behavior, and gain insights into the courses without adversely affecting the student learning process. From the very beginning the co-instructors, industry representatives, and student lab assistants were introduced to the students as an integral part of the course delivery method for the new model-based course format. The students did not consider any member of the instructional team to be an outsider, that is, someone who would possibly influence their natural behaviors.

An in-depth involvement in the design, development, and implementation of both courses gave the instructional team a deeper insight into the course assignments and student progress on these assignments, which was a positive outcome of being participant observers. But, this same involvement may have introduced some bias into the data analysis. To offset any potential bias, another researcher with an outsider's perspective reviewed the findings. The author hoped this outsider's perspective would counter any bias introduced into the case study.

To show evidence for the hypotheses of this case study the following sections describe the two Method Analysis courses. In these sections the author provides the background of the courses and describes the data collected.

CASE DESCRIPTION

A NON-MODEL BASED METHODS ANALYSIS COURSE

The CMGT 332 Construction Methods Analysis course has historically been taught in a traditional lecture-lab format for many years at CSU, Chico. The class has always consisted of a combination of topic-based lectures, discussions, stand-alone assignments, quizzes, and exams. The course is a pre-requisite for CMGT 450 Construction Cost Estimating. CM students usually take it in their third year of the CM Program. Typically, about half the students in this Methods Analysis course have had an internship or some construction experience. The course's primary goal has been to explain, enhance, and reinforce this recent industry experience that the student has acquired on the job by covering such topics as, site layout, methods analysis, sequencing, productivity, crew analysis.

The Fall 2005 and Spring 2006 Semesters served as the example of a traditional non-model based Methods Analysis course for this case study. This non-model based course relied heavily on published articles bundled in a course packet along with the instructor notes and handouts as the course materials. The course was not taught using a learning management system, such as, Blackboard Learn. Table 1 gives some historical comparison of the topics covered in this Methods Analysis course and some comparative context for this case study.

Table 1. Evidence of how the integration of VDC/BIM increased our ability to teach in the Methods Analysis Course

Year	Use of Real-World Projects	Type of Assignments	Methods Analysis Topics Covered	VDC/BIM Topics Covered	Project Constructability
2005-2006	None	Ten Stand-Alone	Site Layout Methods Analysis Productivity Sequencing Crew Analysis Safety	None	None
2013-2014	Three Story Steel Structure BIM Model from Contract Documents	Ten Integrated Project-Related	Site Layout Methods Analysis Productivity Sequencing Crew Analysis Safety	Site Utilities & Foundation Conflicts Schedule Analysis Architectural QTO Clash Detection Constructability Log Constructability Summary Report	Constructability Summary Report (Issues/Resolutions)

During two-hour lecture periods the author, typically presented topics related to methods analysis, such as, site layout, sequencing, and productivity to convey the concepts. Instructor experience in the form of storytelling was used to provide project context for the various topics. The instructor covered a different methods analysis topic in lecture and the students were assigned a related assignment to complete during the subsequent three-hour lab period. The students completed a total of ten stand-alone, topic-based assignments during the semester. Overall, the students' learning process followed a traditional topic-based format with little time for hands-on application of methods analysis concepts or realistic project-based context.

A Model-Based Methods Analysis Course

The other course example in this case study analysis was the new CMGT 332 Model-Based Methods Analysis. BIM had been offered as stand-alone technical electives for over five years, but recently these electives were not well attended, so by early 2013 it had become apparent to some of the CM Faculty at CSU, Chico that they needed to embed BIM tools into the core CM curriculum to reach more CM students. Industry was already requesting that CM graduates have some basic BIM skills. It seemed logical to target CMGT 332 Construction Methods Analysis, as one of a series of three CM courses where the CM Department would take steps to integrate VDC technologies, processes, and BIM tools.

During the Spring 2013 Semester, several CM Faculty led by this author, along with an industry representative, a VP of VDC for a large construction company, met weekly to re-design Methods Analysis as a model-based course. The new design consisted of a mix of discussions, a project model, project-based team assignments, software workshops, training videos on a course YouTube Channel, related web resources, quizzes, and exams. The primary goal was to better prepare the student for their future work in the industry, by increasing their understanding of VDC technologies and processes, and improving their BIM skill set. The basic methods analysis topics, such as, site layout, methods, sequencing, productivity, crew analysis are still covered, but in addition the model-based learning environment allows the instructor to teach more advanced, model-based topics, such as, quantity take-offs, schedule analysis, model analysis, clash detection, and constructability in a more realistic project-based learning environment. Table 2 shows the software used in the Methods Analysis course.

Table 2. Software used in the Methods Analysis Courses

Year	BIM	Scope	Time	Cost and Database	Animation and Graphical	Model Analysis	Learning Management System
2005-2006	None	None	None	Excel	None	None	None
2013-2014	Revit 2014	Revit 2014	Navisworks Timeliner MS Project Primavera P6.0	Solibri Excel	Navisworks Timeliner Sketch-up Power Point	Navisworks Manager 2014	Blackboard Learn

The new course was implemented in Fall 2013 and Spring 2014. These two semesters served as the example of the model-based Methods Analysis course for this case study. Having this project model integrated into the course is a major paradigm shift in the way the instructors deliver this course. Normally one CM Faculty member and one student lab assistant are in the classroom at all times. All course materials, instructor's notes, handouts, workshop Power Points, training videos, Course YouTube Channel, related web resources, quizzes, and exams reside within the hybrid online course format on Blackboard Learn, the current learning management system at CSU, Chico. These course materials are available to the student continuously throughout the semester; anywhere the student has Internet access.

The introduction to the model-based course included the forming of teams, installing BIM software on students' laptops, downloading the project model, familiarizing students with the contract documents, the Blackboard Learn online course, and the physical classroom environment, opening the model, acquainting themselves with the model, and the BIM software tool's user interface. After the initial introduction and set-up sessions, students began working on the first team assignment, site layout, while the industry representative began teaching a seven week series of one-hour workshops, given once a week, on the various BIM software tools, i.e. Sketch-up, Autodesk Revit, Navisworks, and Solibri. The subsequent weeks were devoted to the ten integrated, project-based assignments. The ten team assignments were (1) Site Layout, (2) Site Utilities and Foundation Conflicts, (3) Structural Steel Methods Analysis, (4) Structural Steel Sequencing, (5) Structural Steel Schedule Analysis, (6) Architectural QTO, (7) Navisworks Clash Detection, (8) Model Analysis, (9) Constructability Log, and (10) Constructability Summary Report.

During a typical week throughout the semester the students meet for a two-hour session and a three-hour session. In the new course design these two sessions have been changed from a traditional lecture-lab format to primarily two activity work sessions. Within these activity work sessions the student is exposed to course materials via an instructor or industry representative led topic discussion, an industry representative led BIM software tools workshop, or they are working on their team assignments. The students work in teams of three or four to complete ten integrated, project-based assignments during the semester. The weekly classroom time averages about a third discussion/software workshops and two-thirds team time.

The students created a project notebook to document their team's work on the ten integrated, project-based assignments. They could not have completed these assignments within the course time-constraints or the required level of detail and completeness without a building information model. The model provided project-specific detail and realistic context for the learning environment. The student spent hours learning the BIM tools to prepare for the team assignments and an equal amount of time preparing the assignment reports and presentations. The student teams fairly consistently required an average of thirty to forty person-hours to complete each team assignment over a week to two-week period. Each team had a team leader, who managed the team members and maintained a three-week look-ahead schedule for the assignment tasks. Team assignments overlapped by design to simulate real-world project conditions. At any one time during the semester a team leader may have different team members working on two or three different assignments at the same time.

The students presented the results of their work on the team assignments during the semester through four presentations, various animations, and a project notebook. The instructors graded both digital and hard copy student work throughout the semester. The instructors used Blackboard Learn's Gradebook to communicate the results of their grading with the students.

The project model and the integrated, project-based assignments set the rhythm and the pace of course instruction. Individual, team, and class discussion and Q&A sessions between the instructors, industry representatives, lab assistants, and the students are both planned and spontaneously encouraged during the weekly activity sessions. Overall, the students' learning process has changed to focus more on a hands-on application of methods analysis concepts within a real-world project-based context.

CASE ANALYSIS

A Quantitative Comparison of Student Scores

Educational researchers often infer how an individual processes information by measuring or observing resulting actions or responses (Davidson-Shivers and Rasmussen 2006). This study compares the student scores of the model-based Methods Analysis course with the non-model based Methods Analysis course. Table 3 provides a historical comparison of average student scores for overlapping assignments and final grades in the non-model based and model-based Methods Analysis courses at CSU, Chico. This data illustrates the effect of integrating VDC technologies on the learning environment. It provides some insight into the changes in the learning environment caused by a change in course format. To permit a quantitative comparison of student scores this case study analyzed the average student scores for each overlapping assignment and final grades, as a percentage of the maximum attainable score.

Table 3. Historical comparison of average assignment scores in non-model based and model-based Methods Analysis Courses. Standard Deviation is shown in parentheses.

Year	Site Layout	Methods Analysis	Productivity Analysis	Sequencing	Crew Analysis	Safety	Final Grades
2005-2006	83.85% (5.68)	75.11% (11.6)	71.42% (11.06)	84.32% (6.57)	60.15% (3.26)	89.35% (5.61)	78.94% (5.14)
2013-2014	87.98% (0.17)	84.46% (2.64)	87.50% (0.11)	87.55% (2.05)	87.50% (0.11)	97.34% (2.34)	85.42% (3.84)

Upon close examination of the student scores, it became apparent that in general, the students in the model-based course, who utilized integrated VDC technologies, processes, and BIM tools to complete their project-based assignments, scored better in every overlapping assignment and eventually also in their final grade. The students' scores in the model-based course were markedly better in two areas, Productivity Analysis and Crew Analysis. The instructor attributed this finding to the ability of the students in the model-based course to have a better grasp of the scope of work on the project because of the ability to actually see what work was required via the project model. The instructor also observed in the classroom that a better understanding of scope allowed the students to apply the concepts of productivity analysis and crew analysis because they could see what had to be done for a certain work activity, what labor, equipment, and materials were required, and what the optimum crew make-up would be.

Students in the model-based course could also put information into Navisworks Timeliner to run a simulation of the work activity to check if their decisions about productivity, equipment choice, and crew size gave reasonable time durations to complete the work activity. The instructors observed that this higher level thinking, as a natural outcome of the integrated, project-based assignments ultimately engaged the students more in the course material and thus gave the students a better grasp about productivity analysis and crew analysis. The instructors also noted that the methods analysis concepts were less abstract and more real to the students because they were tied to a real-world project model.

The students' final grades in the model-based Methods Analysis course were roughly a whole letter grade higher than those students in the non-model based course. This noted improvement from an average final grade of a C+ (78.94%) to a solid B (85.42%), for this instructor seemed significant. The final grade comparison indicates that the student group that had integrated project assignments had a deeper understanding of the principles and concepts of methods analysis, not only about the concepts, but also how and when to apply them. In contrast, those students in the non-model based Methods Analysis course seem to have had a more fractured understanding of methods analysis concepts, which the instructor attributed to the stand-alone, topic-based assignments.

Another finding was the wide variation in the range of average scores for the students in the non-model based course. It was much greater than for those students in the model-based course. The main conclusion that the author drew from this observation is that the students in the model-based Methods Analysis course may have had a more consistent and cohesive learning experience. This tightening of the range of student scores may be caused by the consistency that the project model brings to the learning environment. The instructor observed that students were always coming back to the model, to get information, to visualize what an element looks like, and to test their decisions. This continual presence of the project model in the learning environment appears to make a difference in student learning.

What the author concluded from this quantitative comparison of student scores is that students exposed to VDC technologies in a series of integrated, project-based assignments showed a degree of improvement in their overall understanding of methods analysis concepts. Of course, with this type of case analysis comparison, any conclusions drawn must be taken with a certain amount of caution. The trends indicated by this quantitative comparison of student scores definitely show that student improvement in the model-based Methods Analysis course is evident. But, since there was not a control group per se, the results must be tempered with cautious optimism.

A Statistical Comparison of Student Surveys

As another means of testing the hypotheses for this case study the author developed a student survey of those students who completed the model-based Methods Analysis course in the 2013-2014 academic year. Five questions addressed descriptive demographic information, such as, gender, age, college major, construction field experience, and geographical environment. Table 4 shows the descriptive statistics of the student population for this survey. Forty-seven students completed the survey.

Table 4. Descriptive Statistics from Student Survey of CMGT 332 Model-Based Methods Analysis Classes 2013-2014

Variable	**Survey Results**				
Gender	Male = 83%	Female = 11%	No Reply = 6%	NA	NA
Geographical Environment	Urban = 57%	Suburban = 30%	Rural = 9%	No Reply = 4%	NA
Age (Years Old)	0-19 = 3%	20-29 = 91%	30-39 = 3%	40-49 = 3%	50 + = 0%
College Major	CM = 94%	Architecture = 0%	Business = 0%	Engineering = 3%	Other = 3%
Construction Field Experience	None = 11%	Less than 1 year = 19%	1-2.99 years = 28%	3-5 years = 30%	5 + years = 12%

Sixty-five questions asked the students to rate course-related elements, such as, the VDC and BIM components, the course content, method of course instruction, and the hybrid online course components on a five-point Likert Scale, where 1 = Strongly Disagree, 3 = Neutral, and 5 = Strongly Agree. Forty-seven of the seventy-four students completed the survey. Table 5 shows a summary of the average student survey responses. Note that overall, 80.81% of the students rated the course with neutral or positive responses. Only 17.48% of the students rated the course with negative responses.

Table 5. Summary of the average survey responses from the CMGT 332 Model-Based Methods Analysis Classes in 2013-2014. (Standard Deviation) Total Surveys = 47

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Omitted	Total
4.94% (3.64)	12.54% (5.19)	32.57% (9.34)	37.18% (11.76)	11.06% (7.89)	1.68% (3.72)	100.00%

For data analysis the author submitted the survey data to the CSU, Chico Testing Center. This statistical output became the basis for the study's statistical comparison of student surveys. The author checked variables for reliability of measurement and screened the data. All responses were found to be in range.

The author utilized the Discriminative Item Analysis output to conduct a point biserial correlation analysis. The value calculated by the student t-Test for point biserial correlation was used to determine if the point biserial correlation for each survey question was statistically significant. To make this determination the author compared the point biserial correlation values given by the t-Test with the value given for N-2 degrees of freedom in a table of t distribution values, where N = the number of students and the level of confidence was 99.95% [13]. The survey questions, whose point biserial correlation were statistically significant, are listed in Tables 6 and 7, along with the survey results for those questions.

Table 6. Statistically significant question responses from a survey of the CMGT 332 Model-Based Methods Analysis Classes in 2013-2014. Total Surveys = 47

Likert Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Omitted	Total
Question Statement: Learning the BIM Software, i.e. Autodesk Revit, Navisworks, Solibri, and Sketch-up was "helpful."							
Fall 2013	10%	0%	10%	50%	30%	0%	100.00%
Spring 2014	0%	8%	30%	43%	19%	0%	100.00%
Question Statement: Learning to Navigate the construction 3D models was "effective."							
Fall 2013	10%	0%	10%	40%	40%	0%	100.00%
Spring 2014	0%	3%	27%	59%	11%	0%	100.00%
Question Statement: Learning Virtual Design and Construction (VDC) processes, i.e. Constructability Reviews, Clash Detection, Scheduling Simulations, etc. was "effective."							

Fall 2013	10%	0%	30%	20%	40%	0%	100.00%
Spring 2014	0%	8%	32%	51%	8%	0%	100.00%
Question Statement: Learning Site Utilization, Methods Analysis, Sequencing, Schedule Analysis, and Architectural QTO was "easy to learn."							
Fall 2013	0%	30%	0%	50%	20%	0%	100.00%
Spring 2014	0%	14%	27%	49%	8%	3%	100.00%
Question Statement: This course was "effective" in improving your overall Virtual Design and Construction (VDC) and BIM Skill Set.							
Fall 2013	10%	10%	0%	30%	50%	0%	100.00%
Spring 2014	0%	3%	32%	54%	11%	0%	100.00%

The author used the point biserial correlation analysis to estimate the statistical significance of the survey questions because the sample size was small and the population, though thought to be normally distributed, had an unknown standard deviation. The results of the statistically significant survey questions suggest that the probability of the effects of integrating VDC technologies in the classroom was not due to chance alone.

Table 7. Statistically Significant Blackboard Learn-related question responses from a survey of the CMGT 332 Model-Based Methods Analysis Classes in 2013-2014.

Total Surveys = 47

Likert Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Omitted	Total
Question Statement: The Digital Reference Materials on Blackboard Learn were "helpful."							
Fall 2013	10%	10%	60%	10%	10%	0%	100.00%
Spring 2014	0%	14%	27%	54%	5%	0%	100.00%
Question Statement: The Announcements on Blackboard Learn were "easy to use."							
Fall 2013	10%	0%	20%	40%	30%	0%	100.00%
Spring 2014	5%	14%	27%	43%	8%	3%	100.00%
Question Statement: The Announcements on Blackboard Learn were "effective."							
Fall 2013	20%	10%	10%	40%	20%	0%	100.00%
Spring 2014	5%	11%	30%	46%	5%	3%	100.00%

Question Statement: The Content on Blackboard Learn was "easy to use."							
Fall 2013	10%	10%	30%	40%	10%	0%	100.00%
Spring 2014	0%	8%	51%	41%	0%	0%	100.00%
Question Statement: The Content on Blackboard Learn was "effective."							
Fall 2013	10%	10%	30%	30%	20%	0%	100.00%
Spring 2014	0%	11%	43%	43%	3%	0%	100.00%
Question Statement: The Exams on Blackboard Learn were "easy to use."							
Fall 2013	20%	10%	40%	10%	20%	0%	100.00%
Spring 2014	5%	16%	43%	14%	0%	22%	100.00%
Question Statement: The Exams on Blackboard Learn were "effective."							
Fall 2013	20%	30%	30%	0%	20%	0%	100.00%
Spring 2014	8%	16%	43%	11%	0%	22%	100.00%
Question Statement: The Gradebook on Blackboard Learn was "easy to use."							
Fall 2013	10%	20%	40%	20%	10%	0%	100.00%
Spring 2014	3%	19%	27%	51%	0%	0%	100.00%

CROSS COURSE ANALYSIS

A comparative analysis of the two Methods Analysis courses was one of the primary purposes of this case study. Table 1 gives some historical context for the two courses. When compared to each other, the two courses did reveal some similarities. Students in both classes completed ten course assignments. Six of the assignments were overlapping, site layout, methods analysis, productivity analysis, sequencing, crew analysis, and safety.

As for other similarities, the same instructor, i.e. the author, taught both courses and utilized the same classroom. The students were primarily CM majors, approximately 90%, in their third year of the CM program at CSU, Chico. The student populations for each course were approximately the same size, i.e. 93 students in the 2005-2006 course and 74 students in the 2013-2014 course. In both courses, approximately 10% of the students were female. Both student groups were able to learn methods analysis concepts within the same semester time constraints. Both courses had ten assignments, plus quizzes and a final exam. Both courses divided students into teams of 3 or 4 students each.

During the first semester of the new model-based course, Fall 2013, the students openly verbalized their frustration and resentment towards the change to a model-based format. But, the instructor attributed this frustration to a lack of preparation with BIM tools by this particular group of students, who had not had appropriate preparation in the two new model-based courses, CMGT 110 Construction Graphics and CMGT 210 Construction Drawings and Specifications. This student group had taken these pre-requisite courses, when they were still non-model based. In response to this frustration the instructor arranged to offer extra BIM software workshops taught by industry representatives. By the Spring 2014 semester, the instructor noted a marked change in student attitude toward the model-based Methods Analysis course. The instructor attributed this more positive attitude to students having more experience with BIM tools from the two pre-requisite courses in the new model-based series, i.e. CMGT 110 and CMGT 210. Toward the end of the spring 2014 semester several students even commented to the instructor that the model-based format was more "real-world."

In the model-based course students had the opportunity to apply several methods analysis concepts to a real-world project, with the goal being to learn not only about the concepts, but also when and how to apply them. The course format and course materials were based on an actual model and contract documents from a recently built project. This use of real contract documents simulated closely what the students would encounter as Project Engineers in the field. The project scope and quality was presented in the form of a building information model. Thus, the students were not required to build the model for the model-based course, only manage it. There was no project model available for the non-model-based course.

The primary difference between the two Methods Analysis courses is attributed to the integration of VDC technologies in the model-based course taught in 2013-2014. Incorporating a model into the 2013-2014 Methods Analysis course lead to a significant difference in course design, the instructor was able to include an actual project model in the design of ten new, integrated project assignments, whereas the non-model based course had ten stand-alone topic-based assignments. The inclusion of a model moved the student experience beyond the traditional classroom experience to one that simulated the complexity and specific details of a real-world project environment. The project model became the framework around which the instructor was able to design the new, integrated course assignments.

Another significant difference is the number of major topics covered in each course. Refer to Table 1 for a historical comparison of topics covered in our Method Analysis course. By using BIM tools in the course the instructor was able to accelerate the time spent on basic methods analysis topics, i.e. site layout, methods analysis, productive analysis, crew analysis, sequencing, and safety, which freed time to spend on VDC related topics, such as, Site Utilities & Foundation (Conflicts), Schedule Analysis, Architectural QTOs, Clash Detection, Constructability Log (Issue Identification), and the Constructability Summary Report (Resolution Identification).

Project constructability was another area of significant difference between the two Methods Analysis courses. In the non-model based Methods Analysis course, the students never really had the opportunity to address project constructability because the ten course assignments were stand-alone assignments and topic-based, not project-based. Switching to integrated, project-based assignments allowed the instructor to introduce project constructability as a major topic of the model-based Methods Analysis course. Student Teams completed a Final Constructability Summary Report, in which they delineated project issues and resolutions. Constructability although mentioned in the non-model based course, was not a major topic or an assignment.

Another difference that the instructor noted between the two courses was that students also had four opportunities to make team presentations in the model-based course. There were no team presentations in the non-model based Methods Analysis course.

In the model-based course the instructor also required the student teams to compile a project notebook, in which they put their ten, integrated project assignments. This project notebook was graded at the mid-term with the first five assignments completed and at the end of the term with the final five assignments completed. These team assignments were completed and graded as a team. Half of a student's final grade was based on their team assignments; the other half was based on individual performance on five quizzes, a final exam, attendance, and participation. In the non-model based course the assignments were stand-alone and were submitted periodically by each student throughout the semester and individually graded. Final grades were based on individual scores for the ten assignments, five quizzes, a final exam, attendance, and participation. No project notebook was required for the non-model based course.

The level of project detail and assignment complexity was the final significant difference between the two Methods Analysis courses. The model-based format allowed the instructor to design into the integrated project assignments a level of detail and complexity that can only be gotten by integrating an actual project model in the course assignments. The non-model based format had only a fraction of the complexity and detail of the model-based course.

FINDINGS AND IMPLICATIONS

A comparison of the non-model based Methods Analysis course with the model-based Methods Analysis course clearly shows that the integration of VDC technologies, processes, and BIM tools enhances the learning environment. This integration allows for the use of more realistic course assignments and an increase in the real-world project details. It enables students to practice making decisions in a more complex model-based learning environment. This case study illustrates that a model-based Methods Analysis course permits students to learn in a more integrated, real-world manner. The findings, in particular, show that there were improvements in the average scores for all overlapping assignments and final grades in the model-based Methods Analysis course.

The case study demonstrated that integrating VDC technologies let the students gain an understanding of the project details in an integrated and structured way, while slowly revealing the complexities of a real-world project. Automating repetitive, time-consuming tasks, such as, quantity take-offs, gave the students more time to spend on the analysis of appropriate project methods and processes. Overall, the students' output in the model based Methods Analysis course was increased when compared to the non-model based Methods Analysis course, which was delivered in a more traditional lecture-lab format. It would not have been possible to teach all the topics of the model-based Methods Analysis course in a traditional manner because of the time constraints of the term.

The findings from our comparison of the two Methods Analysis courses demonstrated that the integration of VDC technologies improved the learning environment by making the class activities and assignments active learning exercises. In the model-based course, the instructor was able to integrate the assignments into a more realistic project-based learning environment. While, both classes allowed students to learn methods analysis, the model-based course allowed that to happen in a more integrated and realistic real-world environment. Refer to Table 3 for evidence of how the integration of VDC processes and technologies increased our ability to teach in the Methods Analysis course.

This model-based learning approach created a less predictable environment, more similar to actual project conditions, and very different than the typical classroom. This approach was part of the course design that tried to simulate the practical experience of being on a real-world project. At first students were hesitant to engage because they are accustomed to passive learning environments. But, once they saw how the class worked and how real world the experience would be, most students engaged themselves in the course for the duration of the semester.

The model-based format allowed the students to formulate a more visual understanding of the level of complexity and detail on a typical project. Without a project model the relationships and interdependencies between building systems, methods, production, equipment, processes, trades, owner, contractor, architect, engineer, subcontractor, quantities, schedule, and cost, all of which contribute to the complexity of a project, are often lost on the student in the classroom. The project model helped the student gain a better understanding of the project scope, the time, the cost, and the risks that go into completing a project.

Studying methods analysis concepts in a model-based course enables students to apply concepts and make decisions within the complexities of an actual project scenario. They learn about project specific details, the complex relationship between building systems, and the interplay of the players on the project, i.e. the owner, the architect/engineer, the general contractor, and the subcontractors. BIM tools allow the student to better understand the dynamic aspect of the construction process.

To summarize our findings, this case study gives evidence that our hypothesis that the integration of VDC technologies into a Methods Analysis course, allows for a more effective means to teach VDC technologies and processes, to improve students' BIM skills, and to deliver method analysis concepts in a hybrid online course that is easy to use and effective. The study further shows that a model-based Methods Analysis course helps instructors design assignments that are more complex, yet well integrated into an active learning environment. Students learn not only the concepts of methods analysis, but when and how to apply them to a real-world project, which are valuable skills for their future careers in construction.

CASE STUDY LIMITATIONS AND THE NEED FOR ADDITIONAL RESEARCH

As with most case studies, there are always new directions that reveal themselves, not only for further qualitative study, but also for future empirical research. The author is confident that the experiences and observations documented in the case study are a realistic analysis of what happened during the efforts to develop and implement a model-based Methods Analysis course at CSU, Chico.

The underlying common goals of all accredited CM curricula affords a certain opportunity to apply these experiences and lessons learned to courses at other CM Departments. From this case study, it appears that the integration of VDC technologies will effectively allow more complexity, more project-specific details, and more realistic course assignments into the learning environment. While the experiences documented in this case study show that BIM models can serve as a new framework for the CM learning environment. Still, other institutions need to proceed cautiously, as integrating VDC technologies, processes, and BIM tools is a paradigm shift, not easily accepted by all faculty, students and administration.

The experiences and observations delineated here clearly demonstrate how integrating VDC technologies improved the overall effectiveness of the learning environment within a model-based Methods Analysis course. Since other CM Departments normally teach similar topics within a means and methods type of course, this case study's findings may act as a strong barometer of the overall applicability of the findings beyond the local environment of this study's CM Department.

In spite of the positive results documented in this case study and the author's confidence in these results there still exists inherent weaknesses in the study. A case study examining only two courses inevitably brings up discussion about how much can be deduced from the findings and applied elsewhere successfully. The main weakness, therefore, is that the effectiveness, in which the experiences and lessons learned described in this case study, can be applied to other educational institutions may be limited.

Model-based courses are based on active learning exercises, blended learning concepts, and the active commitment and engagement of faculty, students, and representatives from local industry. These variables will impact the extent to which other educational institutions can successfully implement the results described in this case study. This type of course development process takes extensive resources, time, and commitment. Not every CM Department will be willing or able to implement these measures. The particular success of others to some unknown degree will be based on the local context and the commitment of that institution (Lee and Dossick 2012).

To increase the application of this study's findings the author recommends the following additional research be explored. Conduct an empirical study to measure the extent to which BIM tools influence the learning environment. Extend the current research to a wider student population by involving other universities. Develop a standardized exam that can measure learning outcomes across a variety of educational institutions. Conduct a more extensive study in parallel with a control group, for example, a study with some students in a non-model based course versus those students in a similar, but model-based course. Perhaps this study would involve two or more universities. This type of study would allow a timelier, direct comparison of the impacts on learning within the two courses.

In addition researchers need to develop better survey questionnaires that would facilitate more extensive statistical analysis. This additional research could provide more quantitative results to indicate a more exacting measurement of a variety of different factors potentially influencing the integration of VDC technologies in the CM classroom, for example, factors like the degree of complexity, the time spent on course assignments, the proficiency of resulting BIM skills, etc. The author also recommends that additional research efforts be focused on what influence model-based courses could have on other CM courses, such as, estimating, scheduling, and cost management.

The literature review pointed to other areas needing study, for example, barriers to integrating BIM, the need for extensive faculty training and development with VDC technologies, processes, and BIM tools, and building industry partnerships to assist in the integration of new technologies, etc. (Taylor et al. 2008).

Finally, the author suggests the need for research studies that show how effective recent graduates with course work in VDC technologies are performing at their positions in industry, i.e. not only to show the effectiveness of model-based courses in the educational setting, but evidence of their impact on the projects in the field. This type of study would try to answer the inevitable questions, do students who learn BIM skills in their undergraduate education perform better and more effectively on their projects in industry, to what extent do companies benefit by having BIM educated project engineers and project managers on their projects, and does their presence on project reduce risk.

This case study points to findings that indicate more real-world project assignments in model-based courses improve the education of future project engineers and project managers, but no long-term study of their performance in practice has been done. This case study shows that this type of long-term study is warranted.

CONCLUSIONS

Within this paper the author has presented evidence that the integration of VDC technologies, processes, and BIM tools can improve the CM faculty's ability to develop and implement a more effective course to teach construction methods analysis in a more realistic, model-based learning environment. In particular, the author has demonstrated that model-based learning activities are actually effective in teaching and learning VDC technologies. In particular, the author illuminated how the introduction of VDC technologies allowed the instructors to design course assignments that naturally included more complexity, realistic conditions, and simulate real-world project details, which helped students learn how VDC technologies integrate with the pre-planning activities for a project, in addition to improving the students' BIM skill set.

The author analyzed and compared a non-model based Methods Analysis course and a model-based Methods Analysis course. Generally, this case study showed that there are some advantages to integrating VDC technologies into CM courses. In particular, this case study demonstrated that integrating model-based courses can significantly increase the quality and effectiveness of course instruction and generally helps CM curriculum be more aligned with the current industry demands and the challenges the student will encounter in industry upon graduation. By increasing the complexity, the amount of project specific detail, and the realism in course assignments, students are better able to learn how to apply VDC technologies, processes, and BIM tools in a real-world context.

In summary, this study shows that model-based courses can be an effective framework for improving learning environments in a CM curriculum. This new model-based teaching and learning approach has proven to be a paradigm shift in the course delivery method and the learning environment for the CM Department at CSU, Chico. This case study provided an analysis of the study's hypotheses, such that the results were shown not only to be important, but also meaningful. The author believes that this case study shows the potential power that integrating VDC technologies have to make CM curriculum current and relevant and thereby, making graduates' BIM skills more valuable to their future employers.

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