Journal of Construction Education
Summer 2001, Vol. 6, No. 2, pp. 65- 74

1522-8150/01/$3.00/Educational Practice Manuscript

Designing Engineering Contents for a Construction Management Program

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The engineering contents for the Construction Management program at a West Central University had shortcomings in their instructional objectives and delivery, and students frequently required more than the intended number semesters to complete them. Furthermore, administrative mandates compelled a reduction in their total number of credit hours. This article presents the strategies followed to develop a new engineering course sequence, with improved contents, in a very short time span. It also discusses the instructional design philosophy observed for these new courses, and the concerns raised by the participants in their development process.

Keywords: Construction Management, Instructional Design, Curriculum Development, Engineering Contents, Structural Design.

Introduction

There is a general consensus among Construction Management (CM) academicians and industry advisory boards that CM professionals need to have an understanding of the forces acting on construction structures, how these forces are supported by construction structures, and how these structures are dimensioned depending on their materials. Furthermore, CM professionals need to know and understand codes and regulations that reflect these engineering aspects. Laboratory tests, realistic final projects, and similar practical experiences enhance the learning experiences for most CM students. These topics will be called "engineering contents" in this article. But the devil is in the details. Should CM students be capable of designing structural members? Should soils engineering be included as a separate course? How many credits should engineering courses have apportioned? Who should teach these courses?

This article discusses how the engineering contents in the Construction Management program at a West Central University, were revised as part of a general curriculum overhaul planned for months, and made imperative by new university guidelines. These changes will take effect on the fall semester of 2000, and the changes discussed here were developed between September and November of 1999. The objective of this paper is presenting the strategies, pedagogical issues, administrative concerns, and lessons learned during this revision of the engineering contents. Some of the circumstances presented here are unique, and the curriculum decisions taken reflect the character of its CM program. However, many issues could be applicable to other CM programs.

The CM Program at a West Central University in Context

The CM program has been operating for over fifty years. It is one of three programs offered in the department of Manufacturing Technology and Construction Management (MTCM), the other two being Industrial Technology Management and Technology Education and Training. Furthermore, MTCM is in the College of Applied Human Sciences, which comprises nine relatively dissimilar departments, such as Occupational Therapy, the School of Education, Design and Merchandising, Health and Exercise Science, and Social Work. This broad scope has worked well for MTCM, since it has enjoyed more autonomy and appreciation for its mission than some other CM programs housed in Engineering, Architecture, or other traditional colleges.

The program experienced important changes in 1997. A Pre-MTCM program, common to the three department majors, replaced its freshman and sophomore years. The CM program became a controlled major, whose admission requires the completion of the Pre-MTCM curriculum and a minimum GPA of 2.3. Furthermore, a mandatory six-month, six-credit internship was implemented, which can be completed over one semester or two summers. No additional courses can be taken while carrying out the internship.

New university mandates have resulted in further program revisions. The program must be reduced from its current 128 credits to 120 credits by the fall of 2000. A new All-University Core Curriculum, also starting in fall of 2000, has new requirements and course offerings. The program has also strived to accommodate the new (but unofficial in 1999) AACE standards in these revisions.

Current Engineering Contents

The Construction Management program currently provides much emphasis in engineering contents. The current engineering curriculum structure is shown in Figure 1. It consists of six courses with a total of eighteen credits. Statics and Mechanics of Materials are offered in separate courses, followed by courses in Soils Engineering, Structural Design of Steel and Concrete Structures, Wood Structures, and a Construction Materials lab. The Civil Engineering (CE) department offers all these courses, except for Wood Structures, which, for historical reasons, has been offered by the Forest Sciences department.

Shortcomings of Current Engineering Courses

The current offerings have shortcomings in several areas. Many of them had been evident in the past, and the significance of others was made more evident in the research and development process for this revision.

Service courses

Some of the most important drawbacks in the current engineering courses derive from having them offered outside the MTCM department. Their contents frequently tend to reflect a civil

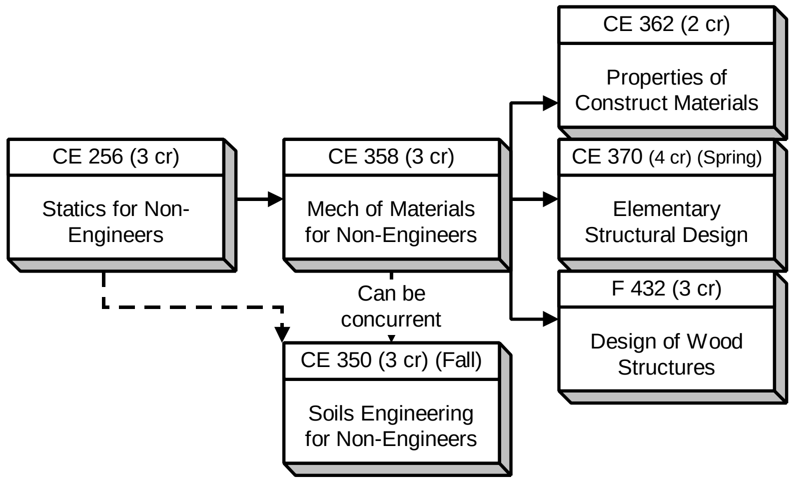

Figure 1. Current Engineering Sequence

engineering perspective instead of providing CM insights. For example, the Structural Design course emphasizes design details, while the rationale behind applicable codes and specifications (e.g., UBC, ACI) is much less stressed. Morris and Laboube (1995) discuss in more detail what constitutes a CE teaching perspective. A more pervasive but equally important problem is the lack of faculty ownership for some of these courses, which can lead to multiple pedagogical problems (Senior et al., 1993). Many CE instructors have taught Statics (a particularly extreme case) over the years. One instructor recently admitted to the class that, at least once, the loser of a straw draw among junior CE faculty determined who taught Statics. In fairness, it must be noted that permanent instructors have enthusiastically offered some of the engineering courses for years.

Transfers and prerequisites

Reviewing the prerequisites of the Statics course provided a particularly insightful case of why long-lived requirements need to be regularly challenged. Statics has currently two prerequisites, M126, Analytic Trigonometry, and M141, Calculus in Management Sciences. For years, students could take M126 concurrently with Statics, provided that they had finished M125, Numerical Trigonometry. An uncomfortable situation arose in fall 1999 when the CE department decided to enforce the M126 prerequisite. An articulation agreement with the local community college allows transferring its Statics course. However, this course only requires their equivalent of M125 as prerequisite. Students caught without the M126 prerequisite defected in mass to take Statics at the community college (CE did offer these students the chance to complete M126, a one-credit math module, in the first weeks of the semester. Many chose not to take advantage of this offer). Several questions ensued. Were these students getting an inferior education at the community college? If so, why did MTCM allow this transfer? If not, why was M126 a prerequisite for Statics? An analysis of these course syllabi showed that, in fact, Statics did not require it! The new curriculum will not list M126 as a prerequisite for any course. Less dramatic reviews were also conducted for all the other courses.

Internship and course sequencing

Many CM students transfer from other programs or colleges. They frequently can complete the Pre-MTCM program in one year and then move on to the CM major. As Figure 1 shows, the current engineering course sequence begins with Statics. Mechanics of Materials, and then the two Engineering Design courses and the Construction Materials lab, follow it. Soils Engineering can be taken concurrently with Mechanics of Materials, but it is offered in the fall only. Structural Design is also only offered yearly, in the spring semester. This sequence has a length of three semesters when a student takes Mechanics of Materials in the fall semester and enrolls concurrently for Soils Engineering. However, this assumes that the student can fit nine hours of engineering courses into the last year, and frequently, the last semester. Moreover, if a student takes Mechanics of Materials in the spring semester, the engineering course sequence requires four semesters. If the student takes Mechanics of Materials in the fall, but fails to enroll concurrently for Soils Engineering, the sequence also becomes four semesters long.

CM requires six months of full-time internship for all students. This internship can be taken in one semester worth six credits, or in two summer sessions of three credits each. Many intern sponsors prefer the six-month option, but only students finishing their engineering sequence in three semesters can take this option without prolonging their four-semester plan of study. Accommodating the internship into the inflexible engineering course sequence has been a major task for many students and their faculty advisors. More information about the internship program is available at the MTCM internship director's office.

Engineering Materials Lab

The Construction Materials lab tends not to be taken concurrently with the engineering design courses. In some cases, this "Smash Lab," as commonly called among students, is taken before the engineering design courses, thus nullifying the intended didactical effect of having a tangible experience along with the design concepts.

Accreditation issues

Although AACE has not finalized its new accreditation guidelines, a preliminary version was used as a point of comparison with the current engineering contents. These guidelines suggest between 20 and 30 credit hours of construction science contents. They should include a minimum of three credits of design theory, six of analysis and design of systems, six of methods and materials, one of construction graphics, and one of surveying. The current CM program has 46 credits covering these topics, substantially more than required. Factoring the university mandate to trim eight credits from the current program, the current engineering contents were prime candidates for an overhaul.

Strategy for the New Contents Development

The engineering contents revision had to be completed in a very short time span. The requirements for the new University Core Curriculum had not been established by the administration at the beginning of the fall semester. Modifying the engineering courses had been discussed for months, but no concrete steps had been taken at the beginning of the semester. The situation with the Statics course discussed before in this article brought a sense of urgency to the engineering contents overhaul, but with a deadline to submit curriculum changes by early November, it was clear that a design-by-committee approach would not be adequate. One of this article's authors has taught engineering content courses, is the undergraduate CM program coordinator, the head of the MTCM curriculum committee, and the MTCM representative to the college curriculum committee. The other author is a structural civil engineer, and has also taught engineering courses in civil engineering programs. The CM faculty decided to entrust the authors with reviewing the existing engineering contents, and recommending their new contents and delivery. The CM curriculum subcommittee met every week during the semester, and at least monthly with the CM faculty at large.

The Civil Engineering department fully concurred with the goal of overhauling the CM engineering contents. They had very little input up to the point where the first course drafts were prepared, since the CM faculty wanted to have maximum flexibility in their research and brainstorming. However, and considering that all but one engineering content course is offered in the CE department as a service to the CM program, it was always kept in mind that the final course structure should be acceptable to both departments. The first curriculum draft proposal was presented to CE representatives and the Woods Structures instructor. Several meetings with all the stakeholders followed. Attendees to these meetings included the two authors and the MTCM department head; several of the CE instructors and the CE assistant department head; and the Woods Structures course instructor.

Instructional Design Philosophy

Professional engineers need a deep understanding of design theory so that they can develop construction codes and specifications. Professional constructors need a deep understanding of construction codes and specifications so that they can develop construction projects. Engineers should have a good grasp of construction project issues to develop sound codes and specifications. Constructors should have a good grasp of design theory to understand codes and specifications.

The above design philosophy was established early on in the contents development process, and formally accepted by the CM faculty at large. Other curriculum design principles included that labs and other practical components should be provided as concurrently as possible with the corresponding theory; that there would be "no stones unturned" and no "sacred cows," that is, the design would cover every possible issue; and that no implementation constraints would be initially considered.

Preliminary Proposal

Several sources were researched to develop the initial contents proposal. While literature on individual engineering course development is available (e.g., Opfer & Gambatese, 1999), there is only scant information on the current engineering contents at CM programs. The summary presented by A. Chini (1995) proved invaluable as a starting reference. Several CM programs sent copies of their engineering syllabi. Contacts with instructors at other programs proved to be helpful.

The Internet was used extensively as a research tool. Most publishers have available on their websites the table of contents of virtually every recent book (e.g., McGraw-Hill at http://www.pbg.mcgraw-hill.com, Delmar Publishers at http://www.delmar.com, Prentice Hall at http://www.phptr.com. Sites such as Amazon.com provide powerful search engines, which can be used to pinpoint textbooks with any target keyword.

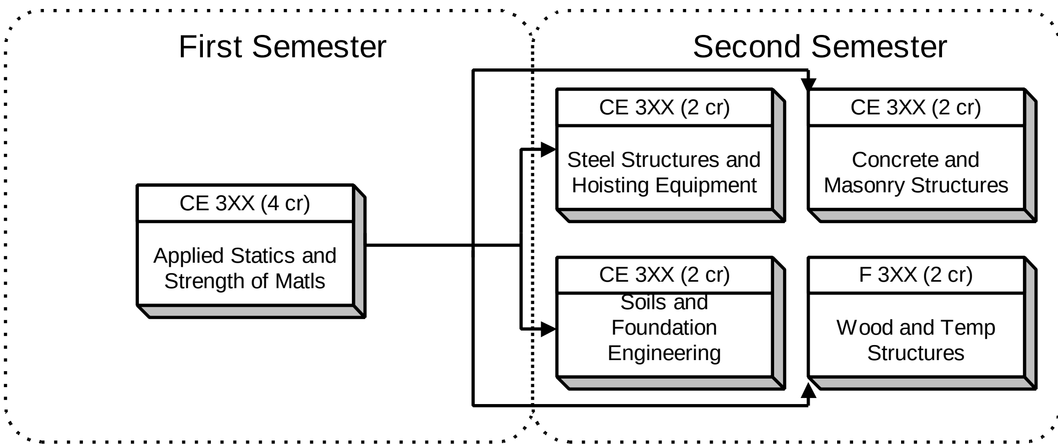

Figure 2. Initial Sequence Proposed

The first proposed course sequence is shown in Figure 2. This arrangement combined Statics and Mechanics of Materials into a four-credit course. Four design modules followed: steel structures, concrete and masonry structures, wood and temporary structures, and soils and foundations. Each of these two-credit modules was to be offered in eight-week sessions, every semester. This implied doubling the meeting frequency compared to a full-semester two-credit course, that is, six hours per week. Although Figure 2 shows the minimum sequence duration of two semesters, it was expected that many students would choose to complete the courses in three semesters, to better balance their total academic load.

The total of credits for the engineering sequence was abridged from 18 to 12 credits. This reduction was made possible in part by the elimination of the Properties of Construction Materials lab. An existing Pre-MTCM course, MC 251, Materials Testing and Processing, included some contents of secondary importance, from a CM perspective (as a Pre-MTCM offering, it also had to cover manufacturing materials). This course was revamped to include more construction-specific contents. The rest of the removed lab course was included in the proposed course modules.

The Schedule of Topics for Applied Structural Timber Materials and Design is shown in Table 1, as an example of the practical and code-oriented contents intended for these modules.

Table 1

Initial Schedule of Topics Example

CE 3XX APPLIED STRUCTURAL TIMBER MATERIALS AND DESIGN
Tentative Schedule of Topics

1. **Introduction.**
   Relevance and objectives. Liability and ethics of professional wood structures engineers and constructors. Codes and standards for timber and engineered wood design, construction, and testing.
2. **Design of Simple Timber Beams.**
   Code design rationale and main provisions. Loads. Working stress computations. Reactions and load bearing. Gang-laminated beam sections.
3. **Design of Simple Wood Joists and Rafters.**
   Code design rationale and main provisions. Published tables. Lateral stability.
4. **Design of Simple Timber Columns.**
   Code design rationale and main provisions. Design procedure.
5. **Wood Connections.**
   Types of connections. Design principles. Commercial alternatives.
6. **Design of Simple Concrete Formwork.**
   Code design rationale and main provisions. Loads. Published tables. Commercial alternatives.
7. **Wood and Wood materials.**
   Wood structure and properties. Commercial timber and engineered wood products.
8. **Plastics and Composite Materials**
   Structure and properties of plastics. Properties of composite materials. Structural applications.
9. **Laboratory tests.**
   Bending and compression of wood specimens. Tensile properties of plastics.
10. **Discussion of Notable Historical Failures in Timber Construction.**

Administrative Concerns

The first proposed sequence brought concerns from several stakeholders, especially the CE department. A main concern was the eight-week, two-credit course sequences proposed. CE instructors are expected to teach 12 credits per year. Most CE courses have three credits. An instructor teaching one of the proposed two-credit courses every semester would most likely end up teaching an additional load of three three-credit courses. In other words, the instructor would exceed the CE standard of 12 credits, and would add a course to the usual load of four courses per year. It would also complicate teaching assistant assignments, and the labs would be overloaded during one half of the semester, and unused in the other half. Administrators also pointed out that two-credit courses are time-consuming and not very relevant in non-tenured faculty dossiers.

The proposed Statics and Mechanics of Materials course was readily accepted. As previously pointed out, this area has not had a permanent instructor. However, other areas with identifiable champions required much more discussion. Permanent instructors protested that their course contents were already lean, and any further reduction in contents was impossible. On the other hand, adding new contents was equally, if not more, unrealistic. CE instructors are expected to teach 12 credits per year. Most CE courses have three credits. An instructor teaching one of the proposed two-credit courses every semester would most likely end up teaching an additional load of three three-credit courses. In other words, the instructor would exceed the CE standard of 12 credits, and would add a course to the usual load of four courses per year. However, much tact and willingness to compromise was necessary to keep moving forward the new course definition discussions.

Final Version of the Contents and Courses

The final arrangement is shown in Figure 3. The eight-week courses were eliminated, and in their place, three full-semester courses of three credits each will be offered. Statics and Mechanics of Materials were kept in one course, as proposed, but some of the originally proposed contents will be covered in Wood Structures. This course will now include temporary structures, and will be a prerequisite for Elementary Design of Structures. This latter course will include steel and concrete structures, similarly to the current approach, but its contents will now reflect the objectives proposed by CM. This program is one of few programs offering Soils and Foundation Engineering. The current course has a dedicated CE instructor, and has excellent (if detailed) contents. It was decided that this area provides part of its character to the CM program, and was kept at its current three credits instead of the two proposed.

This final contents arrangement fulfills the instructional objectives of CM, while responding to the concerns of the CE department. It is administratively simple to implement, since of the four courses, three only require syllabus changes, and one is being reduced from four to three credits. This is especially evident compared to the initial proposal, which required creating five new courses, four of which would follow eight-week schedules. Turfs were protected, too. Wood Structures and Soils Engineering, the current courses with strongest champions, remain at three credits.

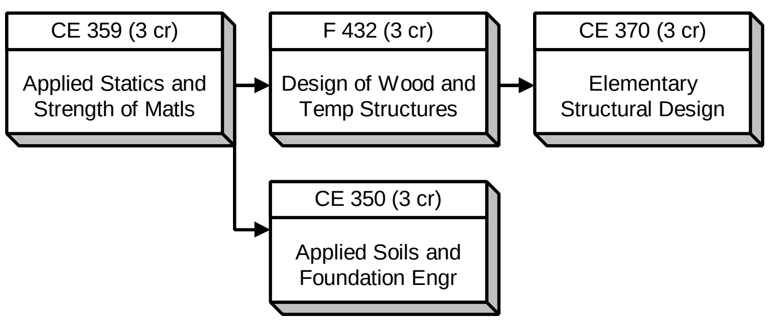

Figure 3. Final Adopted Sequence

Conclusion

There were many lessons learned for the CM program from this curriculum design experience. It clarified the intended role and relative importance of engineering contents in the program. The advantages and limitations of eight-week course modules were examined. The contents of existing courses were revisited, and showed how there can be misalignments between what is being covered in class and what other faculty assumes is being covered. MTCM improved its relations with the CE department and their faculty. The whole research, design and adjustment process took only three months, and showed a viable approach for compressing such curriculum projects. This approach can be summarized as an early, clear definition of objectives, which were entrusted to a small number of faculty members. These faculty members were given much latitude to develop the initial course proposal, and were key participants in the ensuing discussions.

Even with the full agreement in the new contents, there are implementation issues to be resolved. For example, although the new sequence is very likely to be approved by the Engineering and the University curriculum committees, it is not an official change yet. Should students refrain from registering for the last offering of the current Statics next semester? Since only the combined course will be offering in the fall, they would be retaking the Statics contents. One alternative being considered is offering the current Mechanics of Materials in the summer session, so that these students could be ready to start the engineering design courses by fall.

An unresolved issue is whether most or all of the engineering sequence could and should be taught in-house at MTCM. There are good reasons to seek this objective, such as having engineering instructors with a better understanding of CM education needs, and a more agile revision process for any contents area. On the other hand, one reason for offering engineering courses in the CE department has been creating a positive synergy between CE and CM students. Since CE students cannot take the CM service courses for credit, this reason has become less important over the years. A limiting factor for the in-house offerings is that CE would have to give up the faculty lines now devoted for these courses, which could be a long and delicate process.

The present curriculum development process will not be complete until the finer issues of course contents and delivery are completed. As mentioned in the introduction, the devil is in the details, and some fire and brimstones will probably materialize during the spring 2000 semester, when these points will be discussed.

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