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F^{6}H=CEE

Fake Firms & Funny Funds For Four-H=Civil Engineering Enlightenment

Introduction

Senioritis. Believe it or not, it is actually in the dictionary. Well, www.dictionary.com anyway, where it is defined as "decreased motivation toward studies displayed by students who are nearing the end of their [college] careers." Its causes are attributed to a variety of factors which revolve around the student's desire to be done with school and get out into the 'real world' and have a 'real job.' For civil engineers the trouble with this attitude is that it is not consistent with the pre-licensure philosophy and requirements outlined by ASCE Policy Statement 465. PS465 proposes that aspiring engineers attain the pre-licensure Body of Knowledge (BOK) through a combination of a baccalaureate civil engineering degree, a masters degree (or the equivalent of 30 coordinated graduate level semester credits) and appropriate experience[1]. We can show, brief, teach, and inculcate this philosophy, but our students are still going to want to end their baccalaureate education and start their 'real' experience. In response, the authors restructured their program's capstone design course to generate sufficient intellectual excitement to overcome senioritis and be the bridge between baccalaureate education and the 'real world'. In the authors' opinion the capstone course is not the culmination of the undergraduate experience; it is the first pre-licensure experience. Through this process the authors hope that the students will reach the sublime state of Civil Engineering Enlightenment-- that 'Ah-hah' moment when an individual stops thinking and acting like a student and starts thinking and acting like a practicing engineer.

Background

The 'perfect capstone project' is the Holy Grail for many engineering programs. Educators continually seek it and seldom find it, but, when we do, it provides a phenomenal experience for both students and faculty and we feel compelled to share the experience. The archives of the ASEE Conference Proceedings contain at least 352 papers related to capstones. The authors of these papers explore new and innovative structures and pedagogies within the classroom to enhance student learning and implement new ABET and ASCE criteria. Howe and Wilbarger[2] followed up the work of Todd et al.[3] and conducted a nationwide engineer capstone course survey examining course content, organization, and administration. Collier, et al. [4,5] explored the use of a simulated engineering corporation to solve a multi-disciplinary design problem. Kumar and Hsiao[6] advocate the teaching of leadership, communication and other 'soft skills' through problem based and service based learning. Viswanathan and Evans[7] provide guidelines for implementing capstone or masters projects using corporate sponsors. O'Bannon and Kimes[8] describe partnering with a local municipality to provide a public works design-build experience in a two-semester capstone course. Dennis and Hall[9] used a design-build service learning project for a capstone design experience in which students designed and built a timber bridge for a non-profit nature preserve. Cornachione, et al.[10] organized faculty and students into an engineering firm with faculty acting as the 'senior engineers' and students acting as 'junior engineers' in each of the civil engineering disciplines to complete a project. Project documentation, communication, and professional practice were stressed. Within these papers are found discussions of the three principle components of capstone course design: project selection, student organization, and faculty interaction.

Until ten years ago the civil engineering capstone course, CE492, at the United States Military Academy (USMA) was known as “Super Steel”. It contained lessons on advanced topics in steel design including plastic design, plate girder design, connections, and composite construction. The design problem was based on the design of a significant steel structure. The other aspects of civil engineering received little or no coverage. The instructional model for this course began to change in 1999. First, rather than using an instructor generated project, client based projects were sought. The clients generated design requirements, interacted with the students, and used the final project reports as preliminary engineering studies and fundraising vehicles[11]. Second, the focus of the design project shifted to include multiple civil engineering disciplines. Buildings were still a part of the process, but students also conducted hydrologic analyses, developed boring plans, designed foundations and retaining structures, and designed parking facilities. When the opportunity presented itself, environmental engineering students from the Department of Geography and Environmental Engineering were integrated into the design process[12]. Subsequently, the capstone project designed structures and facilities under the development or construction on campus. The strength of client interaction varied with the agency supervising the project and the complexity of the design within each civil engineering discipline varied from project to project. The course maintained this model until 2008. The end of course assessment in 2008 considered the best practices available in the literature and the ASCE BOK2 which resulted in a major redesign of the course content and structure for the 2009 edition in the continuing search to improve student motivation, engagement, and learning.

Developmental Assessment

The course assessment in 2008 indicated that the course CE492 had reached an all time low. As seen in Figure 1, student assessments in most categories dropped by 20% and dropped by over 25% in the critical category of “My motivation to learn and continue to learn increased.” It was not uncommon to find student comments that began with, “This was the worst course I’ve ever had.” This clearly is not the desired student response to a capstone course; hence, immediate remediation was required. Concurrently, the engineering programs at USMA underwent their scheduled ABET certification. In the Civil Engineering Program both the self study and the program evaluator identified a need to improve the treatment of business practices, public policy, and public administration. Additionally, the publication of the *Civil Engineering Body of Knowledge for the 21st Century*[1] by ASCE further highlighted the need to improve the treatment of professional outcomes including business and public administration, leadership, teamwork, and attitudes. The confluence of these three assessments provided the motivation to restructure the capstone course to improve student motivation and the treatment of professional issues.

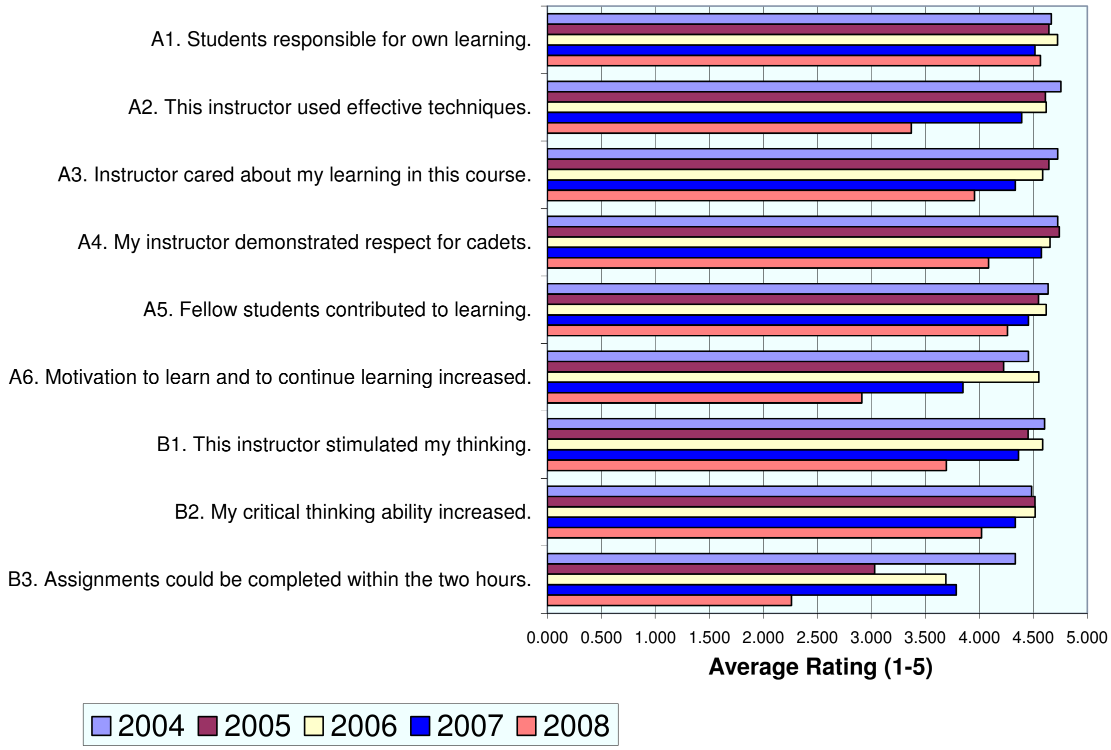

Figure 1 Course Assessment Data

Course Organization

In the past when it focused on the design of a complex building, CE492 was titled "The Design of Structural Systems". The re-structured course is now called "The Professional Practice of Civil Engineering" and the major components of the course design are contained in the title of this paper: *Fake Firms & Funny Funds For Four H.*

Fake Firms—The first component is the organization and function of the student groups and their relationship to the faculty. The senior members of the faculty were organized as the Parent Firm with executive leadership of the department assuming the roles of President and CEO. Other senior faculty members took the role of Firm Vice President with responsibilities in their particular areas of expertise. The course director fulfilled the role of Chief Operating Officer and was responsible for course coordination, administration, and

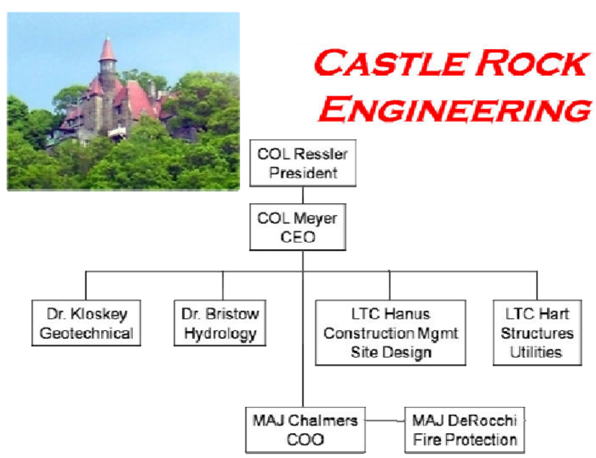

Figure 2. Parent Firm Organization

instruction. Other faculty members with specific expertise such as fire protection provide guidance and instruction as needed. The position of vice president was not a symbolic one. The vice presidents provided guidance and instruction in their area of expertise as well as evaluated the student work within the specific disciplines.

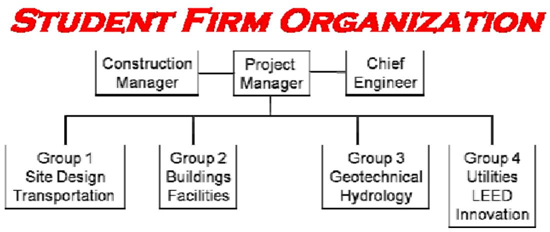

Figure 3. Student Firm Organization

The 45 students in the course were grouped into three sections with each section constituting a 15 member engineering firm. The student firm operated as a wholly owned subsidiary of the faculty's parent firm and was typically organized as shown in Figure 3.

The student positions of Project Manager (PM), Chief Engineer (CE), and Construction Manager (CM) were selected through a competitive interview process. Based on a job advertisement from the parent firm, students submitted resumes and participated in a formal interview conducted by a team of faculty members and an informal interview over dinner. The faculty selected the student leadership based on the interview results, class performance, the individual development needs of the students, and group dynamics. Student firm leadership was then responsible for selecting the design group leaders and assigning the firm members to design groups. This was not simply another method for organizing student design teams. In addition to executing an engineering design, the *Fake Firm* also had to perform many other functions common to the operation of an engineering firm including Peer Technical Review, Performance Reviews and Evaluation, and Continuing Professional Development.

In the design process model used in this course, the detailed component design of each subsystem is contained in the 65% submittal. Prior to the submittal, each *Fake Firm* conducted an internal peer review of each group's design. Group reports were exchanged and each reviewing group prepared a memorandum detailing all of the errors, omissions, and deficiencies of their peers' report. Concurrently each group's design was graded by the supervising Vice President (faculty member) of the Parent Firm. Then, the peer review memorandum was graded by comparing it to the Vice President's evaluation of the same design. The degree of agreement between the student's peer review and the corresponding Vice President's evaluation determined the design group's peer technical review grade. Ten percent of the course grade was assigned to the peer technical review to emphasize its importance. The Fake Firm then had an opportunity to make corrections to the component designs prior to the 65% briefing and submittal.

Since real engineering firms conduct performance evaluations to reward hard working employees, develop inexperienced employees, and terminate those who fail to meet the company expectations, each *Fake Firm* developed a counseling and rating scheme from its organizational structure. The *Fake Firm* then used an Organizational Effectiveness Report (OER) to assess an individual's productivity, performance, contribution, teamwork, and attitudes. The PM, CM, and CE were responsible for evaluating each of the group leaders and group leader evaluated the members of that group. An initial counseling was required before the 10% submittal, a mid-term counseling with the 65% submittal, and a final counseling with the 100% submittal. Five percent of a student's grade was derived from the peer evaluations.

Continuing Professional Development is essential to success in our profession and is codified in many state licensing regulations. To introduce students to this process, each *Fake Firm* was responsible for professional development classes focused on preparation for the Fundamentals of Engineering (FE) exam. The United States Military Academy requires all engineering students to take the FE exam and this process assisted in their preparation. The CE was responsible for the *Fake Firm's* professional development program. The CE assigned topics to ensure proper coverage of FE material, scheduled the sessions over 5 class hours, and ensured that instructors were prepared. Every firm member developed a 10 minute review session focused on one specific FE topic and presented it to the other members of the firm. Firm members were responsible for lesson objectives, reading assignments, and handouts. Each student's professional development class was graded by both peers and faculty for five percent of the course grade. The professional development program culminated with two FE style exams (time constrained, multiple choice answer) as preparation for the FE itself.

Since actual firms have to deal with the unexpected, so did the *Fake Firms.* Spinning the "Fickle Wheel of Fate" generated events common in the business world that could affect a firm's operation. Events, both random and non-random, included:

- Error found on previous design. Pay $5,000 fines and fees and conduct a redesign. (The redesign is an FE practice problem with a 3 minute time limit)
- Building's roof springs a leak. Pay $2,500 for repairs
- Mrs. Hart has another baby—chocolate and doughnuts for everyone!
- Snow Day—everyone go home. (Then the PM says, "But we had something planned today!" Then the instructor says, "Yes you did, but you aren't doing it today. Welcome to the real world.")
- The client is showing up in 10 minutes and wants an update. Prepare and give a no-notice project presentation.
- Win $5,000 in free office supplies! Add this to the firm's income and budget.

This exercise was designed to promote learning, so sometimes events were random and at other times the wheel was stacked to ensure a specific event or type of event occurred.

Organizing as and performing the internal functions of an engineering firm is an admirable educational objective but it is missing one key component of business: the requirement to make a profit! Accordingly, the *Fake Firms* were required to manage their *Funny Funds* and in the end, hopefully, turn a profit. Using guidance and tools provided by a member of the department's Civil Engineering Advisory Board, the authors developed a relatively simple financial management rubric which accounted for many of the financial aspects of running an engineering firm. The *Fake Firms* applied these rubrics during the preparation of the design and attempted to make a profit.

The project managers were responsible for determining both the man-hours required to complete the design and the billing rates for the members of their firms. The billing rate determination began with a specified

Position	Hourly Wage	Multiplier	Billing Rate
PM, CE, CM	$50	3.1	155
Group Chief	$45		$140
Staff Engineer	$40		$125

Table 1 Wage and Billing Rates

hourly wage for each of three classes of employee. Using the rubrics provided for rent, utilities, taxes, administrative costs and target profit, the project managers determined the 'multiplier' to convert hourly wages into billing rates. The specified parameters were developed to lead the project managers to a multiplier of about 3.1. Specified wages and typical billing rates are shown in Table 1.

The *Fake Firms* estimated the man-hours necessary to complete the project and track billable hours using the project budget spreadsheet. In this tool, the project was broken down into phases and tasks. The number of hours each engineer was expected to spend on each task was estimated and then a project cost was determined. Billable hours were tracked on tabs for each individual and summed on the master sheet. Every two weeks the *Fake Firms* invoiced the client for the two week's worth of billable time. The firm then 'paid' its employees, paid the rent and utilities, paid taxes, and paid administrative costs. If the PMs did their job correctly, there was money left over for emergency expenses that might arise in the next two weeks. Loans were available from the First National Bank of Extortionville should a *Fake Firm* have a cash flow crisis. The *Fake Funds* rubric with sample bi-weekly invoice is included in this paper as Appendix A.

Fake Firms using *Funny Funds* is a great way to organize a capstone, but engineering firms are in the business of designing projects and this model really needs the right project to make the experience successful. The review of the available literature and the authors' experiences suggested that the 'right project' shares the following characteristics:

- Scope: the project must be large enough to be a challenge, yet small enough to be accomplished by a student team in one term (or two terms if a multi-term capstone). Additionally, for a civil engineering capstone, the scope must include a variety of civil and related disciplines.

- Realism: the ideal project is a real world project where the students' work is actually going to get used either as a fundraising vehicle[11], as a conceptual design to support further work[11], as plans for a student built project [9], or as actual construction documents[8].

- Client: the presence of an actual client is essential. Just as children are never quite sure their parents are telling them the truth, students often doubt their teachers' assurances that, "You will do this when you graduate." The presence of an actual client dispels this issue. The client generates requirements, establishes limitations, and comes up with the conflicting requirements the young engineers must solve. Additionally, the client often ask for one thing when really wanting something else, and the student engineers learn to provide what is needed, not necessarily what is asked for. Instructor generated projects typically fail to achieve the same level of realism.

For 2009, the CE492 Project was the design of a fair park for *4-H* of Orange County, New York. 4-H is a national youth development organization that encourages young people to "learn by doing" in the areas of science, engineering and technology, healthy living, and citizenship. The project involved the site development and facilities design of a 65 acre park to support the annual 4-H county fair and related agricultural education and youth development activities. The design requirements were articulated in the brochure shown in Figure 4 published by the Orange County Cooperative Extension Office, the 4-H proponent for the county. These requirements were further developed in correspondence with the client including the working lunch shown in Figure 5.

Figure 4 4-H Park Concept Brochure


Figure 5 Lunch Meeting with the Client

Once the requirements were established, the students organized into the design teams shown in Figure 2 to form their *Fake Firms*. They conducted a desk-side site reconnaissance and project analysis and then conducted a site reconnaissance (in the snow of course) See Figure 6. The students then spent the rest of the term figuring out how to fit all of the client's requirements onto the desired site and design buildings, utilities, hydraulic structures, and foundations. The entire course can be described by Figure 7.

Figure 6 Site Reconnaissance in the Snow

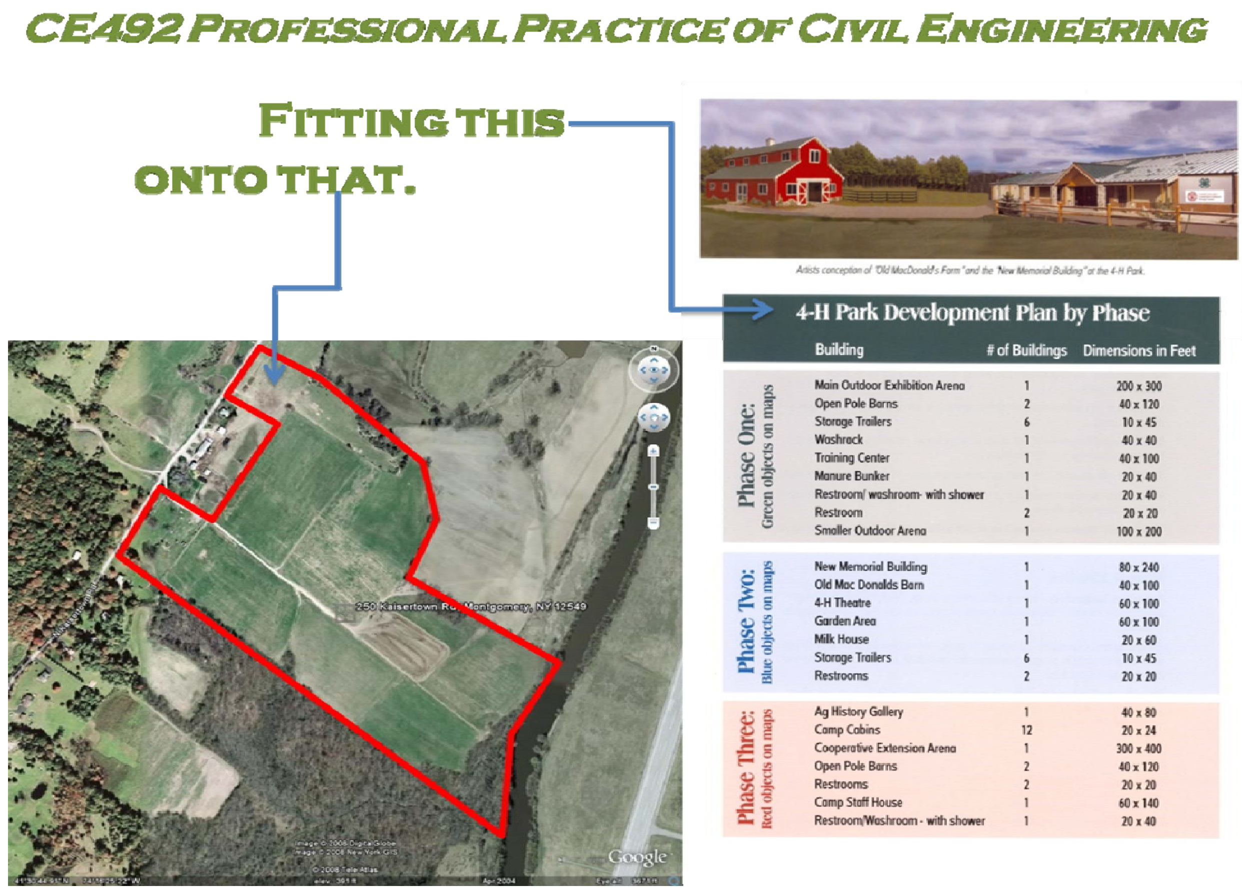

Figure 7 The Professional Practice of Civil Engineering

Continuing Assessment

The purpose of this course organization was twofold: increase student motivation in their final term and serve as the students' introduction to the professional practice of civil engineering. Assessment procedures were established to measure the degree to which these purposes were achieved.

At the beginning of the course, students were surveyed to determine their level of motivation. Students were asked to rate their level of motivation as compared to other courses from 1 to 10 with 1 being "I'll just get by," 5 being "about average," and 10 being "more motivated than normal." As seen in Table 2, the firm leadership (9 students) clearly showed an increased level of motivation as compared to their other courses while the design group leaders (12 students) shows a slight increase and the design group members (24 students) show an average level of motivation.

Student Classification	Motivation Level
Firm Leadership (PM,CE, CM)	7.6
Design Group Leaders	5.8
Design Group Members	4.9

Table 2 Student Motivation

The authors also wanted to know what elements of the course design most contributed to a student's level of motivation. The 45 students in the course were asked to complete Table 3 and indicate which elements of the course design most contributed to their level of motivation. The three factors with the most impact are shown for each group of students.

		Firm Leadership	Group Leadership	Group Members
Engineering Firm Organization	Leader Selection Process			
	Engineering firm w/ specialized design teams	2	1	2
	Peer Technical Reviews			
	Student led professional development (FE Prep)			3(tie)
Integration of Business Practices	Financial Management			
	Integration of senior faculty as VPs			
	Business based communications			
Project Selection	Scope: large project w/ little initial definition	3		
	Ability to divide the project allowing specialization and focus on a specific tasks		3	3(tie)
	Real world project with a client who sets requirements	1	2	1

Table 3 Student Motivation Survey and Results

Overall, the most motivating factor was the fact that this was a real world project. There was a client who will actually use the student work. The second most motivating factor was the organization of a large engineering firm with specialized design teams allowing students to focus on a particular area with a design team. From this point, the motivating factors began to disperse. The firm leadership was intrigued by the ill-defined nature of the project while the group leaders and members appreciated task specialization. It is interesting to note that the group members also rated the professional development program as preparation for the FE exam highly. This was an unanticipated result from the survey.

In addition to increasing student motivation, this course was intended to be the students' first exposure to 'pre-licensure' experience. The best way to assess this is by comparing the tasks assigned and the project results in this academic exercise to the tasks assigned and project results expected of newly hired engineering graduates. This evaluation is currently in progress and will be accomplished by having a visiting professor and an adjunct professor with a combined 70 years of experience in engineering and construction evaluate the course and the student work. They will assess the quality of student work as compared to that of newly hired engineers and the verisimilitude of the *Fake Firms & Funny Funds For Four-H* concept.

Conclusion

Structuring a capstone course in this manner requires a significant commitment of faculty time and resources on the part of a Civil Engineering Program. Senior faculty are involved as Firm Vice Presidents in the interview process for firm management, subject matter expert presentations, and student product evaluation. The course director first must find the 'right project' which is often a very elusive quarry. Next, the instructional and evaluation documents for the design project must be prepared and agreed to by a large group of faculty members. Then three large design groups must be coached, taught, mentored, and evaluated through their first real world program management and design experience. Is it worth it?

The restructured course seems to have had the desired effect. The Orange County 4-H office was extremely pleased with the assistance in requirements definition and conceptual site plan development. The surveys of the students involved indicated an equal or higher level of motivation in this course than in their other courses. The faculty involved were pleased with the effort and motivation observed in most students. One of the project managers even remarked, "I've never seen second semester seniors so motivated about a design project." So far, all indicators are positive, but the truth is, we will not know whether or not we've achieved our goal of making CE492 a student's first pre-licensure experience until we receive a letter from a graduate saying, "I got handed my first big project today. When I looked at it, I thought, 'Hey, I did this in CE492!'"

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Appendix A

"Funny Funds" in CE492,or, How the Money Works"

A simplified approach of engineering financial operations: An engineering firm pays its engineers at one rate and bill the client at some higher rate. For example, a firm may pay a new engineer$25 per hour, but bill the client $80/hour. The difference is called the 'multiplier' and accounts for all the costs inherent with running a business other than the engineer's pay. The lower the multiplier is, the more efficient the firm is. Highly efficient firms may have a multiplier in the low 2s, while an inefficient or specialty firm's may be as high as 4. Typically, the multiplier is around 3. The funds generated though the multiplier are used to cover the company's overhead including facility costs, fees and licenses, non-billable personnel like the IT staff, and copier paper as well as funds for contingencies and profit. Each firm will be required to determine the multiplier for the firm based on the following conditions. Additionally, the project manager will sign a 'not to exceed' contract at the 10% submittal giving the maximum cost of the project. The firm will be paid based on invoices submitted by the project manager.

Fixed costs:

Hourly wage rates	PM, CM, Chief Eng	$50	Staff Engineer	$35
	Team Leader	$40	Modeler	$40

Rent (Room 128): $750/due 1st and 16th of each month (Feb, Mar, Apr)

Utilities: $500/due 1st and 16th of each month (Feb, Mar, Apr)

Variable costs:

Employer's share of taxes: 10% of salary paid

Company administrative costs (CFO, IT, Secretary): 20% of salary paid

Each firm's decisions:

Profit percentages

Contingency (money to pay for the unexpected)

Principal's Pay. (If you seek help from a firm principal or Vice President, outside of scheduled blocks, you must 'pay' them the principle's rate of $185 per hour.

The following are reimbursable expenses that the client will be billed for plus a 10% fee:

Soil excavation

Boundary survey

Permitting fees

Modeling expenses

Anything else the firm can think of and include in the contract

Invoicing: On the 1st and 16th of February, March, and April and on 1 May each firm will prepare an invoice for the parent firm detailing the number of billable hours worked by individuals, the hourly rates for the individual, and the total invoice. Additionally, the firm will submit a report to the auditors showing salary, taxes, rent, utilities, and overhead paid and cash reserves on hand. The 1 FEB invoice will include all billing for the month of January. Thereafter, each invoice will include the information from the preceding half month.

Paying the workers: Each firm will bill the parent firm based on the number of hours worked on this project. To simulate the fact that some of an employee's time is devoted to non-billable tasks and that employees also work on jobs that the firm does not win, employees will be paid for twice the hours billed to the parent firm. For example, if Sally Port's pay rate is $50/hour and her billing rate is $150/hour and she had 10 billable hours this period, the parent firm will be billed $1500 and Sally will be paid $50/hour * 10 hours * 2=$1000. This leaves the firm $500 for other expenses. Taxes and company administrative costs will be based on the $1000 paid to Sally. So, continuing the example, taxes (10% of salary paid) will be $100 and administrative costs (20% of salary paid) will be $200. This comes out of the $500 for other expense, so now only $200 remains for profit and contingency. But don't forget about the lights and the rent….This example should give each firm a starting point to work out the multiplier.

Record keeping and reporting: Each firm will develop a 'Project Budget' by the 10% submittal that will estimate the time required to complete the project. Based on the chosen multiplier, the firm can use the project budget to estimate the total cost and determine the contract not to exceed cost. The project budget can then be used to track actual billable hours. The current project budget will be submitted with each invoice. With each invoice, each firm will submit a financial status report which begins with the balance forward from the last report, adds the billed amount for the current period, deduct salary paid, taxes, administrative overhead, and rent/utilities. The difference remaining is available for contingencies and profit until the next reporting period. The firm's books are to be presented for audit with each invoice.

Loans. Should a firm not have the liquid capital necessary to pay a bill, a loan can be arranged with the First National Bank of Extortionville for a rate of 1.5% per 30 day term (18% per anum). Shorter terms are not possible.

Each firm's goal is to make a 12% profit. If the contracted amount is $100,000, then the target profit is $12,000. More profit than this means that the firm overestimated the time to complete the project and thus overestimated the cost. In reality, this firm would not win the bid. Less than 12% profit means that the margin is too small to justify the risk and the firm does not have sufficient liquidity to pay for contingencies.

Starting Funds: Each firm starts with $10,000 in venture capital provided by a shady financier whom you are not allowed to know, mention, question, contact, or confirm or deny the existence of. It would be a really bad idea to lose his money…

Bi-Weekly Financial Report

Balance at end of last period __________

Interest earned since last period (simple interest of 2% per year for two weeks) __________

Starting balance today: ___________

Income:

Employee	Billable Rate	Billable Hours	Sub-total
PM, CM, CE			
Team Leader			
Staff Engineer			
Modeler			

Total invoice to parent firm __________

Other income (income from reimbursable expenses) ___________

Deductions:

Pay

Employee	Pay Rate	Hours for pay	Sub-total
PM, CM, CE	50		
Team Leader	40		
Staff Engineer	35		
Modeler	40		

Total pay to employees __________

(note: hours for pay is always 2* billable hours)

Taxes: 10% of total pay __________

Administrative costs: 20% of total pay __________

Principal's pay at _____ hours *$185/hour __________

Rent (2 weeks): $750

Utilities (2 weeks): $500

Other expenses __________

Current funds available (starting balance + income-expenses) __________