

More substance than software: a combined CADD and construction drawings course

William P. Manion, M.S., P.E.

The University of Maine
Orono, Maine

This paper describes a combination computer aided drafting and design (CADD) and construction drawings course for first-year students. Using several different delivery and pedagogical approaches, the course is comprised of in-class lectures on civil engineering construction projects in general, laboratory exercises to study construction drawings and YouTube videos to teach CADD software. To engage the students, the instructor uses multiple learning approaches, many regular assessments, a scaffolding of learning and stretches students' cognitive ability. Ultimately, the students like the course, using it as a foundational step in their educational process.

Key Words: Construction Drawings, CADD, Video, YouTube, Graphics

Introduction

Students in civil engineering and construction management usually take some type of computer aided drafting and design (CADD) course in their first year. At the University of Maine, when the general engineering Instructor of the college-wide standard course GEE 101, "Engineering Graphics" retired and was not replaced in 2004, both departments decided to teach it in-house. From that point forward, first-year students in civil engineering have been required to take CIE 101, "Civil Engineering Graphics." Beginning in spring semester 2005, the author has been teaching it using different content, delivery methods and evolving pedagogical style.

Where previously the students simply worked through the mechanics of operating CADD, the author felt they were missing the real context of their drawings – the subjects. Rhetorically, how can they learn to draw without studying what they are supposed to represent?

The CADD software itself was also difficult to effectively teach in a conventional lecture classroom. Two-hour computer laboratory sessions were used for exercises and practice, but large enrollments, smaller 15-20 seat computer labs and high demand from many courses limited access. The students' individual course schedules also complicated the scheduling of laboratory time. A number of laboratory sessions were scheduled in the afternoons and evenings, but often conflicted with other required courses in physics and chemistry.

Finally, the large enrollments of 80 to 100 students posed additional challenges in grading and providing technical support. With students installing and operating CADD software on their own computers, the instructor became the first line of technical support.

The new course is comprised of in-class lectures on civil engineering construction projects in general, laboratory exercises to study construction drawings and YouTube videos to teach the CADD software. By studying construction projects and drawings, the students learn the drawing subjects. The laboratory sessions are scheduled in

a larger regular classroom equipped with 8-seat tables, facilitating group work and handling enrollment with three sections per week. Lastly, teaching the CADD software with video allows students to view and review the material as many times as necessary.

Overall, the new course is working well. This paper begins with course content and outcomes, followed by descriptions of the three major content areas, a discussion and conclusion.

Course Content and Outcomes

The current incarnation of CIE 101, “Civil Engineering Graphics,” includes content in three major complementary areas: general understanding of civil engineering construction projects, reading and understanding construction drawings, and operating CADD software. In more detail, the five course outcomes are: The student will be able to...

1. recognize common components of civil engineering construction projects, including buildings, roads, sitework, heavy earthwork and bridges. (Knowledge and Comprehension)
2. locate and interpret specific construction and design details in a set of construction drawings. (Knowledge and Comprehension)
3. operate the basic functions of CADD software in 2D and 3D. (Application)
4. utilize CADD software to sketch civil engineering project elements. (Application)
5. select and operate appropriate CADD tools to solve graphical problems. (Application)

The course outcomes were developed within the context of Bloom’s Taxonomy (1956). Appropriate to an introductory first-year student course, outcomes 1 and 2 are mostly at the basic knowledge and comprehension level and outcomes 3, 4 and 5 are at the application level. Outcome 5 is the most sophisticated outcome, which perhaps could be considered at a higher cognitive level. It requires students to select appropriate tools and techniques to solve more open-ended graphical problems.

One of the overarching goals of this course is to begin building the foundations of the civil engineering knowledge structure for the students. According to Nilson (2010), structured knowledge is essential to how people learn. Having spent many years in our fields, practitioners and instructors implicitly understand our structural hierarchy of knowledge. However, the students in this course are generally new, and have very little context or understanding of the civil engineering profession. The fundamental knowledge from this course provides visualization, vocabulary and context to build on in future courses and endeavors, such as summer jobs and internships.

General Understanding of Civil Engineering Construction Projects: CIE 101

The textbook readings and weekly in-class lectures provide the knowledge and context required for students to successfully read and understand construction drawings, and to visualize what to draw using the CADD software. This part of the course is literally “construction 101” for students. In the first half of the semester – dedicated to buildings – lecture topics include sustainability, codes, standards, land use and site planning, steel frames, concrete, precast, masonry, and light gauge steel. In the second half of the semester – dedicated to heavy civil work – lecture topics include drainage systems, foundations, sitework and heavy earthwork, bridges, and topography. The textbook, “Fundamentals of Building Construction Materials and Methods,” (Allen, 2009) has chapters on many of these topics, providing the students with detailed reading, pictures and examples.

The lectures are designed to supplement and reinforce the textbook readings by summarizing the key points, illustrating with construction photos, and providing references to the construction drawings used in the laboratory sessions. Since the textbook is oriented toward building construction, a number of the heavy civil topics are only covered in lecture. The style and substance of the lectures can be best illustrated with the following example.

The lecture begins by referencing the fact that steel design is a junior/senior level elective course, placing the students in their overall educational sequence. In context of construction, steel as MasterFormat division 05 is made as well. Using a sequence of pictures and construction drawings, the presentation shows steel shapes, open web steel joists, connections, and decking, base and bracing details. Working through a three-step pattern of basic information, construction photos and construction drawings is particularly useful for understanding the context and drawing representations.

Reading and Understanding Construction Drawings

On a weekly basis, the two-hour laboratory sessions are primarily used to teach reading and understanding construction drawings. Using a set of drawings assembled from two actual local projects, students cooperatively work through a series of questions from lab worksheets. The set of drawings is compiled from two recently constructed local projects, the campus Recreation Center and a DOT-constructed two-span steel girder bridge in nearby Old Town. To keep the cost reasonable, the approximately 50-page drawing set is produced on standard tabloid size (11x17) paper at the campus printing office. Most of the original ANSI C and E sized drawings are reproduced using significant size reduction, but some are partial drawings at their originally drawn scale.

The laboratory worksheets are composed of ten to fifteen questions, designed to lead students through the drawings, with emphasis on learning how to find the answers rather than the answers themselves. In the process, they become familiar with industry drawing standards, styles and symbology, and also how to navigate through a set of drawings. They also learn how to read and understand drawings for the specific content area of the week, as described with the following example.

In the week when steel frame construction is covered, students are asked to find details of the columns, girders, decking and connections. A specific example might be: "What size is the structural steel wide flange column at column line F and 9? How heavy is it?" This particular example requires the student to locate the column in both plan and elevation views, identify and understand its size and length, and finally calculate its weight.

Laboratory sessions are held in a classroom with eight-seat tables, encouraging students to interact, helping each other. Several undergraduate teaching assistants are also employed to assist with and check the students' work.

Operating CADD Software

CADD software is taught primarily using online videos developed by the author using Camtasia Studio (Techsmith, 2012). Produced in a similar manner as described by Yates (2009), the author used the software to record the computer screen and voice simultaneously, followed by editing and eventual publishing to YouTube (Manion, 2010). Some earlier editions of the videos were published to restricted University servers, but publishing to YouTube has been much more successful. In short, the author has never had to explain to students how to use or provide technical support for the YouTube format. The eighteen videos are publicly available, have 195 (and growing) mostly non-

student subscribers, and have been viewed nearly 140,000 times in about two years. In fact, students taking a course at West Point (Quadrato, 2011) have been using them too. The vast majority of comments posted to the site are very favorable.

For the students in the course, a typical weekly CAD instructional assignment involves two 10-minute videos, a little short quiz (LSQ) and a complementary drawing assignment. All of the course content is published to an online Blackboard (2011) site. The content is organized by week, so the students can easily work their way through the material at their own speed. Based on usage reports from the early University server-published videos, the average student spent more than an hour working with two 10-minute video lectures and a 10-question online quiz. The drawing assignments cover a variety of aspects, from title boxes and printing arrangements, steel connection details, site surveying, road sections and finally a three-dimensionally drawn bridge.

From the author's perspective, the effort to produce good video format lectures should not be underestimated. Even with good knowledge of the CAD software, each 10-minute video can take several hours to record and edit. Even though the video software itself isn't difficult to operate, creating good, effective content is challenging. Overall, the goal of the videos is to learn the CAD software, which can't be lost in the delivery method.

Discussion

There are a number of reasons why the course works well, both pedagogical and functional. These include stretching students' cognitive ability, using many regular assessment techniques, a scaffolding of learning, using different learning approaches and parts of the brain, and maybe just because students like the course. It may not be possible to logistically separate all these different factors, but they are presented below as contributors.

At a cognitive level, the first-year students in the course are usually at the "absolute knowing" level of development (Baxter Magolda, 1992), where they tend to see things as black and white. In that context, all the facts and vocabulary in the course are very reassuring. In lectures, they want to write down every detail to make sure they have it correct. However, when they move to reading and understanding the construction drawings with much less well-defined and somewhat ambiguous questions, they can become frustrated. Working with their peers and teaching assistants in the laboratory sessions helps, so they begin to move to the next cognitive level, "transitional knowing," (Baxter Magolda, 1992) where they begin to realize that reality is less definitive, and the nature of the profession allows for multiple correct perspectives and opinions. Using real construction drawings, with their typical flaws and inconsistencies, illustrates how the industry is not black and white, even though it may appear to be at first glance. Although sometimes difficult for the students, this approach also helps validate students' choice of profession by using actual work from the field.

Over the course of the semester, a total of 29 assessments are used, from simply checking off laboratory drawing worksheets, online LSQs, and CADD drawing assignments to four open-notes, open-computer exams given during laboratory sessions. The assessments serve to keep the students active and engaged in the subject, and give them many modes of practice. (Nilson, 2010)

The course is structured as a "scaffolding" (Nilson, 2010) of learning activities leading to the ultimate goal of being able to select and operate appropriate CADD tools to solve graphical problems. From lower to higher, the scaffolding is framed by the same three complementary areas.

- General understanding of civil engineering construction projects: CIE 101
- Reading and understanding construction drawings

- Operating CADD software

The three areas also require students to learn the same material using different methods; first, by reading and seeing descriptions and pictures, followed by interpreting real construction drawings, and finally by drawing it themselves with CADD software. These three activities use different senses and modes, helping students learn using different parts of their brains. (Nilson, 2010).

Course Outcome Results and Course Evaluations

For the most recent semester, results of the five course outcomes, previously listed, are summarized as follows. The percentages are class averages of 84 students, with 100% being a perfect score. Most of the outcome evaluations were determined from results of four in-class exams, except for the fourth one, as noted.

The students performed at 78% for outcome one, (...recognize common components of civil engineering construction projects, including buildings, roads, sitework, heavy earthwork and bridges) based on 32 exam questions.

The students performed at 70% for outcome two, (...locate and interpret specific construction and design details in a set of construction drawings) based on 27 exam questions.

The students performed at 73% for outcome three, (...operate the basic functions of CADD software in 2D and 3D) based on 15 exam questions.

The students performed at 92% for outcome four, (...utilize CADD software to sketch civil engineering project elements) based on seven drawing assignments as homework.

The students performed at 69% for outcome five, (...select and operate appropriate CADD tools to solve graphical problems) based on two large free-response exam questions.

Based on course evaluations, students overwhelmingly like the course. The data presented in Table 1 is from the previous four times it has been taught, on a scale of 1-5, with 5 being the highest. Note that the course scores about 16% higher than the departmental average of all required and elective courses.

Table 1

Results of course evaluations averaged from 2008-2011

| Question | Answer | Score out of 5 | Departmental Average |
|---|------------------|----------------|----------------------|
| How would you rate the subject matter of this course? | very interesting | 4.52 | 3.87 |
| Did you develop significant skill in the field as a result of taking this course? | very much | 4.51 | 3.99 |
| What is your overall rating of this course? | excellent | 4.68 | 3.96 |

Anecdotally, the students like the course. Following are a few of the many quotes written on final course evaluations in the spring 2011 semester.

- This course was a blast, very informative.
- (The instructor) did a wonderful job with his class. Although it was difficult it was still a blast! Labs helped drill in ideas, and A LOT was learned.
- I truly enjoyed this class. (The instructor) made it fun and helped me understand everything well. Thank you (the instructor).

More anecdotally, the students rave about the videos. There have even been reports of roommates and friends enjoying them. This may stem from the author's production style, which is summarized below.

- Make the videos short and pace them rapidly. The students can pause, back up and replay as many times as they want.
- Use voice to describe every action demonstrated, so they hear and see the same thing. This allows them to listen and perform the same steps without watching.
- Don't be too serious. For example, the author usually opens each episode with a comment like "welcome back CADD fans, in this video we will be..."
- Insert random off-topic breaks, less than about 10 seconds long. Early in the process, the author used these as transitions between clips while editing, but found that students really love them. A typical example is the "world's largest bulldozer," with a description of the specifications and approving adjectives. Others are taken from travel experiences, but could be anything at all. At face value, these breaks wake up the viewer, but they may also help the students form a personal connection with the instructor.

There certainly may be other cognitive, psychological and social reasons why the students appreciate the videos so much, but that may be a topic for another paper.

Conclusion

Though many civil and construction curricula include computer aided drafting and design (CADD) courses, most seem to be focused on operating the software. Many also have a course in reading and understanding construction drawings. In contrast, this particular course combines a general understanding of civil engineering construction projects with reading and understanding construction drawings, followed by drawings in CADD software, building a scaffolding of knowledge to visualize and understand the constructed environment.

For the students, the fundamental knowledge from this course provides visualization, vocabulary and context to build on in future courses and endeavors, such as summer jobs and internships. It also appeals to them on a number of cognitive and pedagogical levels. The result is a course that students enjoy, making it a pleasure to teach.

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