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Grounding the Use of Instructional Technology in Principles, Teaching Philosophy, Course Goals and Disciplinary Values

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Out of necessity, when assigned to teach a large introductory class in Construction Science, I quickly learned the requisite instructional technology and its application. 'Learning how to learn' was the ultimate objective of this course. In the process, objectives, goals, syllabus, assignments, projects, evaluations, lectures, and presentation techniques had to be created. After teaching the course two semesters, I sought coaching from Texas A&M University's Center for Teaching Excellence (CTE). This provided an opportunity to reflect on what happened, clarify the theories, examine my teaching philosophy and further clarify the principles that informed the framework for the course. This paper reports on the result of this reflection and is based on wisdom-of-practice scholarship (Weimer, 2006); therefore, it is experience-based and subjective. This paper follows major lines of professional teaching practice, motivation, and findings from decisions made in the process. This paper also captures the evolution of the course, and the areas indicated for further research. More importantly, it advocates a method for teaching with instructional technology, which needs verification by other institutions, as it becomes an area of scholarship suitable for qualitative studies, quantifiable investigations, or descriptive research.

Key Words: Large Classes, Learning, Philosophy, Principle, Teaching Theory

Background

We arrived in College Station, TX from Atlanta, GA, on August 13-15. I needed to get up to speed as quickly as possible on the local/institutional teaching customs, methods, testing, standards and styles of communication and instruction. My primary concerns were with what course I would teach, finding information about the students in the class, creating a syllabus, ordering books, etc. On August 26, I was entrusted with teaching Construction Science Materials and Methods I, and the first class session was Tuesday, August 29. There was no time to plan for this large course or for teaching skills development. Planning and skill development took place concurrently with course delivery.

This course is mandatory for all first year students in the College of Architecture, which means approximately 350 students in the fall and 250 in the spring. As I prepared to teach this very large class, it became clear that the application of specific essentials for teaching large classes could enhance student learning. According to McKeachie (2006), "teaching skillfully may be less time consuming that teaching badly." Aware that a professor's time is limited, I sought ways to maximize doing good, while minimizing doing damage. Personally, I was motivated to become efficient, effective and enjoy teaching students to learn the subject so I could also have time for research, publishing, serving the university and eventually achieving tenure.

A class management system was necessary to minimize administration and maximize communications so that everyone had the latest word on classes, assignments, deadlines, quizzes and exams, and the many challenging day to day activities for a very large class--a system that could operate as “information and communications central 24/7.” During the final exam the entire college system was overloaded and more than 100 students were kicked out in the middle of their examination. Information and communication central proved itself, calming the students by re-setting their entire examination without a hitch. This event is reflected in the student’s comments on course evaluations, but it did not detract from them giving the process resounding approval.

This paper is based on the two types of literature found in the field of teaching by Weimer (2006): wisdom-of-practice scholarship and empirical research scholarship. Wisdom-of-practice scholarship includes personal accounts of change, recommended-practice reports, recommended-content reports and personal narratives. Empirical research scholarship on teaching includes quantitative investigations, qualitative studies and descriptive research. From the above divisions, this paper falls under the category of a recommended-practice report.

The reflective practitioner title is derived from Schön’s work, *Educating the Reflective Practitioner*, 1995:

> “We should think about practice as a setting not only for the application of knowledge but for its generation. We should ask not only how practitioners can better apply the results of academic research, but what kinds of knowing are already embedded in competent practice.”

This paper purports to be more than an anecdotal success story; rather, it embraces discipline, and inclusive scholarship that recognizes that “knowledge is acquired through research, synthesis, practice and teaching,” paraphrasing the words of Ernie Boyer from a decade ago. The major drawback of this paper is the lack of sustained experience. Usually more than two years teaching a course is required for papers proposing pedagogical advice. I refrain, then, from claiming to give advice, but this early edition captures what has taken place and solicits other practitioners who find this paper informative, the method attractive and are in similar teaching conditions, to replicate the process and compare the findings with their own.

General Principle

Graphically, picture the shift from the teacher as a talking textbook to being a sign pointing to where and how one can find relevant information, what one can do with it and why it is important. After all, “we learn if we are extrinsically and intrinsically motivated to learn” (Hofer et al. 1998). In general, I view the classroom as an opportunity for teaching students how to eventually achieve freedom from the educational institutional system so that they may continue learning anything that he or she finds relevant, interesting or necessary in life. This is a carryover from my architectural practice where, after mastering a level of knowledge, my role was finding someone to take my place so that I could seek a new challenge in learning. Teaching large classes requires a mindset that takes into account how students learn, and how to be efficient with administrative work and organization (see Fig. 1); along the way, students learn how to take responsibility for their own learning (also referred to as self-monitoring or self-motivation).

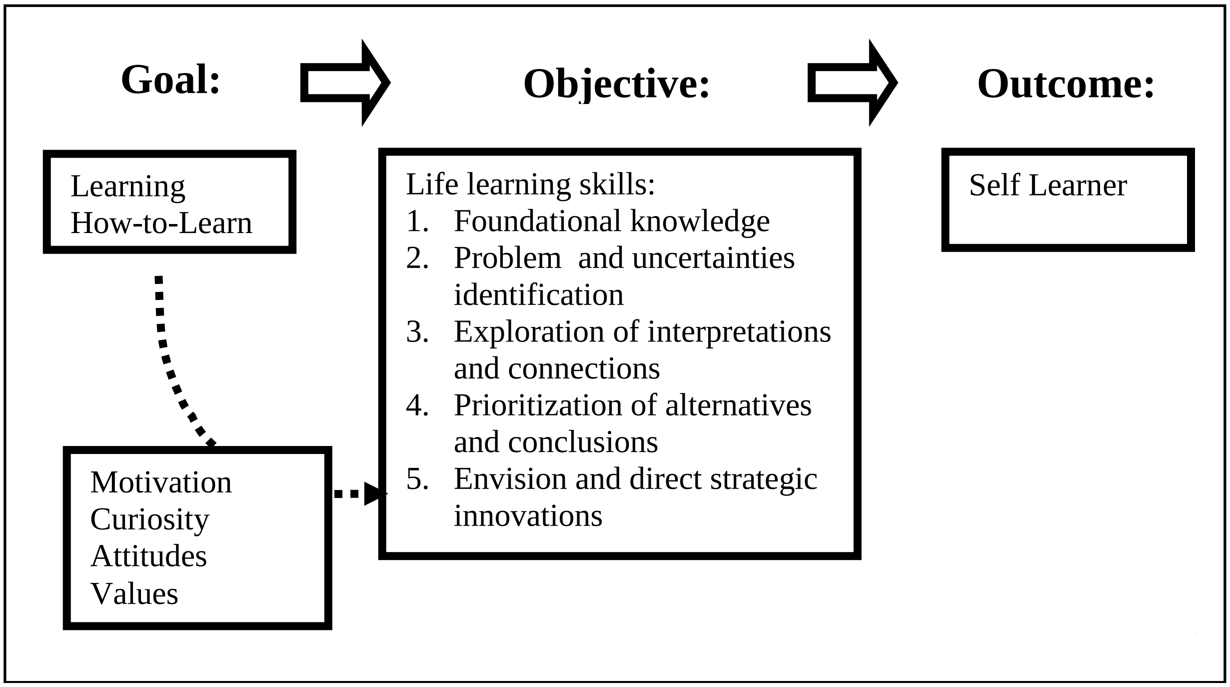

Figure 1: Operational Definitions adapted from Wolcott et al. 2006

Mindset

Before classes began, the department had scheduled a retreat where they invited the Center for Teaching Excellence (CTE) to conduct a departmental Academy for Teaching. The Academy covered subjects like learning and teaching objectives, goals and the elements of a syllabus. However the most important item was the question: What do we really teach? My previous teaching experience led me to conclude that although we give samples of what is important in a field of study or a profession, we are really teaching students how to learn. I remember, in the 1970's, Professor Smith, from Georgia Tech College of Architecture, stating that most architects will end up doing something else in life but what they learned in school was "how to learn whatever a person becomes interested in," a simple guiding principle.

The focus is not on the details of information transfer, but on the process of learning how to learn, discern what is important, where to find and how to filter information and how to think. Teachers, in this sense, serve as pointers--human arrows pointing at knowledge building blocks that academia and the profession has determined to be relevant. This is how we supplant magic (Fraiberg 1996) with science. McKeachie (2006) succinctly describes the classroom transition in six points:

1. What is important is learning, not teaching

2. Teachers can occasionally be wrong
3. Classes are unpredictable
4. Major goal: continue learning after leaving college
5. Learning mostly occurs outside the classroom
6. Reflect on what your students need to accomplish to learn how-to-learn

How do we translate this mindset in a classroom with 350 students, when a typical class contains 35 students? Additionally, the class had freshmen, sophomores, juniors and even seniors, and they were from different disciplines such as Environmental Design – Architecture, Construction Science – building construction, Landscape and Urban Planning and general studies as well as from other disciplines from the Texas A&M campus!

Lectures are related to student listening, and reading, along with listening, is passive ways of learning. Discussions are considered the most effective way of learning **source (year) (**see Fig. 2). The ideal situation appears to be if the entire class or sub-groups are able to discuss a subject at their own pace. The guiding principle is that interactions that facilitate learning need not be limited to those with teachers.

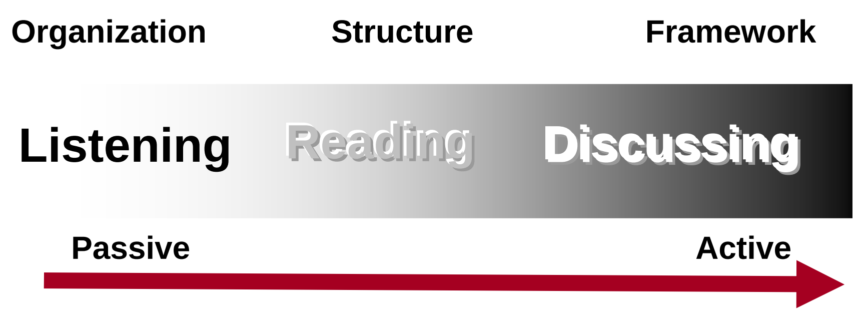

Fig. 2. Gradations of Learning Modes (Adapted from McKeachie and Svinicki (2006)

Tools of the Trade

Teaching has two major components: administration and teaching. Administrative tasks (preparation, assessment, evaluation, and grading) for very large classes, if approached in the same way as small classes, will consume an inordinate amount of time. Teaching tasks (individual student attention, motivation and counseling as well as lectures) for a very large class also require an inordinate amount of time.

Early on I decided to maximize student interaction and minimize administration. The one Teaching Assistant and I enrolled in every course that the Instructional Technology Service (ITS) offered for managing classroom instruction using Web/CT Vista (Blackboard) version 3 (now migrated to version 4) such as:

- Smart Technologies Workshop
- Clickers Workshop
- Blogs and Wikis Workshop
- Vista 4 new users' workshop
- Vista 4 Migrating User Workshop
- Vista 4 Assessment Workshop
- Vista 4 Assignment/Rubrics Workshop
- Vista 4 Communication Tools Workshop

For teaching, besides the ongoing departmental Academy, I enrolled in programs from the Center for Teaching Excellence (CTE), such as:

- Inquiry Based Learning Workshop
- Introduction to the Teaching Portfolio
- Enhancing Critical Thinking Skills by Susan K. Wolcott
- Teaching with Blogs and Wikis
- Developing Students' Critical Thinking Skills by Susan K. Wolcott
- Early Feedback Program 2006 and 2007 (consultant observation, student assessment and a review meeting with the consultant)
- Semester-Long Grant Writing Workshop
- Course Development II: Assessment and Feedback that Demonstrates Student Learning
- Course Development I: Beginning With the End in Mind
- Teaching Large Classes Faculty Learning Community
- Teaching Academy, 2007
    - Writing Effective Learning Outcomes
    - Improving a Course Syllabus
    - Inquiry Based Learning
    - What Best College Teachers Do
    - Developing Student Capabilities
    - Assessment
    - Active Cooperative Learning
    - Project-Based Inquiry Guided Learning
    - Course/Curriculum Design
    - Peer Evaluation and Development Teaching

Based on what I learned and did in the classroom, I was asked to share with other faculty the following: *"What I have learned in Using Vista 4 for a class with 329 students"* at the 3rd Annual Teaching with Technology Conference; and *"Using Technology in the Classroom,"* at the Wakonse South 2006 Conference sponsored by CTE of TAMU. These presentations helped me articulate the work in progress and receive feedback from colleagues.

Fortunately, TAMU, a large and busy university, does not have the impersonal attention that largeness connotes. ITS and CTE provided individual attention and service in helping me learn how to teach; they became models for me to provide, in a large setting, individual attention and service to the students. For example, when I brought to CTE's attention that there were no programs geared to helping teachers learn and share tips and lessons learned about the large class environment, CTE created a Faculty Learning Community that practiced “learning how to learn by group sharing with guidance” another excellent model for walking the talk.

I quickly integrated Web/CT Vista 3 in my plans and on the second semester migrated to Vista 4 which is now a Blackboard instructional technology tool. Of the many features for course management, the most used ones are, in alphabetical order:

- Announcements (which pop-up when students log in)
- Assessments
- Assignments
- Calendar
- Discussions
- Grade Book
- Mail
- Resources
- Roster
- Syllabus
- Who is on Line

Thoughts on How to Assess Large Classes

Assessment of learning and evaluations are a major component of course administration and sometimes offer learning opportunities for the teacher, as well. For this course, I investigated how assessments could become more of a learning tool. In general, it can be said that students like assessments to require reasonable effort and be interesting (Harter, 1978). From my perspective, I was looking for ways to assist students in achieving mastery (demonstrated by a desire to know) rather than to perform (demonstrated by a desire to impress). An acute differential test of this would be that students interested in mastery find mistakes as opportunities while students interested in performance view them as character flaws. Covington (1999) calls them extrinsic (external reward) or intrinsic (self reward) motivations.

Class set up

The class covered twelve chapters and originally I decided to assess two chapters with a quiz and then the same first two chapters plus the next two chapters by an Exam. Since then I have morphed the system to test every two chapters with a quiz, every four chapters with an exam and the entire course with a comprehensive exam, making the progress semi-cumulative. Literature recommends assessing often when using it as a tool for learning; see Fig. 3.

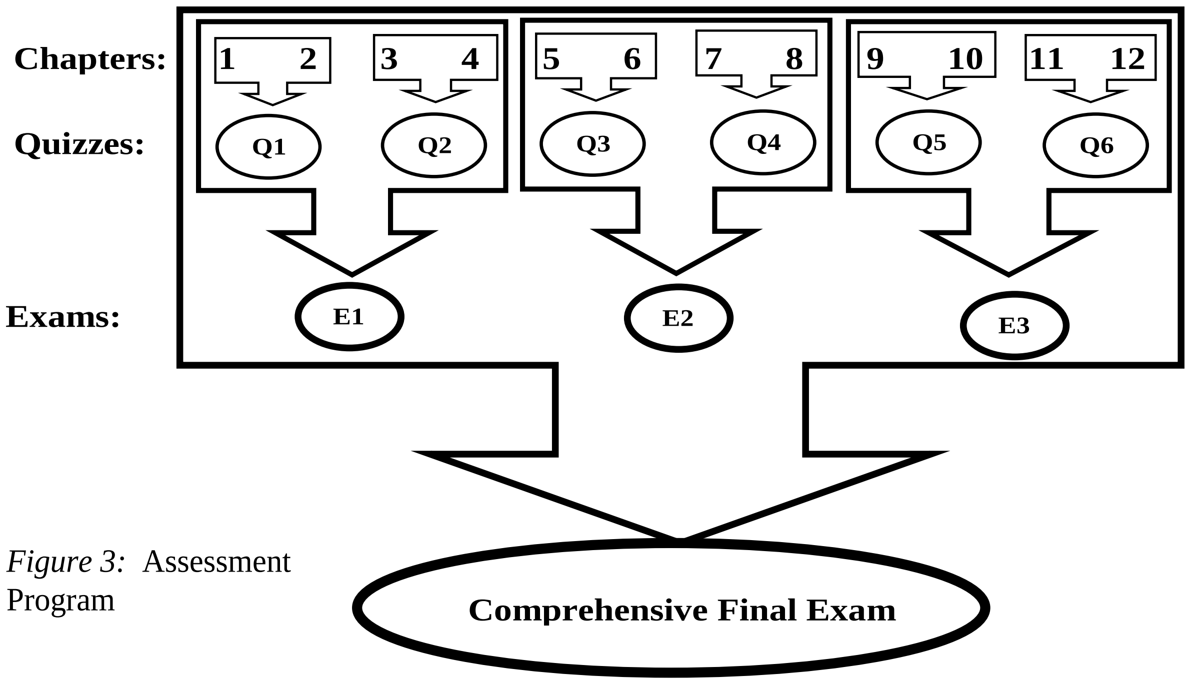

Figure 3: Assessment Program

The assessment process and suggestions on how to study were addressed in the syllabus, as well as in the introductory class presentations. Later on, 'how to study' was repeated before a quiz or an exam and further reiterated during personal student and class evaluation reviews. However the assessments were accomplished in Web/CT Vista, a new tool for most freshmen and even for many other students. As such, it initially created anxiety that needed to be addressed.

Learning is both an individual and a social endeavor (Patrick et al. 1997; Wentzel & Wigfield 1998). The bonds with other students and the professor form a social support system that enhances student motivation, class attendance and participation. Web CT allows each student to post a picture on the class roster thus making it easier for students and the professor to learn students' names and form groups with those they met in class (see Figure. 4).

- **First name:** Jose
- **Last name:** Fernandez-Solis
- **E-mail:** jsolis@tamu.edu
- **Classification:** Assistant Professor
- **Major:** COSC

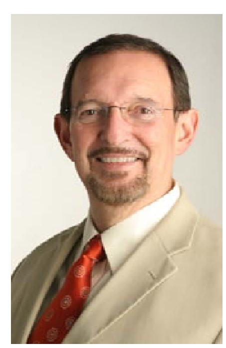

Figure 4: Typical Roster Information in Blackboard

Mitigating Assessment Anxiety

Assessments measure how each student is learning the essence, the building blocks, of the profession, materials and methods. This is a point repeated before and after each evaluation as well as during individual student performance reviews. Progress in the process of learning is more important than grade progress, although the score is an indication of performance at a moment in time. Anxiety is an issue that I treat throughout the semester--it starts with the first day of class and continues in every class.

Academic success has multiple elements that influence the final evaluation. Students can control many of them with their choices and actions: choose to attend class regularly; participate constructively; persist when learning is difficult; devote time and effort in preparing for class; complete assignments according to requirements and on time (be responsible and responsive); take time to review their individual progress with the professor and seek help when needed. Although a grade cannot be attributed to each of the above elements, holistically they are the elements that influence a top grade. Diminish any item and the resulting academic success is affected proportionally.

To minimize students' anxiety, I arrived before class started and after setting up, made conversation with the students that arrived early. After class, I was available while shutting systems down to answer specific questions and receive verbal comments about the presentation. Regarding assessments, a non graded practice quiz on the syllabus was given during the first week of class. This quiz provided guidance on navigating the electronic evaluation and gave me a general view of how the students understood the class contract (the syllabus) and what areas needed further emphasizing. This allowed them control and choice in when and how to take the quiz (Hofer et al. 1998), as the format allows students to decide within a published window the date, time and location. For example a quiz window typically opened Wednesday at 10 am and closed Friday at 4 pm for a 10 question quiz (five true/false [T/F] and five multiple choice [MC]) with an ample 20 minute duration.

Furthermore, during the second week, I gave a fixed bonus point on the last semester comprehensive final exam (CFE). For this bonus exam, I asked the students to not study, not books or note--just become exposed to taking an exam with WebCT/Vista/Blackboard and become exposed to the types of questions that they would later encounter in an exam.

Taking an exam with WebCT/Vista/Blackboard at their own pace, at their own place, on a date of their choosing, is a way of transferring control and choice to students (Lepper & Hodell 1989) on what they consider to be most important: learning and its grade outcome. Exams had a different window than quizzes: they opened up on Friday at 10 am and closed the following Monday at 4 pm. This takes out most excuses of class interference, allows those that like to take it at the end of the week or at the beginning a choice, as well as those that prefer leisure time such as Saturday or Sunday. If there was a conflict on one day, there was another time to choose. Even so, I experienced a number of excuses that tested the edge of believability.

The database of chapter questions initially had a minimum of 20 T/F and 10 MC and they were going to see an exam from a computer randomized series of 5 T/F and 5 MC questions per each of the 12 chapters. Their score would not matter since, by simply taking the entire CFE, they would earn them the 25 bonus points, thus taking the pressure out of performance. This effort also placated those students that felt that because they had worked in construction, they knew the subject matter and those students with a preconceived notion that the class subject matter was easy and would not require study. In one case where the student was adamant that he knew the subject and would make an A in the course, I offered to give him the grade he made on the optional bonus CFE. After a dismal 65% score, the student buckled down to learn the subject matter of the course.

Moreover, this optional bonus CFE created a baseline of knowledge that each student brought to the class, an item that later became significant, as will be explained.

Assessment Set-up

If students take an exam within a window where they can choose the day, time and place, how does one control cheating? Cheating is a major concern of any institution that is primarily focused on testing. If assessments are viewed as a method of learning, cheating takes another perspective. In my syllabus, under the honor code, it states that quizzes are to be taken alone, but exams can be taken individually, with another or in a group. As a matter of fact, each exam asks: Are you taking this exam: alone, with another, with two others, with three others or with more than three. Exams with a group option are a form of cooperative or learning cell when viewed not from a purely evaluation point of view but from a broader perspective as another opportunity for learning (Miller and Groccia 1997; Sokolove 2000, Goldschmid 1971). Did the cooperative exam option improve the grades of those that chose it? This item is discussed later.

The students answered to the question about how they were taking the exam with no self-incrimination. This has been a great tool to assess whether taking the exam alone or in a group affects the score bias. Very interesting results have come from this experiment. A good number of students, after taking the first exam in a group, realized that they were having to take the exam multiple times, the help from other students was minimal or not reliable (some even mentioned that they would have answered a question differently but were persuaded), and they reverted to taking the remaining exams alone. This left those not at the top of the class helping one another; however, when I compared the grades students made on a quiz (alone) with those on an exam (possibly with others), there was no significant difference. Why?

The database of questions is composed of several layers. The questions for any one chapter contain questions that previous classes saw, questions that the students created and perhaps were adapted by the professor (from a low –level question to a higher –level question, per Wilhite 1983) and questions that the professor added, based on items covered in class but not in the text. Besides, any question that previously was found to be ambiguous was deleted from the database. Perhaps the large database of relevant questions and the fact that the computer randomizes each test question to mitigate the possibility of any group of students seeing the same test, is a contributor to the quiz and exam grades being similar.

However, the most important concept behind this set up is that the students are motivated to read the assignments and make up questions for a database they are able to see through the WebCT/Vista/ Blackboard Discussion section for each chapter, giving them a heads-up on what other students found interesting and important, plus the professor's comments on the posted questions. This builds their confidence in learning what is important to learn. According to King (1990), the principle behind this is that "training students to generate thought-provoking questions enhances learning." This approach (students generating questions) goes beyond the think-pare-share of Pressley et al. 1992.

The class becomes one big study group with sub-groups discussing the class material, in a total learning program (see Figure 5).

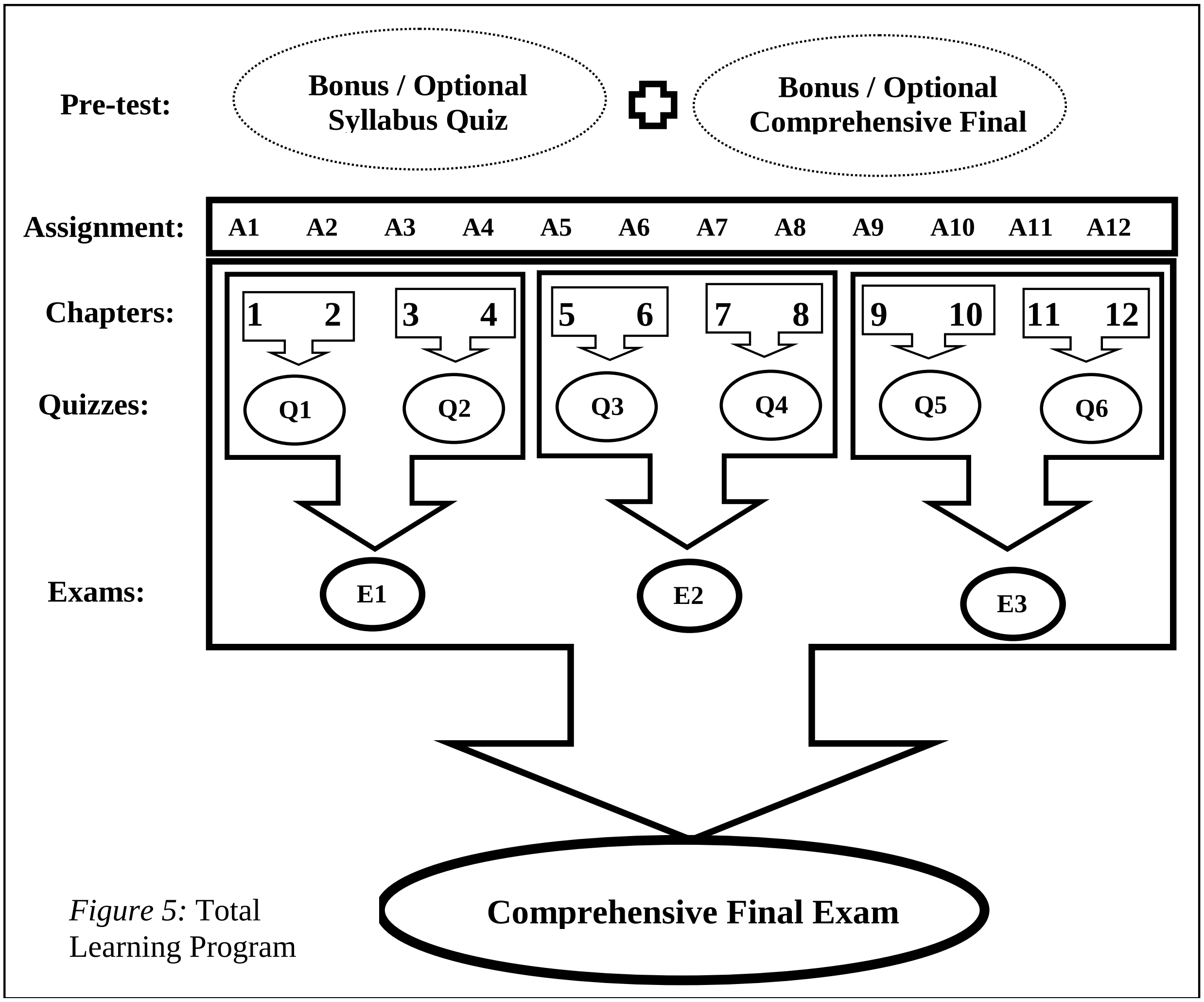

Figure 5: Total Learning Program

Students with a disability were given 1.5 times or twice the time allotted to other students, but Web/CT Vista tracks the amount of time each student takes per question and the total time spent on the evaluation; thus far, only a minority of students took the entire time. As a matter of fact, during the first semester of teaching, the TA accidentally set the time to be 30 hours instead of 30 minutes for a quiz. One student took 6 hours and made a 60%. After checking with CTE, we came to the conclusion that the time pressure could be minimized by doubling the amount of time for quizzes and exams. Since then, there have been no complaints on time and most student finish within the original 30 minutes.

The comprehensive final exam at the end of the semester is now an optional exam that students can take in a group or individually, open book and notes, with an ample window and sufficient time. This takes away the pressure for the student in taking the exam, especially if they score higher than on a previous exam. For those that miss a quiz or an exam, even though there is an ample time window and they could have logged in and taken the exam from any computer in the world, the final exam option is their only make up opportunity.

Notice the standard deviation among quizzes and among exams: they are precisely at acceptable values. The difference between the standard deviation in quizzes with those of the exams is also within acceptable tolerances. The final grade has an even lower standard deviation. In the end, what students will remember a week or a year after the course is more appropriately gauged by the pre-test comprehensive final exam compared to the Optional Comprehensive Final Exam which supposedly was completed under minimal performance pressure, except for those that had missed a quiz or an exam.

In general, prevention of cheating is preferable to punishment. A view of assessments as an opportunity for learning, a moment in time when learning is focused at both an individual and collaborative level, was essential to progressively removing the reasons for cheating: First, I made resources available to the students on a time sensitive assessment. Second, when a quiz window was set up for 30 hours and only two out of more than 200 students took more than one hour, and the student that took six hours scored merely 60%, time sensitivity was taken out of the equation. Time had been a source of student anxiety, and I was glad to remove that impediment. The last taboo encouraging cheating is taking the exam with the advice of others. Reluctantly, at the advice of CTE and by their encouragement to see exams as learning opportunities, collaborative exams were made an option. I have been surprised that the best students have declined this option and I found that individual students' quiz and exam grades were correlated even when the two were taken under different formats. This is definitely a point that merits further experimentation.

Assessments are part of past performance on subjects that are mostly relegated to memory but, when applying for a job or graduate studies, they serve as indicators of future performance. This past performance takes place in a classroom context by an individual, while future performance will take place as part of a professional group. Logic indicates that performance then has two components: individual and collective or collaborative (Lin et al. 2003). The two forms of testing, individual and collaborative, when added together, may end up as a better measure in terms of both validity and reliability at a macro level: validity in that it measures both individual and collaborative effort; reliability, in that both the individual and the collaborative evaluation are within a reasonable range of each other across time and multiple students. This is an interesting fact that merits further argumentation.

Internal validity and reliability of each assessment are based on the following assertions. Validity of the quiz and exam as instruments to test the first block of knowledge in Blooms' taxonomy through the use of True or False and Multiple Choice questions is accepted by the established literature. In other words, it measures what it says it measures: basic knowledge, definitions, first building blocks of knowledge, concepts and deeper thinking of the attributes, criteria and historic evolution of materials and methods in construction. The format appears to be reliable across a limited amount of time although it has not been used by multiple graders at this point in time. One of the reasons for the details in this paper is to entice faculty at other universities teaching this basic course in large class settings to learn and use this format to help validate the findings.

Assessment Questions

Students prepared the T/F and MC questions from their assignment readings either on Saturday, Sunday or Monday and turned in a typed paper version at the Tuesday class, along with a statement of why they found the question interesting, what piqued their curiosity, what else they would like to know about the subject, and any further reading or research that they may have done on the subject matter (see Fig. 6).

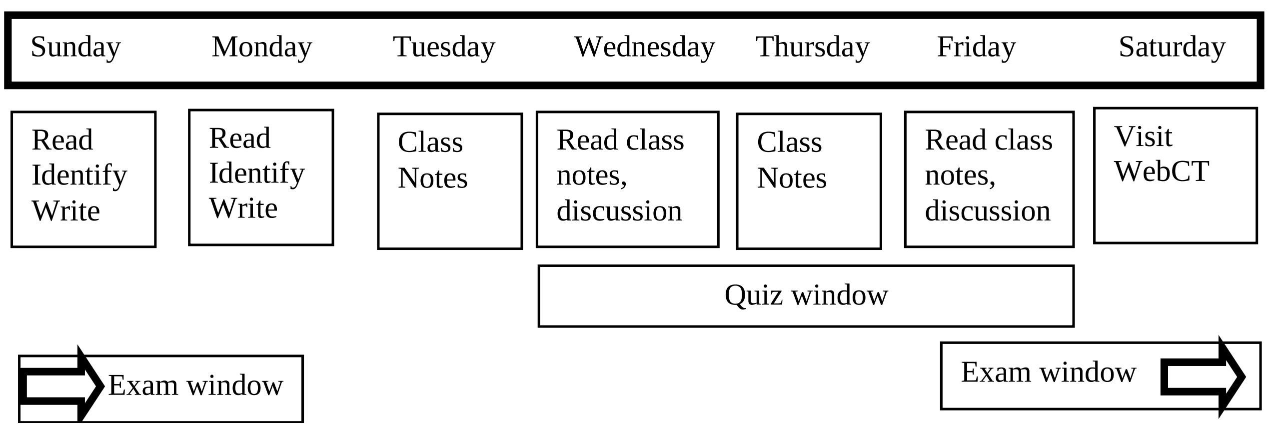

Figure 6: Possible Learning Schedule

The students are encouraged to use the Power Point (PPT) of each chapter that is available on WebCT/Vista/Blackboard as an outline and they should review them before reading the book. The possible learning schedule is based on a 3 credit hour course, with 9 hours of class preparation for a total of a minimum of approximately 12 hours of work weekly. Informally, from students' conversations, there is no direct correlation between study hours and grades since most bright students study and take the evaluations alone, with a reported relatively low number of hours.

The answer needs to also contain the page number where the information can be referenced in the book or note if it is from a statement made in class. An assignment counts for 10 points: handing in a hard copy earns 5 points, the other 5 points are earned when they post the questions on the WebCT/Vista/Blackboard discussion folder, on the corresponding chapter, for the class to see. The TA handles the administrative tasks of turning collecting the papers and posting the electronic version.

The hard copy typed version, along with any other items noted in class presentations, such as questions for discussion or a brief statement, must be turned in at the end of class. The typed requirement means that the question must have been created before class. Un-typed papers received no credit and there was also no credit given if the paper was late.

The posting of the electronic version allows all students to see what others consider important from the readings in the book or in class presentations, as well as the professor's comments (see Fig. 7). If a question merits an "excellent," the students know that the question or a morphed version will be part of the chapter database of questions. If the question merits a "good," it will not. Sometimes a student is asked to elaborate, add information that is missing or re-word the question for consideration. The discussion board of WebCT/Vista/Blackboard belongs to the whole class and takes place off-class, actualizing the statement that most learning takes place outside a classroom context.

From conversations with students, those that took the quizzes and exams alone also preferred to study alone and were usually the top students. Others that studied and took the exam in a group reported that group discussions were beneficial. Students selected their own partners. Generally, students are encouraged to see how a question may be worded differently or

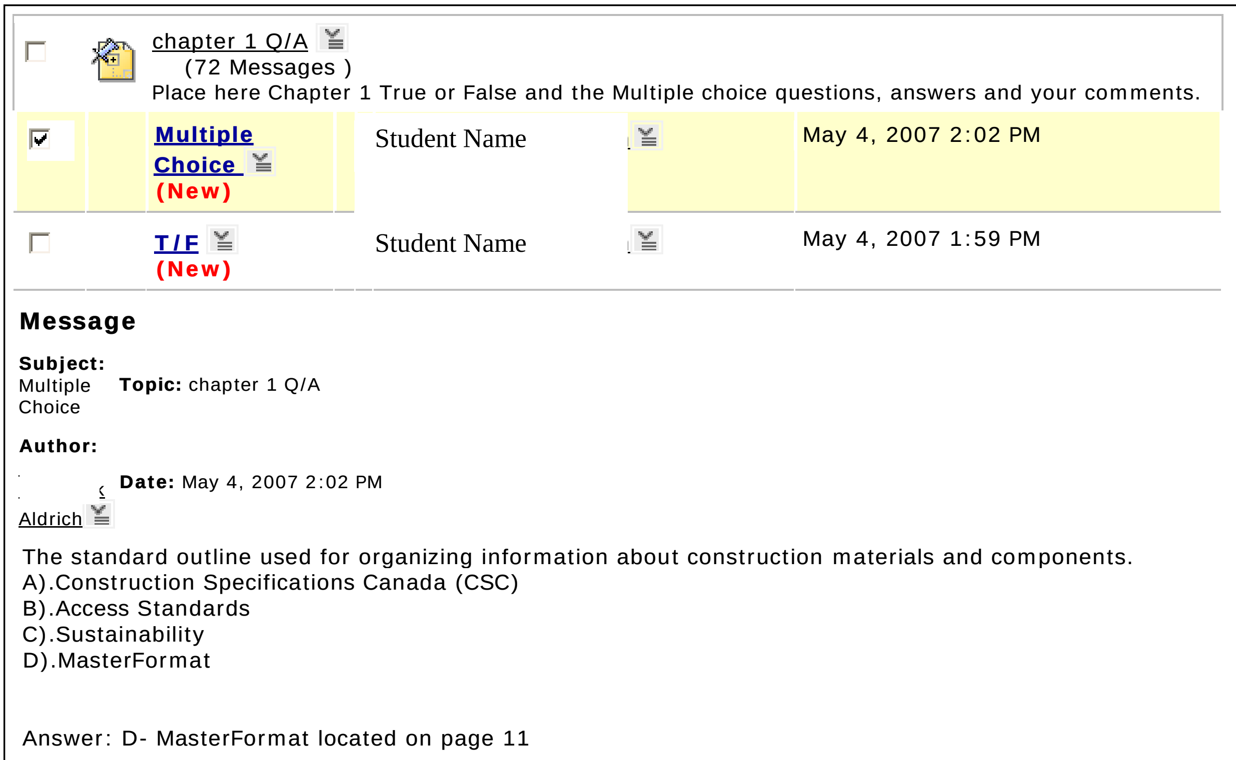

Fig. 7. Sample of Discussion Tab of WebCT/Vista/Blackboard (three screens)

information presented in a questioning form and with practice, their questions are neither too easy, giving away the solution, nor too difficult, out of a recondite context that does not test knowledge. However, all questions require careful review by the professor, a linguistic editor, and a final review with the overall mosaic of questions in the database chosen to see if a picture of knowledge and learning is somehow discernible. In other words, the assignment of writing a minimum of two questions per chapter, one T/F and one MC per student (a class of 200-300+ students generates a considerable number of questions) accomplishes the following:

- The whole class becomes a discussion group, as well as possible sub-groups for study
- Discussion and thinking on how an item of learning can be posed as a type of question with the goal of getting it included in the database (student advantage)
- Discussion on how a question may be morphed and how it could re-appear as a higher-level question (this requires that students think about the material mostly through discussions, Whilite 1983), per the following examples:
    - (MC) How would you apply the concept of __________ in a construction site?
    - (MC) The limited capacity of ___________ affects all of the following EXCEPT?
    - (MC) Researchers of metals and researchers in applications approach the use of __________ differently mainly because of :
    - (MC) Examine the validity of an argument and determine which is the weakest link.
    - (TF) Compare one theory with another
    - (TF) The following are important <u>dimensions</u> (points, criteria, characteristics, attributes) in a comparison
    - (TF) Evaluate, compare or judge the relative values of a ____________ in an argument.

The objectives are:

1. Present the students with multiple opportunities to practice and to see other students practice what is meant by the concept of active learning, self-learning, learning how to learn
2. Provide plenty of examples of how to become self-learners by using bricks and mortar, nails and other common materials and processes as tools
3. Model why it is important that they become self learners through lessons learned, case studies and the rationale (deeper thinking) behind common occurrences and processes.
4. Showcase how to evaluate the evidence behind a product or a manufacturing process, mostly using a historical perspective. In other words, demonstrate how to search for and analyze the rationale underlying what we do in construction. For example (based on Maier 1952 and Bloom's 1956 Taxonomy):
    a. Clarification of a problem
        i. What do we know?
        ii. What data is relevant?
    b. What are the characteristics of an acceptable solution?
    c. What are the possible solutions?
    d. Evaluate these possible solutions against the criteria of the characteristics of an acceptable solution.

Evaluations – Quizzes

Students are informed that the quizzes will reflect an increasing level of difficulty and they should not become complacent if they find the first one easy. The second will be a medium level of difficulty and the third one will be difficult in comparison with the first one. In practice, the record shows a reversal from expectations! Although the first quiz was the easiest, students were apprehensive and usually nervous in taking the first quiz, even after the syllabus and the pre-exam practices. They were not familiar with the system and the types of questions, and it took a quiz to bring home to them the reality of an evaluation on how they were learning. Students' scores actually improved over the course of the semester, even as the difficulty level increased.

Further quizzes contain more comprehensive and complex information and test their increased ability to process information and their improved thinking skills, but experience shows that students who learned how to study, process the information, create meaningful questions, directly in groups or indirectly through WebCT/Vista/Blackboard, discuss other questions. In other words, they have become proficient in learning, at this basic level, in Blooms' taxonomy (acquisition of factual knowledge and development of basic comprehension) with some forays into higher level learning skills (such as analysis, synthesis and evaluation).
During the first class session, and again at least once a month and after each quiz and exam I invite the students to come to my office so that we may get to know each other. Approximately 70% took me up on this offer. Each meeting took approximately 30 minutes, so a class of 350 requires a commitment of about 130 hours. We discuss where they come from, how they performed in high school, what or who influenced their current career path, what experience they have in the field, how they are doing in other classes, their study habits, which class they find the most difficult, whether they have found a person or group to study with, and if not why, and if they have any feedback on what factors facilitate or interfere with their learning. This process requires a good deal of individual attention, but it is where I wanted to put my time and effort, and it has paid off handsomely in course evaluations and feedback.

During the meetings with the students we discuss the individual's performance on the assessments and obviously the question of ambiguity in questions comes up. Regarding ambiguous questions on quizzes or exams, we discuss them to show how the rest of the class that took that specific question did, the merits of the question and what knowledge is being assessed. If the question is found to be ambiguous, it is deleted and everyone that took it is given credit. However, non ambiguous questions are not discounted or eliminated from the data-base, no matter how difficult those that took the question found them, ergo, there were very few 100% scores!

The class performance on a quiz gives a reasonable indication of a question's level of difficulty, as found by those students that were exposed to the question. Comparing how a student did with the rest of the class on a specific question is tempered by the relative level of difficulty of the question, an important factor when discussing student grade attribution. Attribution on the part of the student has three characteristics: locus (internal or external); stability (stable or unstable); and responsibility (controllable or uncontrollable). The best situation is when a student identifies the lack of performance to be external, unstable and controllable. For example, a lower grade is due to not studying sufficiently, a situation that can be remedied by applying more time and effort (possibly studying with a group, reviewing posted questions on WebCT/Vista/Blackboard, etc), thus one over which the student has a choice and can control.

Evaluations – Exams

Exams have the same format as the quizzes but cover more information. The difference here is the option of taking the exam as a group. The underlying reason is to make this primarily a learning event and secondarily, to use it as an assessment. The students have already seen the material in a quiz through questions they missed, and this is an opportunity to revisit the material a little deeper and think about the learning at hand.

Students are encouraged to come visit with me after an exam, just like after a quiz. However, after an exam, approximately 50% of the students have availed themselves of this opportunity to check their performance, or else they did not do as well as they had hoped, and were concerned with gaps in their knowledge. We review how they prepared for the exam and how the group affected the personal evaluation. This is another opportunity to care, motivate and encourage learning.

- Have you missed any classes?
- What is your study program?
- Do you take notes in class?
- Do you have a study group?
- Did you take the exam alone or in a group? How did that affect your evaluation?
- Did you have enough time to complete the exam?
- How did you go about answering the easy and difficult questions?
- What are you going to do differently next time?

Evaluations – Optional Final Comprehensive Exams

A final comprehensive exam brings an inordinate degree of anxiety in students, which is dissipated when it is made optional. Approximately 21% took the Optional Final Comprehensive Exam: 52% of those improved their grades, 10% already had an A and likely took it just to see how they did in relation to their own benchmark at the beginning of the course, and 38% took it and most likely did not have a missing quiz or exam, and did not improve their grades (see Table 1).

Table 1. COSC 253 Spring 2007 Class Statistics	**Actual Grade**	**Percentage**
Final Grade/Total number of students	228	100%
A	78	34%
B	115	50%
C	27	12%
D/F or dropped	9	4%
Final Comprehensive Exam Option	48 out of 228	21% of total =100%
Improved grades	25	52%
Had an A thus no grade change	5	10%
Did not improve grade	18	38%

Evaluations – Final Grade

The assessment that best agrees with the question of what the student will remember in a week, a month, a year’s time, is the delta between what they knew when arriving in class and what they took with them as manifested in the Optional Final Comprehensive Exam.

However, since the quizzes and exams were crafted with the primary intent of being tools for learning, and secondarily, for assessment, it can be inferred that the final grade is first a representation of learning and secondarily an evaluation of each student with self and with the class. The class as a whole identified, to some extent, the questions or areas of interest, and crafted the questions, and the class as a whole determined which questions were ambiguous. The opportunity to take an evaluation as a group can also be construed as a benchmark of the class or sub group against which a student contributes and also is contrasted (see Table 2).

The professor’s questions based on class presentations that augment the course content appear to be the principal differentiator when reviewing with students the questions that they have missed. If someone in the group was not present in class to capture what was being discussed, there was a gap in the knowledge that the group or individual cannot surmount.

Table 2. COSC 253 Spring 2007 (Sample)

Final Grade 100	Quiz #1 100	Quiz #2 100	Quiz #3 100	Exam #1 200	Exam #2 200	Exam #3 200	Syllabus Quiz 10	Pre-test Opt. Comp. Final Exam 120	Optional Comp. Final Exam 120	**Evaluation Point basis**
83.7	79.1	80.6	83.8	160.1	170.6	158.0	7.6	58.7	85.8	**Average**
83.7	79.1	80.6	83.8	80.5	85.3	79.0	76	48.9	71.4	**Average %**
8.6	10.5	11.2	10.2	17.3	16.6	18.8	1.5	8.8	12.3	**Standard Deviation**
	24/16	20/20	20/20	20/20	20/20	20/20	5/5	60/60	60/60	**True or False /Multiple Choice**

Course Evaluation and Feedback

Table 3 is a comparison of the final course evaluation with the department. The course was also observed by the CTE and a critique made in reference to the movement of ‘reformed teaching.’ The majority of students scoring the highest grades took the course exams individually. However, the ones that formed a group through discussion and the interface with each other, learned how to learn, as well. Most failing grades in are from students that dropped out of the course for various reasons, but the system carried their presence until the end and they had to be accounted for with a grade.

Both courses were evaluated at the start of the semester and at the end: The following are representative comments from the students on the subjects of course anxiety, taking the evaluations on line, and the professor's performance, both at the start of the course and at the end.

Table 3. Student Evaluations: COSC Dept. average and Dr. Solis average

Year 2006	Spring	Summer	Fall
COSC Dept Average	4.142	4.386	4.265
Dr. Solis' Average	N/A	N/A	4.36

Early Feedback (score 3.89) (**Spelling corrected**)

- Positive aspects:
  - The material is taught in an extremely effective manner. The student is expected to learn the basics from the readings, but Prof. Solis has made it clear that we are able to ask him questions if we are unsure of even the slightest piece of information. His lectures also help to clear up any confusing portions that the book may not cover as thoroughly as the students hope.
  - He thoroughly tests us on the material of the class. This helps us to really get to know this material which is important to our majors.
  - Prof. Solis makes himself available to us so if we ever need help he is there. He takes time to explain things to us in his own words not just straight from the book.
- Least effective aspects:
  - There is a TON of information in the chapters and I don't know because we haven't taken the first test yet, but I am scared. I feel that it is necessary for you to talk about all the information that will be on the test in class or at least have it on the power point. I think a more fast paced and thorough review would be best on the class time before the exam.
  - On the first quiz there were two questions that were misleading.
  - No complaints really, just that WebCT is not the most reliable site.

End of the Semester (score 4.36) (**spelling corrected**)

- Positive aspects:
  - Although I found this class very boring, I thought Professor Solis did an excellent job because of his thorough knowledge from his experience, his cheery attitude, and his high expectations of us as students, and his overall passion for teaching and importance of learning.
  - The most effective aspect of this course I think is the online Exams. This is because you can take it when you feel confident about the subject matter.
  - I really enjoyed the online exams and quizzes. I also enjoyed how the professor used WebCT for updates and other things. It was a convenient way to find answers to questions.

    - Professor Solis was an excellent teacher! The exams were a little difficult, but I would definitely take another class one of courses.
- Least effective aspects:
    - Grades for the bird house were idiotic and made no sense. I know someone on the community who got a 100 said: she worked for no more than hour: half. On the other hand I spent 15+ hours on bird house and get a B. Solis quizzes: exams being online were not good he would word questions wrong: would piss everyone off so he would have to change grades after they were over. On one of my exam I got an 86 and 5 days later it turned in to an 84%. On his syllabus he had quizzes posted as a certain day: the quiz would actually be a class or 2 ahead of the syllabus. I' m running out of paper, I could probably write for days on how Solis is a Newb.

Techniques for Starting Large Class Discussions

Undoubtedly one of the most challenging tasks within a large class is to start a discussion. Based on recommendations found in McKeachie (200?) and Svinicki (2006), I asked 4 or 5 students, since that is about the number of areas in the auditorium, to act as 'interviewers' for the class by asking the questions that either they think other students would like to ask, if other students passed on to them questions that they would like to consider asking. The interviewers were also asked to paraphrase or summarize a question or issue from time to time as necessary to obtain clarity and a different perspective.

The first assignment is key: typed, background information they had to provide:

- Last name, First, Student Identification Number
- Program (ENDS, COSC, LAND, GENS, OTHER, year in the program (Fr, So, Jr, Sr)
- The minimum number of questions for Chapter 1
- Any research of background information or evidence that they found interesting
- Why they chose the question, what is of interest or what piqued their curiosity on the subject?
- What would you like to have further explained about the subject?
- Did you encounter any problems with the readings, discussions or are there any unresolved problems from the previous meeting?

A short paragraph on the following

- What are your expectations for this course?
- What bugs you most about a teacher?
- What bugs you most about other students?
- What are your concerns about this course?
- What have you heard about this course?
- What grade are you willing to work for in this course?
- What would you like to know about your professor?

Observations

Although the lecture format was challenged by printing, television, teaching machines, computer and now web based on-line-learning, there appears to be a persistent need for human contact and learning that spikes curiosity, intrigue, fascination, interest, value and importance of a subject matter. The lecture/listening format emphasizes motivation and other qualitative attributes and serve as a human model of how to organize the information seeking process and models thinking strategies (see Fig. 2). The motivating aspect of my lectures, based on 30 years of experience as an architect practicing contract administration, that is where design meets construction, is to relate how and mostly why what they are learning is important, and knowing that information translates into skills that are valuable in doing things right the first time, avoiding conflict and possibly litigation. The delivery method is as important as the information and to that end, I try to make my exchanges with the students varied and full of novelty, surprising even myself in the performance. If something is interesting to me and I find it enjoyable, perhaps it will transfer to the students as a subject worthy of interest and enjoyment.

The readings provide a structure of an example of the data and information to be mined. As a focus of information it is a mother lode, concentrating on processed and semi processed thinking patterns for the learner to practice outlining and extracting valuable insights. The ongoing discussion through WebCT/Vista/Blackboard with the class and the professor at large, as well as with other selected students, provides the framework for practicing thinking strategies, manipulating the evidence, applying rationality, deciphering theory and practicing scientific principles at large while learning the tools of the professional paradigm within a cultural framework.

Using the proposed evaluation format, there is not a class period lost to evaluations and assessment! This allows more time for class discussions, lectures and early dismissal (5 to 10 minutes) to allow brief after class student interactions. I also take considerable time (15 minutes) during the classes before a quiz or an exam to go over study habits, what students have reported in general that they did to improve their study and learning habits, familiarize them further with the format, and give them pointers on how to take the evaluations such as:

- Know the material through remote and proximate preparation (see Fig. 5)
- Go through the evaluation and answer all the question about which you have a reasonable degree of certainty
- Go through the evaluation a second time and attempt those questions that you left out the first time
- What remains are difficult questions for you. If possible, for each question, eliminate obviously incorrect choices and answer as many questions as possible
- With the remainder, use your notes, books and power point slide presentation to research the most difficult questions for you
- If running out of time, there is no penalty for incorrect answers, take what appears the most reasonable answer to you.
- Remember that studies have shown that students usually change right to wrong answers (Mueller and Wasser (1997).

After the evaluation I also take time (15 to 20 minutes) with the entire class to keep them informed of their performance, what the class average was, and how the issues of test ambiguities will be handled. I invite them to make an appointment to discuss in further detail their study and learning habits and any assessment issues that they would like to raise.

Although not articulated by the students, I observed that in the first sessions, before they learned how to access the power point presentations, which were an outline of ‘what has been found important’ in the chapter, the students took copious notes. Afterwards, the students stopped taking notes and just stared. For some time I thought that I had lost the students but assessments indicated that they were listening deeply, were motivated and challenged to learn and did learn through the process. It appears that the students were thinking and elaborating knowledge by linking it with concepts, facts and principles within their own framework.

During the lectures I try to emphasize the principles at work, knowing that if grasped, the details will be more easily retained. However it is the principle that is illustrated with samples and shown from different perspectives, that remains after time has blown away the details into deep memory. Clarity of principles, and fun in the presentation of details is a good combination (see Figure 8).

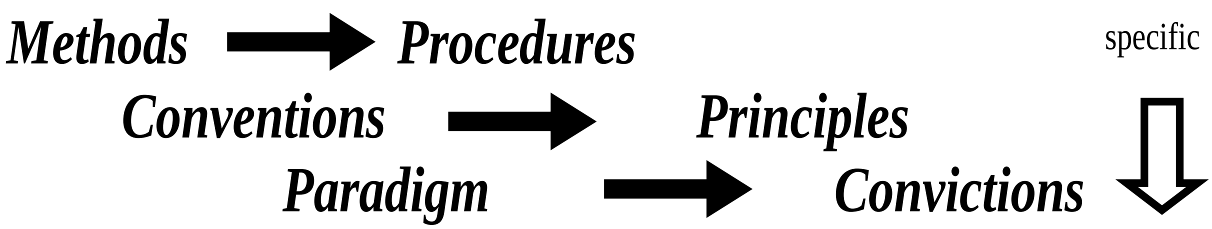

Figure 8: Characterization of Conceptual Relationships Used in a Field or Discipline

An example of a principle: building construction communicates graphically. I model for the students how most of what we do in design and construction is translated by visual cues such as sketches, drawings, charts, graphs etc. Students are encouraged to think visually and take notes by sketch and notations rather than sentences and words. Graphic representation increases flexibility, spontaneity and mnemonic devices of association that aid with information retention (Mayer 2001). By using graphic representation, students become proficient in this type of language (symbols and meanings) that the profession employs extensively. Why it that we have this intermediary form of communication? It is has to do with the fact that most human were pre-literate before the advent of the printing press. Drawings were the preferred method of communicating between the literate (royal) architect and the (mostly pre-literate) builder. Although we use words in verbal communication the preferred mode of communicating in the profession essentially remains graphical in nature.

For example, I describe a site plan in words and have the class write it out and then draw it. We then compare notes on the final drawing that is shown on the projector. Case in point: drawings are a preferred form of communication and record keeping in the built environment profession.

During the first semester, when a student came with a valid excuse for missing a quiz or an exam, all I had to do was to open up the window and the problem was solved, a practice that I have discontinued. Now, those that miss a quiz or an exam have the final comprehensive exam option to make up for one item, either a quiz or an exam. However, even though the excused student took the quiz or exam after the class, the grades were not different from his or her other grades; that is, they were in line with the individual student's trend. On line testing in this fashion eliminates having to bring enough paper tests, of different versions, in a crowded classroom with no empty seats to spread the students out, having tests missing from students not turning them in and the effort of passing them out, collecting the 350 tests and grading them! During the test, if it was in a classroom setting, I could envision a number of students coming to complain about ambiguous questions and wanting corrections right on the spot. This potential interruption is also eliminated by on line testing.

During the first and second semester of teaching the course, only three quizzes were given and an exam covered two chapters that were covered in the previous quiz and two new chapters. The current format follows the advice of more frequent testing; thus there are six quizzes and three exams. The additional quizzes, taken individually, provide motivation for learning and mastering the material before taking an exam of a larger body of knowledge. The large database makes it likely that in the exam the students will see some of the same questions, but mostly new questions that other students have contributed. Thus, a participatory setting for taking the exam is allowed with the hopes of generating discussion and cooperative-collaborative learning (interpreted as interdependence in working towards a common goal, Cooper et al. 2003).

Conclusions

According to the student evaluations of the course, we can infer that the lack of time for course preparation had no negative impact on the teaching or student learning. The goal of minimizing the negative through the use of instructional technologies appears to have enhanced teaching and learning. The course managing tool along with enhanced class discussions, student generation of relevant and insightful questions, the promoted individual, collaborative, cooperative learning ambient contributed to satisfy the student need for social interaction.

Where there any changes in teaching and learning practices as result of the new technology? From the teaching side, a conscious emphasis on using technology, lectures, discussions, assessments and the entire course experience as an opportunity to showcase the students how to learn a complex subject using instructional technology was a major change. From the students, according to their course evaluation and comments, it appears that there was a high level of student engagement in learning; and a high level of student interaction with the instructor and other students that was propitiated by the instructional technology.

Did the changes in teaching practice and use of technology help students achieve the course goals and learning objectives? Everyone that took the final comprehensive examination option had a remarkable increase in score from the pre-test FCE; students report that they not only learned but enjoyed the course and research indicates that learning is more permanent when it is enjoyable.

How does the technology impact teaching and learning efficiently? From an instructor point of view it allows a one source course management system that is integrated; the use of time for student interaction instead of grading and managing complaints; was able to put what was learned in practice, on the run, then the following semester investigated the principles and theory behind and evolved the course for a third presentation with better preparation and management skills.

Improvements and Further Research

Undoubtedly the student response system (also known as clicker) would be an excellent tool to have in class to improve student participation and discussion, however at the time these two courses were offered the clicker was not properly synchronized with WebCT/Vista/Blackboard/Vista 4.0 version and could not be relied upon.

There are several areas of improvement that come to mind: One is to convert the PowerPoint presentations from content outline to content questions; the other is to increase the number of case studies during the course that are specifically tailored to the course material; incorporate the minute and 'half sheet' papers; use the student response system as soon as it is compatible with Blackboard; learning to use an electronic appointment calendar and tie it in with one master calendar; using the concept of virtual office hours thus being available on line at announced times for the students; visiting and observing other successful large classes; videotaping a class and reviewing it with the Center for Teaching Excellence continue practicing pin-drop silence (pregnant pauses) to allow concepts to sink in; continue mastering the art of creating a virtual picture of what is being said for the students to grasp; practice on the spot cadence to allow for a performance with breaks.

The findings of teaching this course two semesters needs further study and corroboration. I am planning, if given the opportunity to continue teaching the course with the syllabus and set up mentioned in this paper and add to the findings as well as learn to interpret what the students are learning with this process. I hope that in four years, when the freshmen 06 begin graduating to have the opportunity of performing an exit interview on what they learned the most in COSC 253. My hopes that it is nothing in particular, just that they learned how to learn and that it helped them throughout their university experience.

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Empirical Application of Building Information Modeling to Academic Building Construction

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Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. The BIM is expected to speed up the design process and enhance communication between stakeholders. Although the BIM concept has been aggressively utilized by many designers, there is little empirical evidence of the merit of BIM in terms of utilizing it in construction. Lack of confidence in the merit of BIM in construction makes most general contractors reluctant to use BIM for their projects. SpawGlass teamed up with Texas A&M University to investigate the merit of BIM in construction. The research team applied the BIM concept to the Sam Houston State University (SHSU) Academic Building 5 project seeking proofs that BIM facilitates general contractors to improve construction planning. As a first step, the research team created a BIM model and started using it to facilitate communication among project participants. This paper presents the process of creating the BIM model and what research team has learned from utilizing it on the job site.

Key Words: Construction, Building Information Modeling, Communication Technology.

Introduction

The planning process is critical to the successful development and execution of a construction project. Current planning practices adopted by the construction industry continue to be substantially manual. Project information is primarily exchanged via paper documents, and the visualization of the facility is marginally communicated using 2D drawings. Experienced constructors are capable of interpreting the 2D drawings and bar chart schedule. But for a complex construction project the exploration of advanced planning techniques could play a pivotal role in the management process.

Understanding the 2D drawings requires education in the conventions of drawing. Individuals need training to visualize a structure in their mind from reading 2D drawings. Moreover, developing a construction schedule is even harder because one must build a structure step-by-step in one’s mind after visualizing it. Nowadays, the construction industry is more familiar with the uptake of 4D models (3D + time) to improve visualization of construction schedules. The most common feature of 4D visualization is that it brings together the Gantt chart schedule information and three dimensional components of a construction project (Ahmed & Walid, 2002).

One should also note that human beings obtain 83% of their knowledge from visual observation, thus making graphical representation of knowledge a necessary communicating tool (Murigio 1969). Top ranked engineering, procurement and construction firms like Stone and Webster, Black and Veatch, Bechtel Corporation and Fluor are using Visualization technologies for reviewing constructability, checking interference, material take off, and conveying design intent, but its implementation in the industry has yet to reach maturity (Mahoney, Tatum and Kishi 1990).

A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability. Some have identified BIM as only 3D modeling and visualization. While partially true, this description is limiting. A more useful concept is that a BIM should access all pertinent graphic and non-graphic information about a facility as an integrated resource. A primary goal is to eliminate re-gathering or reformatting of facility information; which is wasteful. BIM standards have many objectives but one of the most important is to improve business functioning so that collection, use and maintenance of facility information is a part of doing business by the authoritative source and not a separate activity (Edgar & Smith 2006).

BIM in Design and Construction Industry

Mortenson Construction used 3D/4D technology for the Walt Disney Concert Hall project designed by Frank Gehry. To some extent, Mortenson was forced to adopt 3D as they received a 3D model from the architect as contract document. The 3D model was in the form of 3D line wire frames, and Mortenson had to convert each and one of them into 3D geometric polygons. For the auditorium ceiling, Mortenson received a 3D CATIA model so Mortenson had to use this for designing the actual ceiling panels in 3D world using CATIA. The 3D model also functioned as shop drawing for construction. The same was true for the ductwork above the ceiling, and other components of the building. Being a complex building to construct, the scheduling was critical and Mortenson collaborated with Stanford's CIFE and Walt Disney Imagineering to create a 4D model, integrating the time factor into the 3D model. Mortenson found 4D a very powerful communication tool and now routinely uses it on projects (Khemlani 2006a).

For its more recent Denver Art Museum Expansion project, Mortenson embraced innovation and aggressively implemented 3D/4D without being forced into it as with the Disney Concert Hall project. What also helped in this case was the both the architect and the structural engineer were also using 3D for their respective tasks. Mortenson used both the architectural and structural models to create a detailed 3D construction model integrating all the main subsystems: the concrete model comprising foundations, basement, and core walls; the steel model comprising beams, columns, plates, and angles; the architectural model comprising the shell, interior walls, ceilings, soffits, doors, and windows; the mechanical system comprising ducts, and shafts; the sanitary, water, and gas plumbing systems; the electrical system including light fixtures, conduit, and trays; the fire protection system including pipes, fittings, and heads; and other miscellaneous components. The detailed model helped in multi-disciplinary coordination and clash detection through the use of NavisWorks; it also allowed the complex details of the project to be better visualized in 3D (Khemlani, 2006a).

The GSA (US General Services Administration) has been one of the leading owners at the forefront of BIM implementation. The GSA has even taken the extreme step of mandating the use of IFC-based BIM and believes that BIM adoption should not be driven by cost savings alone, but for its many other benefits such as the ability to explore different engineering systems, perform energy analysis for LEED certification, derive specifications automatically, and eventually eliminate the use of paper and paper-based processes (Khemlani, 2006b).

Stubbins Associates are using their "hypertrack" process, where the entire team; architect, engineer, owner, and construction manager; is brought together at the very beginning of a project. This has resulted in projects being delivered 2 to 14 months ahead of schedule, and budget savings ranging from 5% to 10%. Stubbins was doing this even before its BIM implementation got underway, but is finding that BIM is ideally suited for the hypertrack process (Khemlani, 2006b).

Case Study at Sam Houston State University

Sam Houston State University’s Academic Building 5 Project. is a CM at risk project and SpawGlass Construction is involved with the project since its inception along with WHR Architects. Revit was used by the architects to prepare construction documents. Thus the project underwent thorough design analysis before reaching the construction stage. The construction began on 24th May 2007 with a 16 month scheduled completion date. SpawGlass teamed up with Texas A&M University to probe the advantages of BIM for construction sequencing and conflict resolution at site.

The information provided by the Revit model was not sufficient to construct a time schedule based sequence structure. Thus all building elements were remodeled to suit the construction schedule. This led to the creation of a second model termed as “Construction Model” and let to additional time investment. In the first phase the Architectural and Structural elements were created in Constructor 2007 of Vico Software. The second phase of the project involves the creation of MEP model and testing scheduling connectivity, an essential component of ongoing research. The project is thus closely supervised on computer as it is built on site providing an opportunity for contractors to resolve site based issues. The model is being tested in site co-ordination meetings with sub-contractors. For instance, during the steel sub- contractor meeting, the model was used to explain the sequence of steel members and floor decks. This assisted the sub-contractor to come up with detail sequence plan to locate the steel storage areas and identify erection strategy. The 3D model provided the opportunity to locate and communicate design conflicts. For example, the image shown below highlights a beam with a missing end connection support. An RFI was written with this concern and clarifications were sought from the Architects. Sequencing and scheduling aspects of the project are currently under test and the research team is collaborating with software vendors to seek the best possible solution.

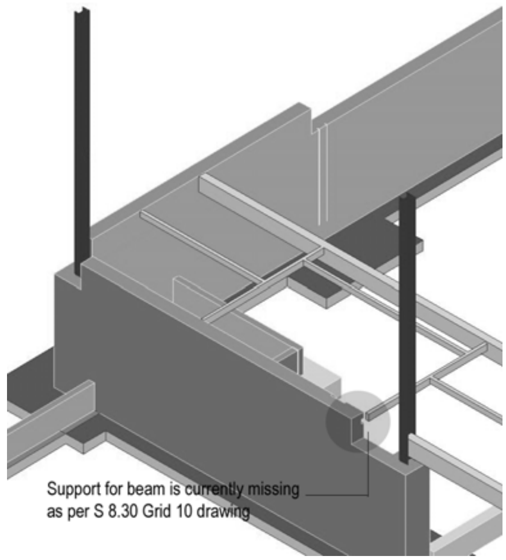

Figure 1: Snapshot of project model looking at missing end support for a beam

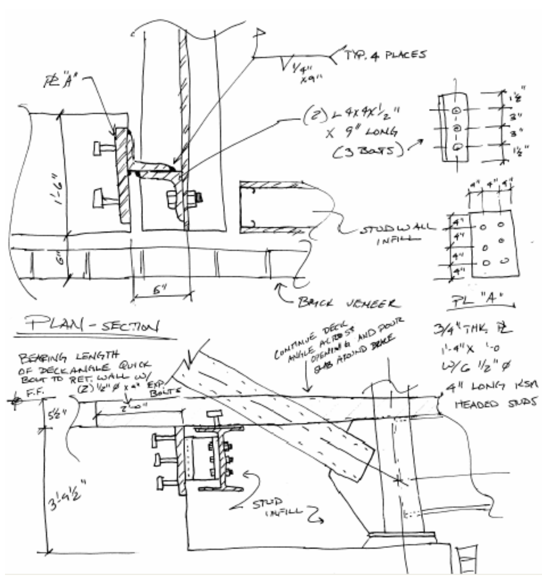

Figure 2: Detail connection drawing sent by the Engineer to resolve the above problem

Significance of the study and future questions

Based on field observations it was realized that 3D modeling aspect of BIM definitely plays a significant role in design clarification and communication. The other aspect of BIM to extract scheduling information for achieving a 2-way dynamic connection between the simulated building elements and time-schedule has been a cumbersome process and is under research tests. The ownership of the project model and amount of time invested by contractors to handle BIM information is a critical question and will form an important component of the final research findings. Lack of confidence in the merit of BIM in construction makes most general contractors reluctant to use the BIM concept for their projects. Knowing many construction projects that pioneered the use of new technologies have ended up getting cost overruns and schedule slips, few general contractors want to place their project at such risk. With BIM, new methods of project delivery systems need to be discovered to enable a common platform for all project participants. The BIM model needs to be created, updated and shared constantly between project participants contributing towards building a shared resource project knowledgebase. Integrating the contractor's project needs, such as time schedules, project resources and material procurement in the BIM model from the beginning stages of the project can substantially minimize contractor's resistance in handling BIM information.

Acknowledgement

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Peer Evaluation in an Active Learning Group Project

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Active learning is reinforced in hands-on projects. Peer learning is an effective teaching tool. Peer evaluation is appropriate in group projects. Peer evaluation is an effective motivational tool for stimulating group participation. Students are reluctant to provide critical evaluation of peers. A matrix-based algorithm for anonymous peer evaluation with variable degree of instructor control can be adapted for multiple groups and rubrics in a hands-on laboratory project. This project builds on an active learning model for a scale model reinforced concrete structure.

Key Words: Peer Evaluation, Active Learning, Concrete Design, Model Building, Group Projects, Rubrics

Introduction

Group projects are great for construction management students. The team concept develops necessary career skills. Group projects encourage peer learning. Students may learn better from another student than from an instructor. It is natural to expect students working on group projects to evaluate the work of other students in the group. However, peer grading can be frustrating for the instructor. Students tend to be lenient when evaluating the work of other members of the group. This lack of critical evaluation was observed on the peer evaluations performed by students that worked in teams to construct scale model reinforced concrete buildings in a reinforced concrete and formwork course (Bray & Manry, 2007). This paper proposes to implement and extend an existing robust peer grading scheme (Feigenbaum & Holland, 1997).

Background

A hands-on, active learning approach to teaching reinforced concrete and formwork design by building a scale model of a reinforced concrete structure has been shown to be effective in motivating construction management students to learn structural design concepts (Bray & Manry, 2007). Figure 1 shows a scale model reinforced concrete building. The scale is 1" = 1 foot. Students constructed the model in teams over a six-week period of a semester course. Students worked in semi autonomous groups for six weeks during a one semester course. The student project represented a significant part of the course grade and became a reference for design examples and calculations for the remainder of the course. The project grade included peer grading. The fall 2007 semester was the fourth cycle for the group project.

Revisions

Several revisions have been made. The number of models built has been reduced from six to one. The group selection and grading process was modified in fall 2006 and 2007 to model the construction process. The instructor selected students to assist the instructor in the role of Owner's Representative and in the role of Project Manager to represent the Contractor. The Project Manager selected a staff and foremen for the labor crews. The foremen selected crew members from the remaining students. Figure 2 shows the organization of the groups.

Figure 1: Scale Model Reinforced Concrete Building

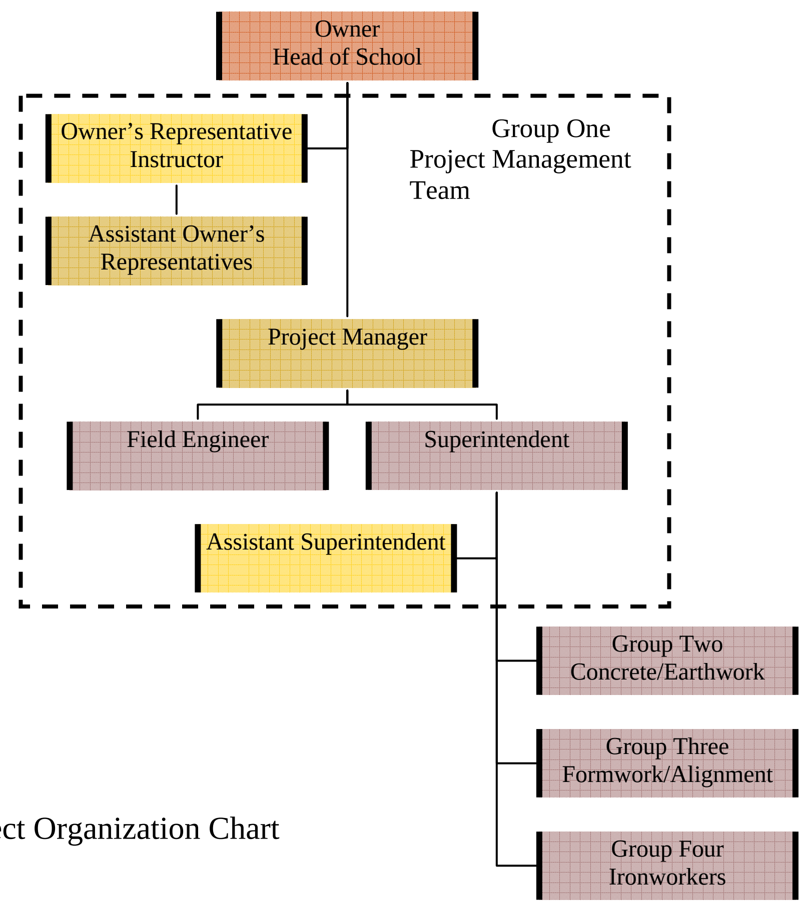

Figure 2: Project Organization Chart

The group grading methodology has also been changed. Table 1 shows the first peer grading scheme implemented during the third cycle, fall 2006. This simple scheme allowed individuals to assign a portion of the grade of another individual in the group. The instructor retained control of 60% of the project points. The problem with this approach soon became obvious. Most of the time students did not take the time to critically evaluate their peers. In almost every case students gave the maximum rating to their group members. The exceptions were in extreme cases of absenteeism, lack of cooperation and failed leadership (Bray & Manry, 2007).

Table 1

Peer Grading Weights Fall 2006

Student	**Source of Grade**
Project Manager	20%-field engineer 20%-superintendent 60%-owner's representative
Field Engineer	30%-project manager 10%-superintendent 60%-owner's representative
Superintendent	20%-project manager 5%-field engineer 15%-crew foremen 60%-owner's representative
Crew Foremen Ironworker Concrete Forms	20%-project manager 10%-field engineer 10%-crew 60%-owner's representative
Crew Members	20%-crew foreman 20%-other crew members 60%-owner's representative
Owner's Representative	20%-project manager 10%- field engineer 10%-superintendent 60%-instructor

Peer Evaluation Method

The revised peer grading scheme has four groups as shown in Figure 2. The dotted line in Figure 2 encloses group 1, the project management team. Each group is assigned a grade by the instructor according to the rubric shown in Appendix A. Members of the group complete an evaluation matrix assessing themselves and the other members of the group (Feigenbaum & Holland, 1997). The grades of the individuals in the group will be distributed about the average of the group grade. In the revised scheme, a rubric is provided for assessment of the group members. The rubric for the group assessment of the Project Management Team is shown in Table 2.

Table 2.

Peer Evaluation of Project Management Team

Criteria	**Points**
Leadership-*Showed individual leadership in the form of preparation, enthusiasm, commitment, organization, and communication to the degree appropriate to the position within the group by taking initiative.*	20
Cooperation-*Willingness to work together to accomplish the job of the group.*	20
Communication-*Shared information with the group, particularly in written form.*	20
Participation-*Did the appropriate share of work.*	20
Attendance-*Present and on time for work.*	20
TOTAL	100

Figure 3 shows the mathematical algorithm for distributing the group grades (Berryman, 1999). The Individual Evaluation Ratio (IER), a weighting factor, is calculated from the points assigned to individuals and the total number of points assigned. Figure 3 shows the calculation of the individual score using the IER. In this equation, the weight given to the peer evaluation versus the instructor can be controlled by varying the percent of grade controlled by the student as shown in Figure 3.

$$\text{IER} = \frac{\sum \text{Points Assigned to An Individual in the Group}}{\sum \text{Points Assigned}}$$

$$\begin{aligned}\text{Individual Score, \%} = &\left[\ \text{\% of Grade Controlled by Students} \times \text{Group Grade, \%} \times \text{IER}\ \right] \\ &+ \left[\text{Group Grade, \%} \times (1 - \text{\% of Grade Controlled by Students})\right]\end{aligned}$$

Figure 3: Individual Score Calculations

Data Collection Method

In the fall 2007 cycle, an innovative method will be used to collect the group evaluation data. A spreadsheet is being developed to collect the group evaluations. Figure 4 shows the user interface of the spreadsheet. By using Visual Basic for Applications (VBA) in Microsoft Excel, the student only need select their name from a pull-down menu. The data input screen shown in Figure 4 is generated. The VBA code causes the form to be populated with the names of the group members. The student is prompted to evaluate each member according to the rubric. In

Figure 4, each tab corresponds to an item in the rubric. The value of the slider bar is relative to the value of the rubric item. For example, in Figure 4, each rubric item is actually worth 20 points. However, the slider bar works on a percentage scale, so selecting a value of 75 on the slider bar will assign 15 points for this rubric item. The student uses the slider bar controls or the text box to rank each student. The student returns the saved spreadsheet to the instructor. VBA code facilitates completing the calculations as described above. This method saves time and helps keep the assessment anonymous.

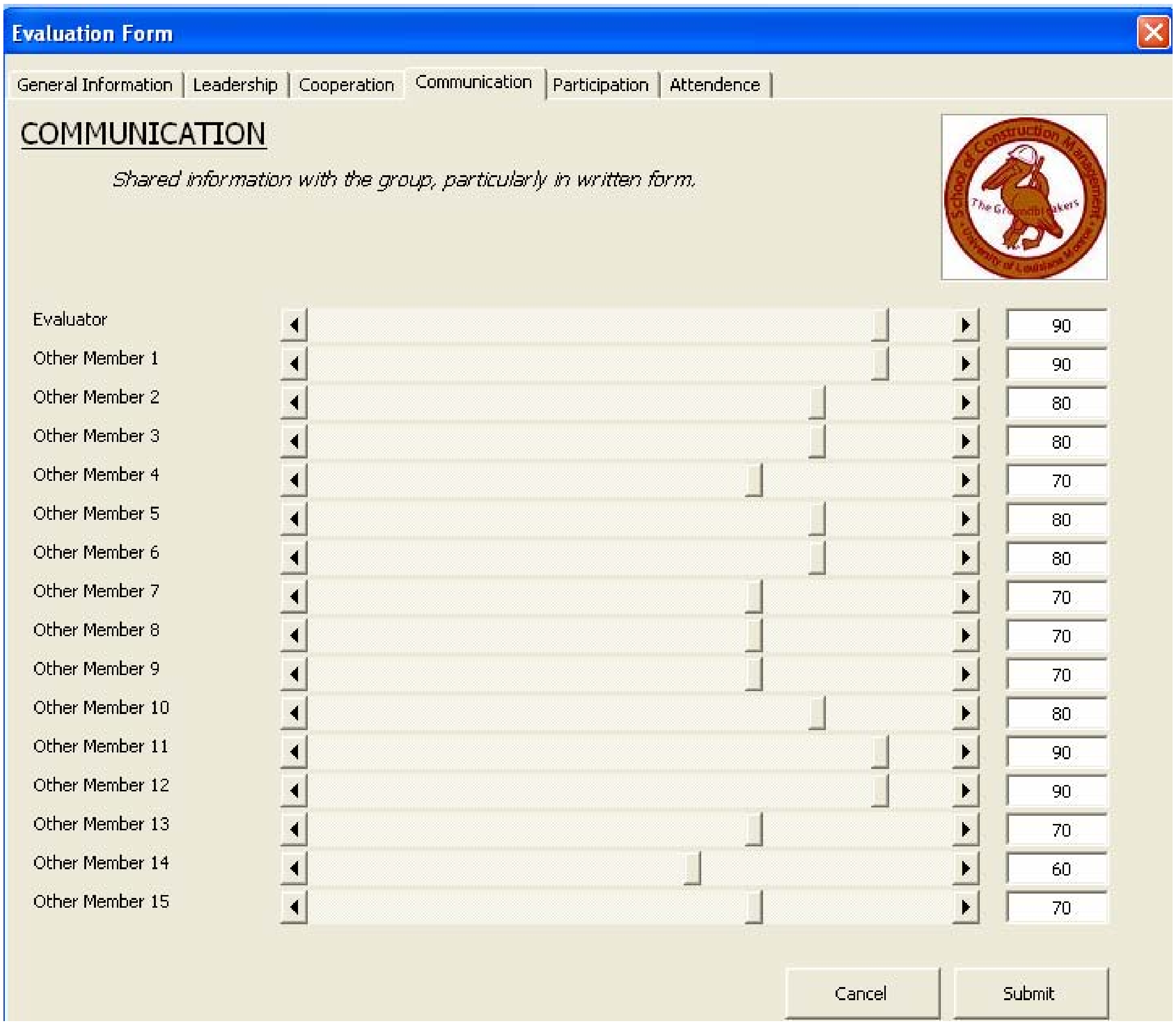

Figure 4: Screen Shot of Input Form for Peer Evaluations

Future Work

Peer grading conducted in fall 2007 will be compared with earlier, less sophisticated methods used in the concrete project to determine if students perform more critical evaluations of peers. The automated data collection method will be evaluated by the instructor. Will students evaluate peers differently when using the input form in Figure 4? Peer grades assigned with the guidance of a rubric will be compared to grades assigned without the use of a rubric to determine the effectiveness of rubrics for peer evaluation.

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Appendix A

Engineer's Evaluation of Project Management Team

Criteria	Points
The project is on or ahead of the scheduled progress.	10
Project clean up was performed according to the Engineer's instructions.	10
Contractor's safety plan was executed.	10
The project webcam collected project photos according the Engineer's instructions.	10
Purchasing procedures were followed and materials were used thriftily.	5
The project site plan for tools and storage was followed.	5
The Owner's Representative kept a daily log of the Contractor's activities.	5
A concrete yield test was performed and initial test cylinders were made according to the Engineer's instructions.	5
Test cylinders were made for each concrete pour. The cylinders were made and stored according to the Engineer's instructions.	5
Followed plans and specifications.	5
The progress was indicated on the project schedule.	5
The Owner's Rep was given 24 hours notice to check alignment before concrete pours.	5
Concrete cylinders were tested and a control chart of breaking strength was maintained according to the Engineer's instructions.	5
Quantity takeoff and batch calculations were submitted to the Owner's Rep 24 hours prior to the pour.	3
A system of files was maintained including the Project Documents and correspondence.	3
Owner's Rep had supervision on site when work took place on site.	3
Contractor had supervision on site when work took place on site.	3
Responded to Engineer in timely manner.	3
TOTAL	100

Incorporating University Student Group Projects based on Actual Residential Construction Projects

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This paper describes a pedagogical approach to teaching residential construction capstone courses involving the collaboration between industry and students in the planning of housing developments. The purpose of the course curriculum is to provide students with a theoretical and experiential based understanding of key components of the residential development and construction process including market analysis, site analysis, site planning, residential design, entitlements, marketing strategies, management planning, estimating, scheduling, and customer service planning. Theoretical course content is administered through lectures, assignments, and examinations and is graded according to individual performance. Experiential content is incorporated through semester projects and is evaluated by group performance and individual peer reviews. Industry sponsors contribute basic project details, including site locations and housing designs, and assist student teams through guest lectures, site visits, and direct correspondence. Accrediting agencies and industry advisory councils have emphasized the importance of integrating practical components in construction education and this course pedagogy does so through facilitating industry and student collaboration.

Key Words: Residential Construction, Education, Homebuilding, Residential Development

Introduction

Subprime mortgages, mortgage lending, green construction, LEED certification, market analysis, marketing, site selection, land development, construction software and networking applications, prefabricated trusses and wall panels, innovative building methods, value engineering, project controls and customer service, are just a few of the subjects major homebuilders must know well in order to have a successful business. Large homebuilders are no longer just builders of homes, they are developers of land, originators of mortgage loans, and sellers of real estate. The residential construction industry is an industry of constant change. How do educators prepare students for the construction industry when residential construction related courses are so scarce within construction education?

Residential construction capstone courses can be effective tools in exposing students to the unique aspects associated with the homebuilding and multifamily construction industry. Developing a residential construction capstone class can be a complex endeavor for instructors. There are many different capstone course paradigms that exist. Decisions must be made about the structure of the course, the content, the class projects, industry involvement, evaluation and grading policies, and student group arrangements. This paper discusses a residential construction capstone course pedagogy implemented at Texas A&M University, Department of Construction Science.

One basic question that construction academics must consider is whether application based teaching methods are effective or necessary in university curriculum. Bernold (2005) boldly asserted engineering education must reform itself in order to accommodate an overwhelming number of creative students who do not learn well with the traditional pedagogical format of lectures, homework and tests. In his article, he provided a historical perspective by describing the educational philosophy of Alexander Meiklejohn, a strong voice in the 1930's speaking out against the commercialization of universities. Bernold explained how Meiklejohn's supporters felt the "'departmentalized university' was instruction, not learning centered, thus inhibiting the use of educational methods that stimulate student learning." The study examined topics including the failing education reform of the 1990s, substituting fixed course plans and lectures with learning communities, weeding out classes versus coaching classes, accommodating teaching around the learning cycle, and studies of engineering students study habits and skills. In conclusion, Bernold explained how two key questions needed to be addressed by educators: "What changes are necessary to create a community based teaching environment that allows each student to actively engage in a holistic learning process, and how can we empower our students to excel within such a drastically different educational paradigm." This study emphasized the importance of incorporating alternative forms of education to better teach multiple student learning types.

Various methodologies have been implemented in the past to inject application based curriculum into university level courses. Senior (1998) discussed different practical components that could be infused in construction courses such as simulation and gaming, case-based instruction, internships, service learning, field visits, and application papers. He provided a review of related literature for the each of the aforementioned practical elements. Senior concluded that more practice oriented curricula will be the norm and not the exception in future construction education.

Since this paper concerns an industry sponsored project, it is appropriate to examine academic literature related to project based learning. Chinowsky, Brown, Szajnman & Realph (2006) described a pedagogical approach to teaching civil engineering courses based on projects rather than lectures. The article initially discussed five alternative approaches utilized in construction education: the traditional approach, integrated engineering curriculum, the model approach, the case study approach, and the non-civil engineering approach. Chinowsky, et al. then introduced the project based learning (PBL) approach to construction curriculum. To validate course effectiveness, the authors conducted a study which involved follow up interviews with participating students, their employers, and faculty members within the university. The questions specifically addressed employment opportunities, subject understanding and domain understanding. Of the 24 students that graduated having experienced the PBL course, all believed their ability to communicate their PBL experience to potential employers provided them with an advantage in obtaining employment. Six personnel directors of corresponding employers were interviewed and stated that they believed the PBL graduates were more mature, better communicators, and had a greater understanding of working with clients. University faculty members commented on the students' ability to form questions that extended beyond the normal boundaries of an assignment. Every student interviewed either agreed or strongly agreed they gained a deeper understanding of the construction industry. In conclusion, Chinowsky, et al. highlighted two advantages of project based learning are that educators have the “opportunity to expand beyond a knowledge point concentration” and that students have the “opportunity to explore problems that encourage skills beyond traditional analytic intelligence.” This study did not adequately validate assertions made through rigorous quantitative analysis, however it provided relevant discussion points emphasizing the importance of incorporating project based learning into construction curriculum.

Albano and Salazar (1998) explained a project based graduate course entitled “Integration of Design and Construction” that was offered during the Fall semesters of 1995 and 1996 in the Department of Civil Engineering at Worcester Polytechnic Institute. The goal of the course was “to provide a project-based, practice-oriented opportunity for teams of students to deal with the problems of functional integration.” The course pedagogy integrated class discussion, laboratory, and lecture activities as well as a real world project provided by industry participants. Student performance and feedback were used to validate the value of the course and to help with adjustments in curriculum content. The effectiveness of the course was not supported by related data. The integrated and collaborative design of this course is similar to the one described in this paper, but is applied to design and construction projects.

Several peer reviewed articles have specifically examined construction and engineering capstone course pedagogy and effectiveness. Todd and Magleby (2005) presented a case study for developing a two-semester senior design capstone course at Brigham Young University. The study discussed the importance of identifying and meeting the needs of various stakeholders including students, faculty, academic administrators, and industry. Conceptual models for capstone programs, program design considerations, and a case study made up key sections of the article. Todd and Magleby included data related to feedback from alumni and found that the capstone class ranked number one within the department’s course offerings for its usefulness in preparing them for their careers as practicing engineers. This article provides a detailed and useful overview of important items to consider in the process of creating a capstone course.

Massie and Massie (2006) outlined a method that can be used in organizing student teams for capstone design and build group projects. Their article introduced the Team Project Document (TPD) that can be used by students and faculty advisors to establish goals and objectives and to facilitate communication among team members. The TPD was modeled from the United States Army’s Officer Evaluation Report Support Form (OERSF), which was “designed to foster the communication process between senior and junior officers.” Massie and Massie included a case study in which he TPD was used by students and faculty in the Sunrayce biennial intercollegiate competition to design, build, test, and race a car powered by solar energy. The team finished the race number 29 out of 29 teams racing. According to the authors, finishing last place may have been due to other externalities.

Paul (2005) provides a description of a Civil Engineering Design capstone course offered by the Department of Civil and Environmental Engineering at the University of Delaware. The article consists of a historical course perspective, a course overview, and descriptions of fundamental course elements. The capstone course is a four credit course lasting two semesters. Approximately 55 senior level students are divided into four teams, separated by disciplines, to complete an actual project. The four teams are overseen by instructors who are practicing professionals. A full time faculty member manages and directs the course activities. Classes consist of lectures and team meetings. Major and minor deliverables are expected each semester. The major deliverable in the fall semester is each team's proposal to provide engineering services on the project, accompanied by an oral presentation. The major deliverable for the spring semester is each team's engineering report, also accompanied by an oral presentation. One quarter of each student's grade is given by the instructor's evaluation of participation in team and discipline sessions, one quarter of the grade is given by the instructor's evaluation of each team's deliverables, and one half of the grade is given according to the team's peer evaluations. The involvement of an instructor as well as multiple industry professionals who meet regularly with student teams appears to be an effective capstone format, but may be difficult to coordinate for many colleges and universities isolated from major populations.

Academic literature related to capstone courses and practical elements in construction education is abundant. The peer reviewed articles offer tremendous insight and applicable strategies for capstone course design. At the same time, there are methodologies that appear to be not so effective. A consistent theme throughout the literature is that course pedagogy is constantly being altered, tested, and refined.

Course Overview

The residential capstone course at Texas A&M University, Department of Construction Science, is a senior level course designed for students preparing to enter the homebuilding or multifamily construction industry. It specifically focuses on project management and exposes students to market analysis, site analysis, land development, residential design, building codes and entitlements, estimating, scheduling, financing, subcontracting, marketing, business planning and current trends in design and construction. The intent of the course is to provide students a broad perspective of the residential development and construction process as viewed by production homebuilders. Expected core competencies for students completing the course have been outlined through nine learning objectives which are listed below in Table 1.

Table 1
Course Objectives

1. Understand and apply the fundamental concepts necessary to analyze a region for its housing market potential
2. Know how to apply the key decision variables in analyzing and developing sites for optimum housing layout
3. Understand the principles and procedures of housing design
4. Be familiar with residential building codes, their origin, and their application
5. Understand and apply common financing options for residential projects
6. Demonstrate knowledge of estimating, scheduling, and project planning procedures for residential projects
7. Be familiar with residential contracting and subcontracting, and documentation procedures
8. Understand and demonstrate residential project marketing techniques and principles
9. Understand the global economy's impact on U.S. homebuilders

The three credit hour course content consists of lectures, assignments, quizzes, exams and a semester project. Sixty-five percent of the grading is based on theoretical content and thirty-five percent is concerned with the experiential based semester project. The grading policy is listed below in Table 2.

Table 2
Grading Policy

Course Tasks	**Percentage of Total Grade**
Assignments	25
Quizzes	10
Exams (2)	30
Project*	35
Written – 30 percent of project grade	
Oral – 5 percent of project grade	
*Peer evaluation applied to overall project grade	
Total	100

Theoretical Course Components

The residential capstone course introduces students to development and construction terminology and theory through lectures, guest lectures, readings, assignments, and site visits. Evaluation of the theory component of the class is based primarily on individual performance as exhibited through assignments, quizzes, and exams.

Lectures and Guest Lectures

Course lectures are given by the professor and by guest lecturers from the residential construction industry. Lectures are designed to expose students to the theory behind topics they will be expected to incorporate in their semester project. These topics are pertinent to current homebuilding and multifamily construction trends. Topics include the history of homebuilding, market analysis, master planning of communities, site analysis, land development, the process of homebuilding, estimating, scheduling, financial analysis, project management planning, building codes and entitlements, marketing planning, customer service, alternative construction systems, and sustainable construction and development. Industry sponsors typically provide several speakers to explain different components of the construction process such as estimating, scheduling, land development, and value engineering.

Reading, Assignments, and Site Visits

Two textbooks are required for the residential capstone course. They include a land development book and a residential construction materials and methods book. Readings are assigned to correspond with lectures. The land development book explains the basics of market analysis, site analysis, entitlements and government regulations, site planning, environmental issues, and other land development topics. The residential construction textbook explains construction terminology as well as building materials and methods.

Students are given assignments with the goal of theory application. Assignments include required readings, writing tasks, and oral presentations. One assignment given to students each semester is to propose a location for the development and construction of 50 homes priced between 100,000 and 150,000 dollars within the state of Texas. Students are required to perform market analysis in justifying their recommended city and submarket. Students prepare an executive summary explaining their recommendation with copies of supporting data. They present their findings to the class as well. The class then votes on which city they feel would best accommodate the development. As a result of the assignment, the students have been exposed to researching demographics, economic characteristics, and psychographics of cities.

Site visits expose students to actual homebuilding processes they may have only read about in textbooks. The goal of visiting sites is to show students various stages of the construction process. Selected sites typically have several houses under construction at different phases of completion. Students can see pre-slab sites, sites with concrete slabs, sites with exposed framing, dried in homes, and model homes. Site visits to production homes, high end custom homes, apartment complexes, town homes and condominiums can provide students with a glimpse of the diversity of product types within the homebuilding industry.

Grading Policy of Theoretical Components

The grading system for the theoretical components of the course aims for the assessment of individual performance. 65 percent of each student's grade is comprised of assignments, quizzes, and exams. Assignments account for 25 percent of the final grade. In class quizzes account for 10 percent of the final grade. There are approximately five quizzes a semester and they typically are administered at the end of class and incorporate the material covered that day. Depending on how many quizzes are given, one or two quiz grades are able to be dropped by students. These quizzes provide incentive for class participation and attendance. Two exams are given each semester and are each worth 15 percent of the semester grade. The test questions are derived from lecture materials, guest lecture content, textbook readings, and site visit details. Exams provide incentive for students to perform their required readings and to be active within the class activities. The exams most often are multiple choice exams consisting of thirty to forty questions.

Experiential Course Component

Each semester the residential capstone class is given the assignment of creating a development proposal from start to finish. The proposal must contain a market analysis, a preliminary site design, a financial feasibility study, residential designs, a development estimate, a construction estimate, a project schedule, a project management plan, an explanation of entitlements and regulatory issues, a marketing strategy, a customer satisfaction strategy, and an executive summary. An industry sponsor contributes basic project details from developments they have constructed, including site locations and housing designs, and assists student teams through guest lectures, site visits, and direct correspondence. Past industry sponsors have been DR Horton Incorporated, Stylecraft Builders Incorporated, and the Hanover Company. Residential unit types have included single family homes and apartment complexes.

For several semesters, students were divided into groups of three to four members and given the task of preparing an entire development proposal. Classes ranged in size from 15 to 39 students and yielded five to thirteen separate projects. The small size of the groups gave students good exposure to interdisciplinary components of a development plan. However, the projects were not very detailed and accurate due to the large amount of data and analysis necessary to complete such a project. As a result, the course project was adjusted by assigning groups of students to produce specific sections of the proposal. One group of students was given the task of overseeing the cohesiveness, design and formatting of the project. The entire class was responsible for creating one development plan. The goal of these changes was to produce a more detailed and comprehensive finished product.

Grading Policy of Experiential Component

The project grade accounts for thirty five percent of the semester grade. It is comprised of a written development plan grade worth 30 percent and an oral presentation grade worth five percent of the project grade. Peer reviews are conducted and can affect each student's project grade. Industry sponsors are asked to participate in evaluating the development proposals and presentations.

Evaluation of the written project involves grading each section independently and then averaging the section grades to obtain an overall written grade. Attention to detail, creativity, accuracy, and exhaustive work related to each project category are criteria for grading.

For the oral presentation grade, students are evaluated on their effectiveness in conveying necessary project information to the audience. They are also graded on their ability to answer questions posed to them. The oral presentation is expected to be a summary of the written project. It is important for team members to choose wisely what information they feel should be emphasized during this phase of the project.

Students are required to submit a peer evaluation for each team member based on a 1-100 percent scale. These grades are averaged for each team member and applied to the overall project grade. For instance, if John Doe's team earned an overall project grade of 100 percent and his personal peer reviews were 90 percent and 100 percent, Mr. Doe's project grade would be 95 percent.

Conclusion

Residential construction capstone courses for graduating college seniors are excellent venues for combining theoretical and experiential based curriculum pedagogy. Students enrolled in these courses have had years of experience in memorizing and reciting terminology and theory and are a semester away from starting their construction careers. The capstone course can play an important role in helping facilitate the transition from academia to industry by exposing students to actual projects and industry professionals while still in the classroom.

Finding the correct balance of theoretical and practical components for the course can be a difficult pursuit. It is easy to overwhelm students with too much theory while at the same time expecting them to complete a large project. Without classroom structure and theory, students may lose interest, motivation and perform poorly.

Important decisions affecting the dynamics of a capstone class are the size of student groups and the scope of work required from each group. Smaller sized groups tend to increase the accountability among members in performing their share of tasks. Student teams will either be required to complete their own project or take responsibility for a specific portion of the overall project. With large projects, it may be best to divide them into parts and assign those parts to specific student teams. As a result the entire class will work together to produce a well detailed project.

The success of a capstone course with industry collaboration depends on the proper selection of industry sponsors. It is important to select a sponsor who has the time, passion, and resources to contribute to the class. Collaboration with industry through the capstone course not only benefits the students, but also the academic program and the industry participants. Academic programs benefit by developing stronger relationships with industry members. Industry sponsors can benefit by having direct access to a pool of potential employees.

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Energy Use During Construction

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This paper presents a portion of a dissertation research project that examines energy consumption during the construction process. An energy study was made for the construction of three buildings to determine what data was available. Three other construction sites were visited to determine how readily energy data can be recorded on the site. Four construction energy phases were developed from this research; 1) site clearing and preparation, 2) building structure, 3) interior finishes, and 4) commissioning. The main energy consumption during Phase 1 is diesel fuel for earth moving equipment. Phase 2 and 3 energy consumption varied considerably among the projects, were difficult to quantify, and are low compared to other phases. Thus they may not be economical to evaluate. Phase 4 electrical energy demand was high due to HVAC commissioning requirements and power up of all electrical power uses. These few construction projects are not enough to make definitive conclusions about what percentage of the total project cost is spent on energy. However they are a step in helping to locate energy use, develop methods to quantify it, and make predictions as to which project tasks warrant further energy studies.

Key Words: Construction, Energy, Utility Costs, Embodied Energy

Introduction

Rising energy costs should be a concern to contractors, designers, and owners; yet because these costs are imbedded in materials, equipment, or overhead it is difficult to make a quantity takeoff for energy. Are these fluctuating energy costs a significant part of the total project cost?

This paper presents a portion of a dissertation research project that examines energy consumption during the construction process. The objective of the original study was to develop a guide that may be used by designers and contactors to evaluate their construction energy costs. In developing this guide construction energy costs for existing buildings and buildings under construction were examined. While the number of buildings studied is not enough for valid statistical evaluation, energy trends during construction were identified. This paper will discuss these findings.

Sources and Concerns of Construction Energy

On-site construction consumes energy in two ways; 1) the use of gasoline and diesel operated equipment, and 2) the use of from-the-grid electricity. In addition, construction equipment using gasoline and diesel in combustion engines increases air pollution. The EPA has adopted a tier program in which all off-road equipment, including construction equipment, will be required to meet new air quality standards by 2008 as dictated in their document *Reducing Air Pollution from Nonroad Engines* (US EPA, 2003).

Fluctuating energy costs affect many aspects of building construction, from the price of materials to the price of diesel. Since different construction methods require different amounts of energy, the difference in energy costs may become a decisive factor in choosing a construction method. Just as importantly, the construction method and materials impact the embodied energy of the building. The embodied energy for some energy efficient buildings exceeds the lifetime building use energy as found in a study of modern European buildings (Casals, 2006). Given these considerations, how does a contractor know which method consumes more energy, what is the potential cost of that energy, and how do change in energy costs affect the cost of construction and the true sustainability of a building?

Energy costs, sustainability, and pollution are all concerns owners, architects, engineers, and contractors must consider when looking at the feasibility of a project. The first step in making these considerations is to document the construction energy costs. One method of determining energy use during construction would be to record daily meter readings, and observe the jobsite every day recording the quantity and duration of use for all tools and equipment that consume power. While this would give very accurate data it is time consuming and therefore costly for contractors interested in energy consumption. It is therefore important to determine what construction tasks consume more energy and focus research time on these tasks.

Electrical Energy Consumption During Construction

Electrical energy consumption was studied for three buildings under construction on the Texas A&M campus. Table 1 displays the three buildings and their parameters. The Jack E. Brown Chemical Engineering building is a seven story laboratory, classroom and office facility with special construction for mechanical piping required in the Chemical Engineering laboratories. The General Services Complex is a two to three story building that houses offices and student services. The State Chemist building is a single story state laboratory building that also has special mechanical piping to support the laboratories. These buildings vary in size from 205,000 sf to 20,000 sf and in cost from $38 million to $4.5 million.

Table 1 Building Parameters for the Three Projects Studied

Building Parameters	Jack E. Brown Chemical Engineering	General Services Complex	State Chemist Building
Building Square Footage	205,000	200,000	20,000
Building Cost	$38,000,000	$21,000,000	$4,500,000
Cost per Square Foot	$185	$105	$225
Number of Stories	7	2 and 3	1
Construction Time (mo)	26	17	13
Type of Building	Research	Offices	Research
Type of Structure	Cast-in Place concrete	Tilt-up Wall & Steel	Tilt-up Wall & Steel
Special Features	Glass & Aluminum Curtain Wall, Chemical Laboratories	2-Story & 3-Story Sections	Chemical Laboratories

Monthly electrical utility information was obtained for each building. Figure 1 shows their monthly utility consumption. It is important to note that while the timeline scale remains the same for each graph, the energy use scale is different. Also the electrical energy consumption at the beginning of each project is very low compared to the consumption at the end of the project and appears to be zero, although it is not. The electrical consumption for the Jack E. Brown Chemical Engineering building ranges from 44 kWh per month to 345,700 kWh per month. For The General Services Complex it ranges from 33 kWh per month to 338,300 kWh per month. And for the State Chemist building it ranges from 0 kWh per month to 3,025 kWh per month.

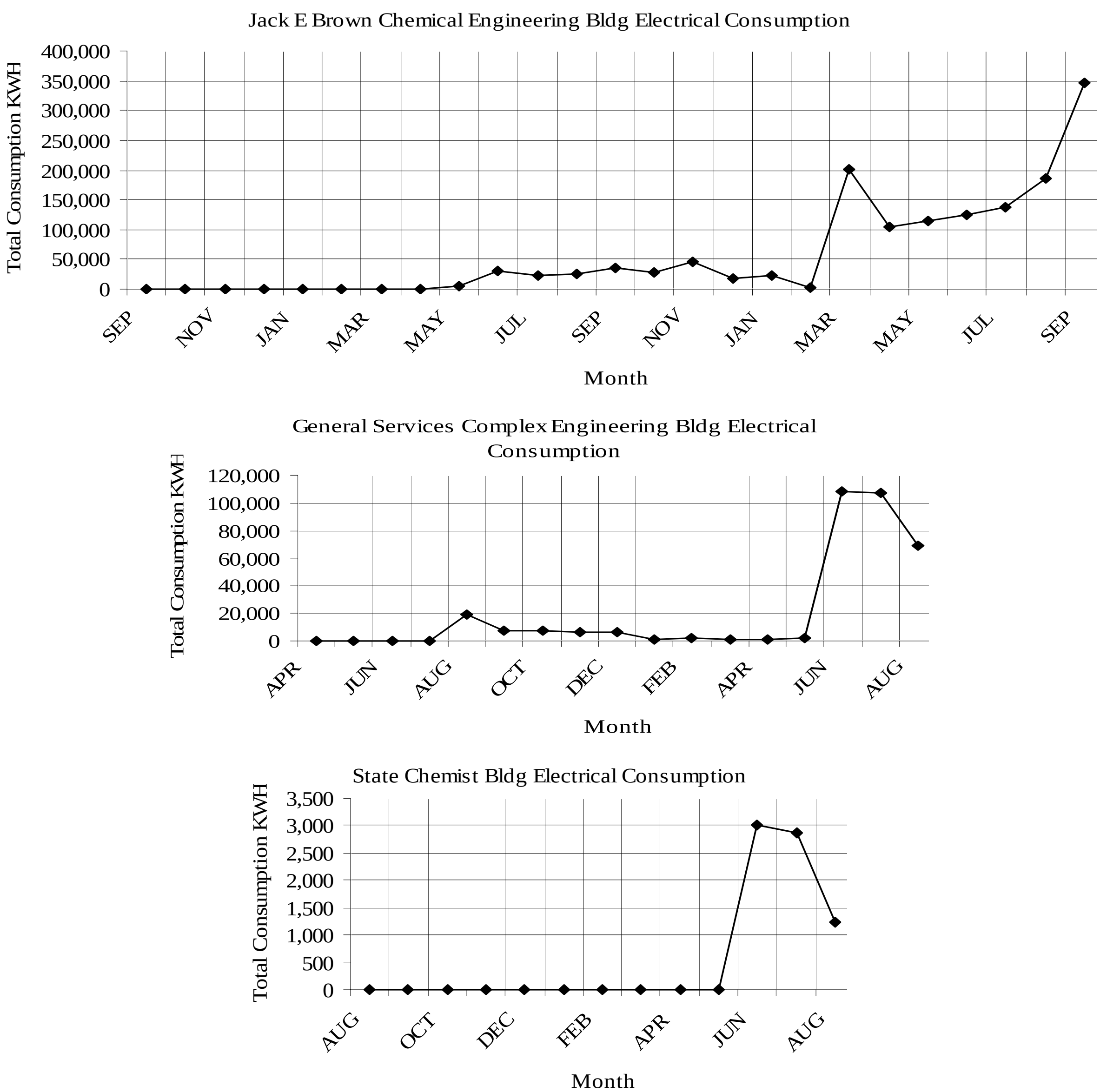


Figure 1 Electrical energy consumption per month for each building.

Energy Consumption Phases of Construction

Breaking down each graph according to the magnitude of the energy use and then comparing them to the construction tasks performed for that month leads to energy consumption trends. This information combined with knowledge of construction allows the encapsulation of energy consumption into four phases of construction.
The four construction phases for energy consumption identified are 1) site clearing and preparation, 2) building structure, 3) interior finishes, and 4) commissioning.

For the purposes of energy study the first construction phase, site clearing and preparation, begins at the beginning of the project and ends when major earth moving equipment is removed from the site. Energy consumption during this phase is mainly in the form of diesel used to power earth moving equipment.

The second construction phase, building structure, begins when construction trailers are installed or a temporary power is set up at the site and ends when a temporary power drop to the building is installed. Phase 2 includes foundation work and structural framing. There may be some overlap with phase 1 if construction trailers are installed early on the site or the project is performed in phases. An example would be large development projects such as strip malls or housing developments. There are several categories of energy use during this phase; one is to power the construction trailers, another is to provide security and task lighting for the building as it is being constructed. Welding of structural members is another use of energy and is usually provided by a diesel operated welding machine although some sites set a temporary utility pole to provide this power.

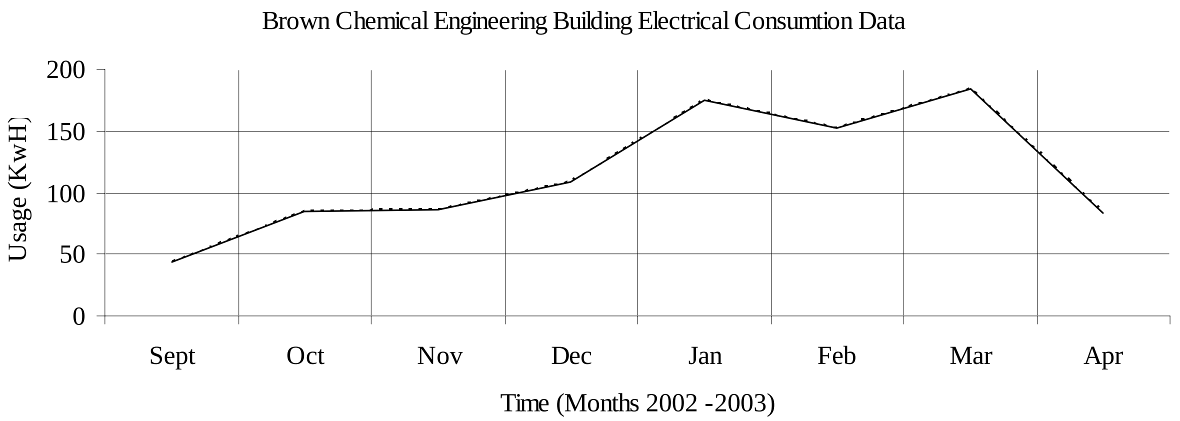
The third construction phase of energy use, interior finishes, begins with the installation and heat up of a temporary power drop to the building and ends when permanent power is turned on in the building. A major consumption of electrical energy use during this phase is the mechanical controls testing and temperature and humidity control of the building during finishes and mill work. Flush-out of construction volatiles in the building may occur during phase 3 or 4. Task and security and lighting may be provided by the permanent lighting fixtures of the building.

The fourth construction phase of energy use begins when permanent power is turned on and ends when the owner assumes responsibility for the electricity bill, takes possession of the building, or when substantial completion is achieved. During this phase the building mechanical systems are fully operational. Commissioning is performed during this phase of construction.

Construction Phases for the Jack E Brown Chemical Engineering Building

For the Jack E. Brown Chemical Engineering Building, a separate contract was issued to install service utilities and upgrade existing infrastructure required for the building services. The construction energy phase 1 was encompassed in this separate contract. At the beginning of the building project no site preparation was required in order to install the construction trailers.

Therefore the second phase began on the first day of the contract “notice to proceed”. Figure 2 shows the monthly utility consumption over the 8 months of the second phase and correlates it on the time line with major construction tasks obtained from the project schedule.



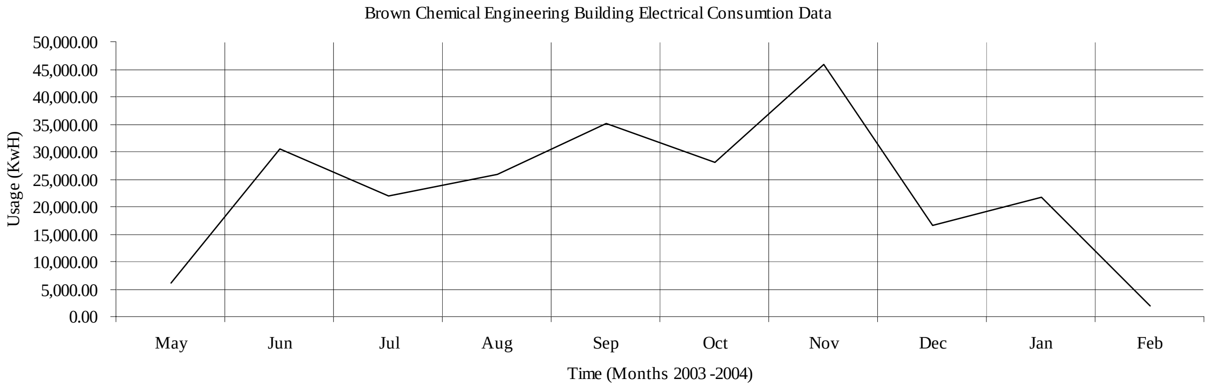
Layout & Temp Structures. Temp Electrical	Drill Piers & Perimeter Wall	Erect Tower Crane, Level 1 Pours	Level 2&3 Pours	Level 4-6 Pours, Structural Steel, MEP	Level 7 Pours	Roof Pours, Duct Work, Mason & Dry Wall	Finish Pours Set up Temp Material Hoist
Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr

Figure 2 Monthly utility consumption correlated with construction tasks for phase 2.

The construction tasks for phase two use little electrical energy with construction trailers the main electrical energy consumer. Since the construction trailers are powered by a separate electrical meter, their consumption for the duration of the project in known. The average monthly electrical consumption for the trailers was 130 kWh. This value appears to be low considering the number (4) and use of the trailers.

The total cost of electricity for Phase two was $88. The total cost for the construction trailer electricity was $290 over the entire project. Electricity for this project was provided by Texas A&M University who sets their own rates and the rates were fixed in the construction contract.

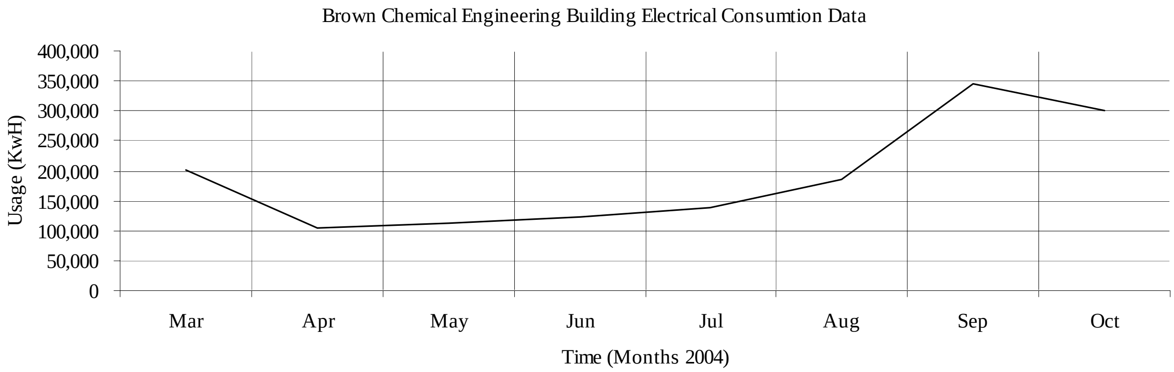
Phase three for this project is marked by the power up of the temporary building meters and continued for 10 months. Figure 3 presents the monthly utility consumption correlated with construction tasks for phase 3. The average monthly electrical consumption for this phase is 23,372 kWh. This includes both the building use electrical and the trailer electrical consumption. It should be noted that the building consumption is two magnitudes higher than the trailer consumption and the vertical axis scales for Figures 2 and 3 reflect this magnitude difference. The average monthly cost for phase 3 is $2,220 and the total phase 3 electrical cost is $22,204.



Metal Stairs, Curtain Walls, Piping	Test Air Handle for Leakage, Damp Proofing and Flashing	Install Elevators	Continuation of all Work & Matrix Steel	Remove Tower Crane, Install Drywall; Tape & Float	Stairs, Electrical, Lab Racks	Remove Material Hoist, Ceramic Tile	Case Work, Electrical Fixtures	Masonry, Remove Scaffold	Mech Controls Testing, Flooring & Millwork
May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb

Figure 3 Monthly utility consumption correlated with construction tasks for phase 3.

Phase 4 began with the switching from temporary building power to permanent service and ends when the owner takes possession of the building. This phase lasted for 8 months. Building commissioning began in September and the temperature and humidity were brought up to occupancy levels. Figure 4 presents the monthly utility consumption correlated with construction tasks for phase 4. The average monthly electrical consumption for this phase is 188,936 kWh. This includes both the building use electrical and the trailer electrical consumption. It should be noted that the building consumption for phase 4 is almost one magnitude higher than the phase 3 consumption and the vertical axis scales for Figures 3 and 4 reflect this magnitude difference. The average monthly cost for phase 4 is $14,043 and the total phase 4 electrical cost is $112,344.

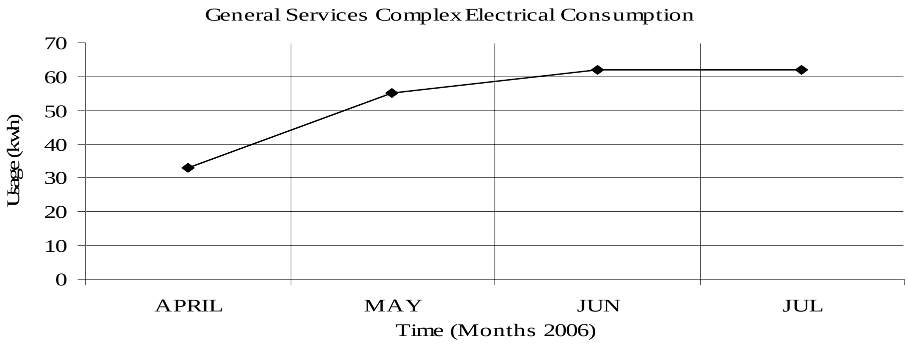


Fire Proofing, Hang Entry Doors	Millwork, Plumbing Fixtures, Terrazzo	Drywall, Electrical, Fixtures, Terrazzo	Drywall, Electrical, Fixtures, Terrazzo	Roof, Sprinkler Punch Work, P-lam Doors & Hdwr	Removed Trailers	Punch Work, Landscaping Building Commissioning	**Owner Move In**
Mar	Apr	May	Jun	Jul	Aug	Sep	Oct

Figure 4 Monthly utility consumption correlated with construction tasks for phase 4.

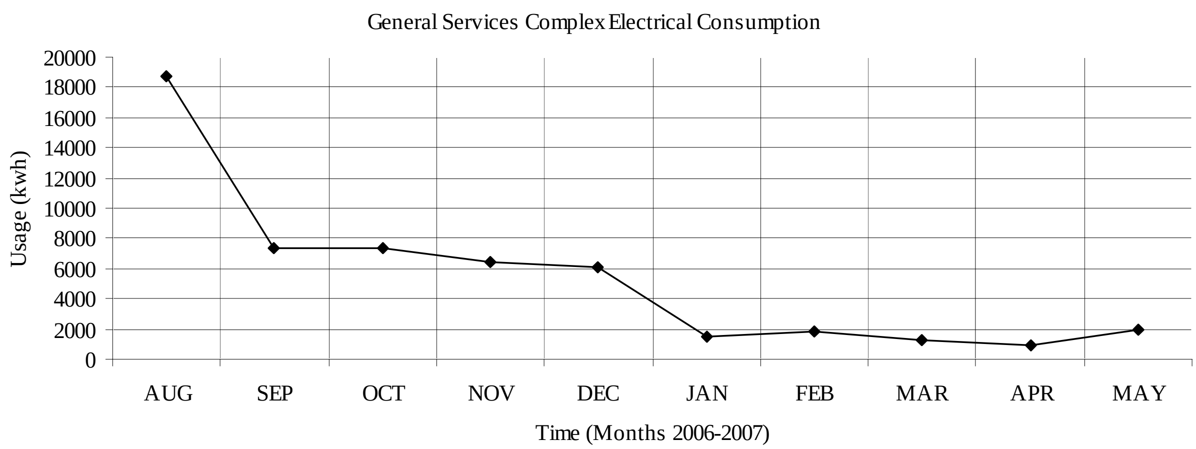
Construction Energy Phases for General Services Complex

Phase 1 for the General Services Complex occurred over less than two months. The first task was to prepare a site for the construction trailers and a gravel parking lot for employee vehicles and initial staging of materials. Construction trailers were installed during the first month and temporary power turned on. There is some overlap of phases 1 and 2. Figure 5 shows the electrical consumption during phases 1 and 2. The main consumer of electrical power is the construction trailers. The average monthly use was 53 kWh. This number also seems low considering that six trailers were powered though this meter. The total cost of electricity for phases 1 and 2 is $22.



Mobilization **Temporary Power**	Site Prep	Foundation Work	Pour Slab on Grade
Apr	May	Jun	Jul

Figure 5 Monthly utility consumption correlated with construction tasks for phases 1 & 2.

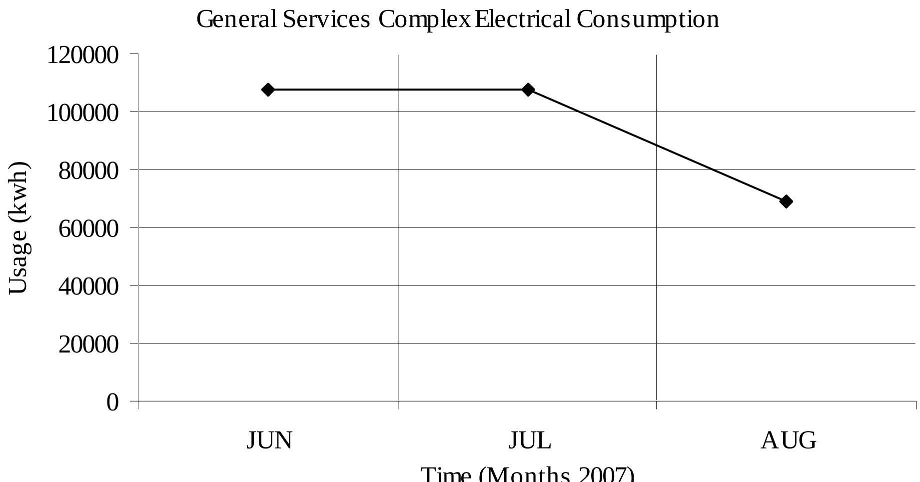


Tilt up Wall Panels Security lighting	Structural Steel	Second & Third Floor Deck	Mechanical Equipment	Finish out Shell	Interior Finishes	Tape & Float	Ceilings	Mill Work	Flooring Finish Area 1
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May

Figure 6 Monthly utility consumption correlated with construction tasks for phase 3.

Temporary power to the building was established in August marking the beginning of phase 3. Figure 6 shows the electrical consumption for the 8 months of phase 3 along with the major construction tasks performed. A spike of electrical usage occurred in August when the tilt-up walls were installed. Framing has a higher electrical usage than the interior finishing. This is a reverse of the pattern from the Brown Chemical Engineering Building mainly due to the type of building structure. The Brown Chemical Engineering Building was mainly a cast-in-place concrete structure while the General Services Complex was tilt-up walls with structural steel framing. The average electrical consumption for phase 3 is 5,348 kWh and the total cost of electricity for phase 3 is $10,056.

Phase 4 began in June with the turn on of the buildings permanent power and continues for three months as shown in Figure 7. The average electrical consumption for phase 4 is 94,872 kWh and the total cost of electricity for phase 4 is $5,468.



Finish Area 2 **Commissioning HVAC**	Finish Area 3	Finish Area 4 **Substantial Completion**
Jun	Jul	Aug

Figure 7 Monthly utility consumption correlated with construction tasks for phase 4.

Diesel Consumption

Diesel consumption data was not available for the three building studies. A short term study was performed on a separate site to look at diesel consumption. Site preparation for a 250 acre new retail development was observed. The finished project will include roadways, parking lots, and nine commercial building areas. The total building footprint area is 383,942 square feet. The roadway portion of the project began in June 2007 and is expected to be completed by September 2008 at a cost of $2.5 million. On the days that the project was observed, the existing vegetation has been removed and earth work had commenced. This is a major earth moving project that incorporates heavy earth moving equipment. The diesel consumption was estimated by listing the equipment, the gallons per hour of diesel consumed by each piece of equipment, and the approximate hours the equipment was in use for two days of observation. Computations result in

874 gallons of diesel fuel consumed per day for each of the two days of observation. The current cost of off-road diesel is $2.35 per gallon. This gives a $2,053 cost of diesel per day. It is estimated that this level of diesel consumption will occur on approximately 70 days. This gives an estimated cost of diesel of $140,000 or 5.7% of the total cost of the construction subcontract. This warrants a more detailed study of diesel use in phase 1.

How readily available is energy information?

Two additional sites were visited to determine how readily available electrical energy information was. A church addition and a strip mall both believed to be in the energy construction phase 3 were observed.

One site was a new sanctuary addition to an existing church. Two electrical drops were made to accommodate the new construction. One for the contractor's trailer and one for all electrical power needs during construction. Both drops had separate circuit panels and the drops were made from the existing electrical service. No meters were provided to distinguish the electrical uses from each other or from the current use of the church. However, meters or other monitoring divides could have been installed with the service panels and daily or weekly readings made.

The other site visited was a strip mall shopping center. At this site the building and the construction trailer had separate electrical meters. Readings were taken twice a day for each meter for four days and work tasks were noted. The building meter read one additional kWh for each 12 hour period. This is not inline with the expected consumption of 96 kWh for the lighting alone. The trailer used a total of 88 kWh for the four days observed. This can be projected to give an expected one moth use of 660 kWh. This appears to be accurate for a small trailer that runs an air-conditioning unit 24 hours a day. Problems with meaningful electrical meter data persist. Meters need to be checked and calibrated to assure accurate information.

Conclusions

While some useful data was obtained and phases of energy use have been developed more detailed studies need to be performed. Current construction practices make actual energy costs difficult to measure. Monthly electrical meter readings cannot tell the energy consumption of individual construction tasks; especially on projects were many tasks are performed simultaneously. Diesel fuel consumed can be tracked by using the in service hours of each vehicle and the estimated hourly vehicle fuel consumption. Diesel fuel can also be measured from fuel invoices for fuel delivered to the site.

Construction phases for energy trends during a construction project have identified areas for further, more detailed investigation. Diesel fuel consumption is larger for the beginning of a project during earth work. Electrical consumption is larger at the end of the project when HVAC systems are tested and flush-out of the building performed. While diesel use is more of a function of the amount of soil to be moved, electrical consumption is a function of the time spent in each phase of work. Continued study of energy use during construction can led to more specific conclusions and may improve the energy efficiency of the construction process.

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Can the Lowly Stop-valve Sink Your Best Water Conservation Efforts?

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The objective of this study is to determine if the stop-valve has a significant effect on the liters per flush of flush valve water closets. Sixteen water closets were observed in a office/classroom building. Flow in meters per flush, flush duration in seconds and stop-valve position were measured. Flow and duration were measured five times for each stop-valve position for each fixture. The findings show that the stop-valve position can have an average effect of plus or minus 50 per cent on the measured water closet flow rates. This large effect suggests that rigorous methods be developed to accurately position the stop-valve for optimum water conservation and fixture operation according to EPA standards.

Key Words: stop-valve adjustment, flush valve, gallons per flush, water conservation and plumbing system commissioning

Introduction and Literature Review

The water closet or toilet accounts for up to 90% of the water consumption in offices (Grant and Moodie, 2002). Most non-residential restrooms in the US have toilets with tankless flush valves. This type of fixture typically comes with a stop-valve that can be adjusted with a screwdriver. This valve controls the amount of water available to the flush valve on the water closet or urinal. It can be set over a wide range such that the water supply is completely shut off or is open fully with little flow resistance to the water closet. Figure 1 below shows a typical stop valve available from Sloan Valve Company (Sloan Valve 2006).

The installation instructions give no indication that the position of this stop-valve has a significant effect on the water consumption performance of the fixture. Since for a water closet it is unlikely that the installer would supply solid waste to the fixture bowl, it is hard to see how the installer could properly judge as to the cleansing effect of the valve flow.

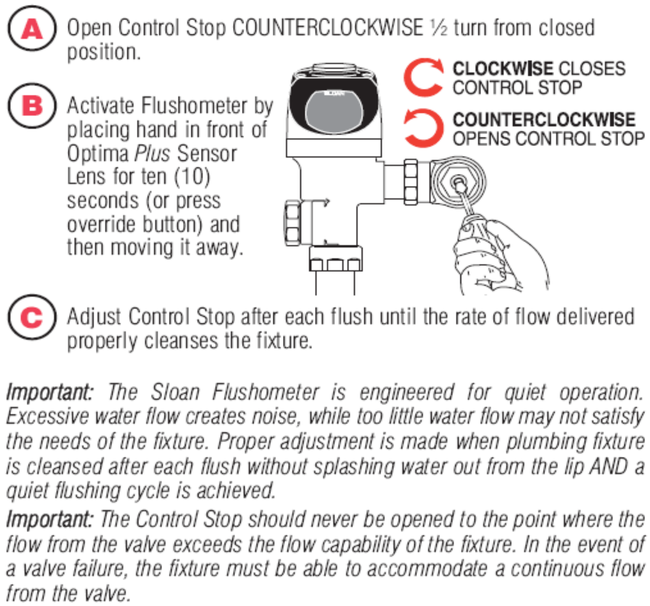

Figure 1: Stop-valve adjustment instructions. Source: (Sloan Valve 2006)

Method

Sample Selection

A large university building was selected for this study. It is a combination of office, studio and classroom use. Its four floors each have one male and one female restroom. Each male restroom has two lavatories, three urinals and two water closets. Each female restroom has two lavatories and four water closets.

The water closets in each restroom are a mixture of automatic flush valves and manual flush valves. This study uses data from all of the automatic valves in the building except for one that was not working properly at the time of data collection.

Data Collection

The main reason this building was selected is that it has a very accurate, electronic water meter. The Rosemount meter is designed to measure volumetric flow by detecting the velocity of a conductive liquid that passes through a magnetic field. Figure 2 shows the meter. Each time a fixture was flushed, the flow volume was read off the meter and entered into a spreadsheet. Data were collected during times when the building was lightly or unoccupied, weekend nights.

Figure 2. Rosemount water meter

Flow duration was obtained from digital recordings made of each flush. WavePad, free audio editing software, was used. WavePad audio editing software is a sound editor program for Windows. It allows one to graphically measure the time duration of each flushing.

Data

The observational unit in this study is the plumbing fixture. The population of interest is all the automatic flush valves in ELAC Building A at Texas A&M University. The variables are stop-valve position measured in quarter of turn increments from the full open position, liters per flush and flush duration in seconds. There were five flow and time observations made for each stop-valve position.

Findings

As can be seen from Table 1, the position of the stop-valve has a dramatic effect on the flow rate of the flush valve. When one considers that the Energy Policy Act of 1992 limited the flush volume of water closets to six liters per flush, the range of flow relative to this standard is from 53% to 145%. This is the average for the 16 water-closets observed in this study. One could generalize by saying that based on the position of the stop-valve, the flow volume of any particular fixture in this group could be anywhere from 53% of its specified value to 145% of that specified value. This is quit a surprisingly large range.

The graph in Figure 3 shows just how consistently the stop-valve position effects liters per flush. The graph shows the complete range (from full open to full closed) of the stop-valve. Since the flushometer adjustment instructions suggest the initial setting of the stop-valve should begin at one-half turn from full closed, the lowest two values for each fixture were omitted from the minimum values in Table 1.

Table 1.
Maximum and minimum flow

Fixture	1w1	1w3	1w2	1m1	4w2	4m2	4m1	2m2	
% Spec	164%	139%	151%	155%	145%	127%	134%	143	
Max	9.84	8.34	9.06	9.3	8.68	7.64	8.03	8.59	
Min	4.47	4.5	4.07	3.45	.75	2.37	2.6	3.17	
% Spec	74%	75%	68%	58%	12%	39%	43%	53%	
									Avg all
Fixture	2w3	2w2	2w1	2m1	3w4	3w1	3m2	3w3	fixtures
% Spec	169%	129%	83%	113%	150%	143%	151%	146%	145%
Max	10.11	7.74	4.98	6.79	8.99	8.58	9.03	8.75	8.68
Min	4.57	3.83	1.53	3.38	2.91	3.18	3.41	3.61	3.17
% Spec	76%	64%	25%	56%	48%	53%	57%	60%	53%

This graph suggests that two of the fixtures may not be working properly (top and bottom lines). Otherwise, the rest of these fixtures exhibit very a tightly grouped pattern. It is also interesting to note that the six liter per flush line cuts all but the bottom most fixture between three-quarters and two turns from full open

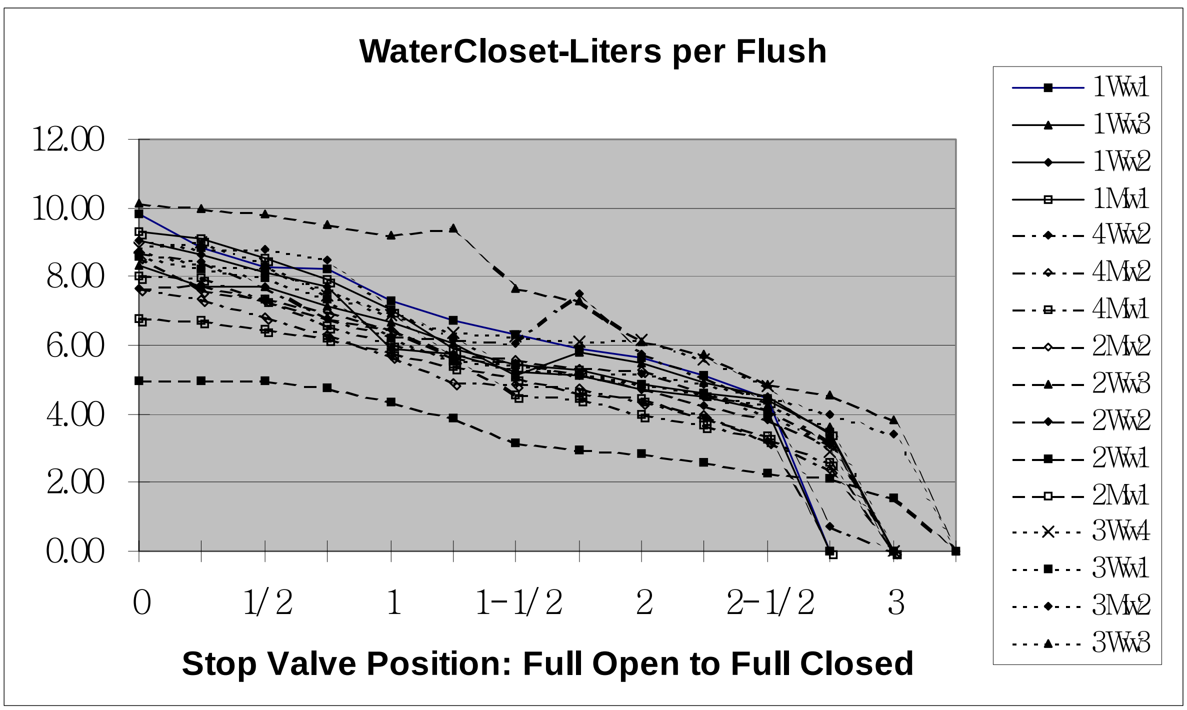

Figure 3: Stop-valve graph – liters per flush vs valve position.

Conclusions and Recommendations

The conclusion of this study is that the stop-valve position alone could increase or decrease water consumption for flush-valve fixtures in office buildings by 50%. The potential magnitude of this effect requires that rigorous methods be developed to insure that this valve is set properly.

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2007
Associated Schools of Construction Region 5

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Richard Burt	TAMU	
Jim Carr	UALR	
Ifte Choudhury	TAMU	Award Nominee
Felix Cuellar	OSU - OKM	
Mukaddes Darwish	TT	Presentor
Doug Gransberg	OU	Proceedings Editor
Marwa Hassan	LSU	
Joe Horlen	TAMU	
Miles Hunter	OSU	
Julian Kang	TAMU	Presentor
Daan Liang	TAMU	QEC only
Bill McManus	OU	
David Manry	ULM	Presentor
Tammy McCuen	OU	QEC only
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