An Integrated Teaching Method for Design Courses

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This paper describes a method for teaching design topics. While the example is for a Design of Steel Structures course with no grader or TA support, the methods and concepts are adaptable for a wide range of design courses and formats. The objective is to provide approaches for students of varying learning styles to internalize design concepts and provide confidence in their ability to complete designs of an overall structure rather than individual components. A unique component implemented to address this is a reference structure interleaved into course content throughout the semester.

Keywords: design course, pedagogy, interleaving, steel design, engineering, structural engineering

INTRODUCTION

Design courses in the Civil Engineering curriculum can be challenging for both students and instructors. It is usually the first introduction students have to problems with multiple solutions, using codes/specifications and designing actual structures. Prior courses in the curriculum are often set up to have well defined solutions to well defined problems. Though ideally these previous courses would introduce open-ended problems and varieties of methods for students to pursue, the reality is that the design courses are typically the student's first immersive experience in design, and design textbooks are still focused on isolated topics without any true inter-relationship between topics developed throughout the semester.

Effective learning takes place when prior knowledge is activated and built upon to develop procedural knowledge and bridge students into new topics (Ambrose, et al., 2010). Per Felder and Brent (2016), for teaching to be effective, the students need to have a clear understanding of why the material being taught is important and to understand the application to solving technological problems. Getting students to transfer their knowledge into increasingly disparate contexts can then increase their underlying understanding of the material (Ambrose, et al., 2010; Felder and Brent, 2016). Teaching is most effective when components are included that require students to address multiple hierarchies of the cognitive (ideally including aspects of remembering, understanding, applying, analyzing and evaluating to different degrees throughout the semester) and affective aspects of the revised Bloom's Taxonomy (Krotwohl, et al., 1964; Krathwohl, 2002) (though other taxonomies can be used as well (Fink, 2013) and should be included when possible). Research has shown that using various methods of explaining concepts, both concrete and abstract, can accommodate the many learning styles which students may have (Felder and Silverman, 1988; Randolph, 2000), and overall behavior examples are very good inductive introductions to new topics. Interleaving, a method of alternating between two different teaching methods, is another useful method for ingraining STEM material for students (Felder and Brent, 2016). A version of interleaving using different contexts could be interpreted as using straightforward textbook type questions and following them up with

questions specifically related to a specific structure to provide overlapping conceptual applications. By the end of the class, an instructor would hope that the students have obtained fundamental new knowledge, have the ability to transfer this to other contexts, and have initiated an underlying interest and confidence in their abilities required to pursue a path of life-long learning throughout their careers.

Research and case studies have shown collaborative learning activities to be a very effective model for teaching (Felder, 1995; Howell, 2000; Ponton, et al., 2001; Randolph, 2000; Springer, et al., 1999; Terenzini, et al., 2001). The effectiveness often relates to the amount of active learning (Clough and Kauffman, 1999; Felder, 1995; Felder and Silverman, 1988; Randolph, 2000; Terenzini, et al., 2001), and the time for reflection on material during the activities (Felder, 1995; Felder and Silverman, 1988; Randolph, 2000). At the same time, for groups to be effective they must have dynamics which are conducive to learning (Rosser, 1998) and assignments must have sufficient complexity to make the group work critical to their completion (Felder and Brent, 2016). Overall, results of research show significant improvements in achievement, student retention, and attitude towards the program when collaborative or cooperative group learning is included in classes (Springer, et al., 1999). While there has been a lot of attention to the flipped classroom concept over the past few decades, the use of teamwork, active learning and reflection can be a critical component of traditional assignments as well.

This paper describes a method, developed over 22 years, for teaching a relatively large capacity (up to 70 students) Design of Steel Structures course that generally has no grader or TA support. A unique component implemented is a reference structure interleaved into course content throughout the semester. The methods and concepts are adaptable for a wide range of design courses and formats.

DEFINING GOALS AND OBJECTIVES

Over the years, the Design of Steel Structures course described has evolved in order to address many learning/teaching concepts, and respond to direct and indirect student feedback. The goals are to make the course as effective as possible in teaching the fundamentals of steel design, as well as to integrate the material into a wider context in order to prepare students for their future careers and promote life-long learning interest and skills. Objectives beyond understanding of specific design issues are included that may not be typical of traditionally taught steel design classes. These objectives focus on providing a bridging context to each topic, providing different approaches for students of varying learning styles to internalize design concepts and providing student confidence in their ability to complete designs of an overall structure rather than individual components. These objectives vary throughout the semester and among assignments.

Broader objectives include:
- Providing specific ties to previous and future classes
- Providing an encompassing context for all topics that threads through the semester
- Teaching each specific topic to provide a balance of intent, theory and code provisions
- Evaluating both calculation abilities and reflection on internalization of the material
- Instilling confidence in abilities for self-directed learning

Specific objectives are more clearly indicated in the description of the course components.

COURSE COMPONENTS

The method used in this course relies on inductive teaching (Prince and Felder, 2006; Prince and Felder, 2007) where a specific reference structure is introduced at the beginning of the semester and referenced throughout the course. A new structure currently under construction is selected each year to provide timeliness and direct relevance to state of the practice that is often lacking in the curriculum. By providing a specific structure to be designed and then incrementally giving students more and more freedom in their designs also provides aspects of inquiry based learning (Inquiry-Based Learning, 2015) and case based instruction.

A variety of steel structures under construction in our rural area have been selected, optimally with a section of regular framing and other areas of non-regular framing that can be used for comparison. Examples of moderate complexity are shown in Figure 1. It has been found that these structures are much more effective than simpler designs. The complexity requires students to make some assumptions in order to calculate structural loads and design members, thereby gaining confidence that they can comprehend the design of more challenging structures. Typically, even the more complex structures have a series of bays of regular framing that can be used as the basis for assignments. Actual design documents are provided through the secure course web page, with the permission of the owner and engineer (and architect when required). The students use these construction documents to determine the parameters (dimensions, sizes, designer constraints/notes) needed for homework. Voluntary tours of the construction site co-led by the instructor and contractor/project manager have had student participation from 80-100%. Sample tour descriptions and photos are included on the course web page for reference. Ideal conditions for the tours include partially erected steel with connections in the process of being completed, some floors placed but with other locations having shear studs, and metal deck exposed (Figure 2). Personally seeing specific elements of the structure that are designed in assignments provides a palpable physical representation of the calculations. The tours serve many other purposes, highlighting the many disciplines involved in the design and construction of a building, impressing on students the importance of thinking about the constructability of their designs (which often influences design choices), and allowing the instructor to point out many features or concepts that are likely beyond the scope of the course but need to be understood by the structural engineer (connection to architectural and mechanical features, fireproofing, detailing of openings, general framing concepts, etc.). Additional information regarding the tours can be found in Civjan (2020).

FIGURE 1
EXAMPLE STRUCTURES OF MODERATE COMPLEXITY
(PHOTOS USED BY PERMISSION)

FIGURE 2
OPTIMAL CONSTRUCTION TOUR TIMING
(PHOTO USED BY PERMISSION)

Design assignments in the class are of two types, core concepts (^{cc}) worked individually or as pairs and implementation of concepts to the reference structure (^{is}) which are worked in groups of three to five students (maximum of four is optimal) and are expected to require significant discussion within the group. Assignments typically alternate (within an assignment or with subsequent assignments) between core concepts and interleaved implementation topics related to the reference structure. Homework throughout

the semester rely on previous results to maintain continuity related to the specific structure. Typical assignment topics are as follows, with some topics combined into individual assignments:

- [is]Determine loads on the structure based on ASCE-7 (dead, live, snow, wind, seismic)
- [is]Determine forces on specific beams, girders and columns
- [cc]Determine Flexure and shear capacities of general sections
- [is]Design specific beams and girders based on forces determined in previous homework
- [is]Analyze lateral force resisting system (LFRS) variations (truss and moment frame)
- [cc]Determine compression capacities of general sections
- [is]Design specific columns, braces and combined force members in the structure
- [cc]Determine tension capacities of general sections
- [cc]Determine bolt and weld capacities in general
- [is]Design tension brace and connection based on forces from previous analysis

Group assignments are only assigned when the complexity is sufficient to make teamwork worthwhile, approximately 4 of the 8 assignments. Two common problems encountered in group assignments are students divvying up the problems, or individuals who are not participating fully. The approach to dealing with the former is to have problems that rely on the result of a previous problem as input. Significant points are then deducted when continuity of a concept or calculated value is not consistent between problems on an assignment. Short answer open-ended questions are included to see if students have gained insight into their results or can apply concepts to other situations. These similarly rely on insight from answers to multiple problems on the assignment. Often an individual from a group will come to office hours to discuss these questions. It is generally effective to open any discussion with "what does the rest of your group think" and offer to discuss with the group rather than with the individual. Lack of participation by individuals is typically addressed by allowing groups to change between each assignment, though there are many other effective approaches. Non-participating members often come to office hours looking for a new group and a quick discussion about why they are no longer in the previous group usually corrects the problem. A policy of 50 percent grade deduction for any student turning in work with an incorrect group number is generally effective at addressing students who show resistance to working in a group.

The first two assignments of the semester take place when topics are focused on LRFD design concepts and loads. These assignments are intended to set the stage for the entire semester and highlight teamwork and provide a controlled self-directed learning activity. Rather than walk the students through all aspects of ASCE-7 dead and live loads they are given an extended period (two weeks) to familiarize themselves with the construction documents and determine the nearest ASCE-7 live load categories to the architectural descriptions of spaces. With only minimal guidance of sections of ASCE-7 to be used and some guidance on specific equations to apply the students work together to determine approximate dead and live load of a typical floor, snow loads on the roof and wind load on the structure (some simplifying assumptions are provided if the structure does not have clear rectangular features). A manufacturer catalog is provided for students to select metal deck and slab thickness, introducing professional reference materials. Results provided in the solution set are then used as the basis for the next homework where students determine the ASCE-7 seismic load on the structure and floor distribution of live and dead load to provide shear and moment diagrams of typical floor beams and girders as well as the total load that these transfer into a column at a typical story.

Once the students have spent a considerable effort determining the general loads on the structure, there is a certain ownership of the results that is capitalized on for the remainder of the semester. For every topic, some questions will deal directly with the actual reference structure and refer back to the solution set to these first two problem sets. Open-ended questions are often included that relate to how assumptions in the load calculations could affect the results.

In general, assignments alternate between general concepts in an initial assignment and the application to design or analyze a component of the reference structure in the follow up assignment. For example, the existing capacity of members in the actual structure are calculated, then the determined shear and moment diagrams from estimated loads are used to design alternate beam sections, the summation of estimated

column load at multiple floors is used to design compression members and compared to those specified in the actual structure, etc.

Further learning and reflection is expected through open-ended short answers required on assignments that ask student groups to postulate why their results do or do not match what was used in the actual structure, estimate how much error might be introduced in their calculation assumptions, etc. There are no specific right or wrong answers expected in these questions, but the expectation is that it sparks some discussion among groups and they can arrive at a reasonable explanation. Typically disparities are attributable to the beam members being designed compositely (composite action is ignored in the introductory steel design class) or members are upsized to minimize deflections/vibrations. Similarly, class approximations in assuming identical column load at each floor results in some variation in design choice sizes. It is expected to be a very productive learning experience when students realize that their homework results will not necessarily match an experienced design engineer result, but that their design is equally valid for the assumptions made. Though subjective, over the course of the semester student responses typically show a growing confidence in their results. These types of questions are included both on assignments and exams to promote communication and critical thinking efforts, with the intent of reaching a higher level of learning for these topics.

At approximately the third point of the semester the students are asked to perform a two dimensional analysis of the lateral resisting system in the structure. The loads applied are based on the larger of the wind or seismic forces at each story and a typical lateral resisting frame is used, with the assignment making a rough estimate of the percentage of the load that would be carried by each frame (i.e. apply ¼ of the seismic load to a frame since there are 4 relatively similar ones resisting load in that direction). Often structures have braced frames in one direction and moment frames in the other, which is ideal for the class and an analysis is done for one of each system type. Other structures have similar systems in each direction, so some modifications are made for the assignment. For moment resisting frame lateral systems bracing can be arbitrarily inserted, with students asked to also change the column and beam sizes to see that these do not significantly affect brace forces. For braced frame lateral systems, developing the assignment can be a little more time consuming, requiring removal of the braces, fixing the connections and determining modifications to the girder and column sizes that result in reasonable lateral deflections. The assignment can then ask students to double or halve the column sizes, followed by the girder sizes, to observe the relative affects. A mistake made in previous years was to have students develop the computer models for both assignments. It has been found to be much more effective to have them develop the braced frame model from scratch, as students should be able to calculate forces in the statically determinate structure (with severe reductions taken for major errors) and gross errors are less likely. For the moment frame assignment the instructor provides a basic model with all geometry, member sections and loads applied for the moment frame. Students are expected to fix the appropriate connections and run first order and second order analysis of the frame, and then make modifications as required for the Direct Analysis Method. If the basic model is not provided, some groups will make modeling errors that undermine their learning of how the moment resisting frame system and Direct Analysis Method function.

Results from these analyses are then used to design compression and tension members (braces) as well as analyze combined force members (moment frame). Students are asked to evaluate the capacity of the existing member in the structure (typically an HSS section) without much additional direction, which allows them to see the applicability of the general design concepts to other member types and compare W shapes (compression) or double angles (tension) that have similar capacities and could therefore also be used in the structure. Tension connections are then designed for the brace member (actual HSS and assumed double angle members).

Unfortunately, the course structure does not allow for any recitation or laboratory periods, so most feedback to students is directed through solution sets, comments on graded homework, brief statements made in class and emails to the entire class. If included, recitation sessions could focus on more discussion of differences between student and designer member selections, how varying member sizes would affect overall structural behavior, and some repetition of calculations for additional practice. The field trip could also be mandatory if scheduled during this time period. Without these periods, the methods of

communicating these concepts are through explanations on solution sets, brief class comments and email. Solution sets include explanations of differences between what students designed and what exists in the actual structure (introducing concepts of composite beams, cost savings through repetition, vibration of floors, architectural constraints, etc.). Comments include approaches that may be more effective (less detailed calculations that provide reasonably similar results, specific details or concepts not included, etc.) and class statements focus on common mistakes made as well as things to observe in current assignments. Emails to the class are used to clarify typical questions, correct assignments as necessary and provide more detailed comments on common mistakes made in student work. While some students get frustrated with instructor errors, it is common for there to be a few mistakes throughout the semester due to modifying homework each semester to be specific to the reference structure. This should not discourage anyone from trying the approach. In the end, it can actually be a positive learning experience for students to see someone more experienced make a silly error, own up to it and correct it.

Throughout the semester deliberate and specific references are made to previous courses in order to reinforce the idea of the curriculum being a continuum rather than individual isolated topics. Examples include the variability in material results in strength of materials laboratories relating to design resistance factors, concepts such as friction in slip critical connections and seismic forces being calculated from mass and accelerations from physics classes, actual steel connections not being truly fixed or pinned as assumed in previous structural analysis and statics courses, differences between elastic behavior used for all previous structural analysis calculations and inelastic behavior being considered in steel strength design, and the omission of second order effects and other simplifications in analysis performed in previous courses compared to analysis required to properly design moment frames and combined force members. To enforce the continuum, at the end of sections topics that were not covered but are relevant to design are mentioned along with where in the curriculum (stability class, advanced topics in steel design class, etc.) or in Design Guidelines students could find more information. For instance, some level of composite design, fatigue, the design of built-up sections, more detailed connections, structural vibrations and construction issues are covered in other elective courses, while specifics of high-rise construction, advanced modeling guidance and details of many topics are addressed in Design Guidelines, textbooks and research papers. Brief mentions of these topics along with an assignment requiring students to find and evaluate information available from on-line, industry and research database sources is intended to get students thinking about developing life-long learning skills.

Supplemental assignments can be used to address issues of office culture, life-long learning and ethics and have been recently introduced into the class to replace term papers that were previously required. Examples include prompts for responses to requested field changes in the reference structure, literature searches for information on additional design issues and office and construction site culture. For instance, asking students how they would handle a call from the field informing them that a material was mis-ordered, how a call from an architect telling them that a load was changing would affect their design, what to do if they find a mistake in calculations after steel is ordered, whether code changes in new editions indicate unsafe designs, etc.

GRADING

While it may seem like providing new structures and solution sets each year would be overly time consuming, it is actually quite manageable. Student work determining ASCE-7 loads varies widely, from groups that determine exact square footage of each room in the building to approximate percentages. So long as results are within 10% of the solution set the methods are likely reasonable with grading deductions mostly taken for gross errors. The grading of these assignments can focus more specifically on likely errors, such as floor distributions of seismic base shears, proper distribution of wind load and snow drift calculations. Other assignments are fairly straightforward application of these loads, athough determination of appropriate lateral force resisting systems (when both brace and moment frames do not exist in the structure) can take some effort and planning of the assignment. As an added bonus, homework assignments are fairly consistent from year to year, but the structure changes. Therefore, there is minimal effort in

coming up with completely new assignments, but at the same time there is little advantage to a student who has seen a previous solution set, since they would need to compare the structural drawings (which they don't have for the older structure) in order to understand whether steps are relevant and whether comparisons to the designer choices have any relevance to the new structure. It is encouraged for students to work together to talk through approaches to problems or check answers, but if individual assignment work is similar to other students a meeting is held to talk through how they collaborated and point out any methods that need to be changed for future assignments. By starting with self-selected group homework assignments, it is quickly clear which students will be working in study groups, so this simplifies the grading process. A grader for this course has only been provided by the department three of the 22 semesters and it was found that much more effort and guidance is required to coordinate grading of open ended questions, provide relevant feedback and correctly identify whether design errors are significant or minor. While this is true in any design course, it is important to look for graders who have mastered the material to the point of understanding these issues and clearly communicate your grading expectations.

OTHER METHODS FOR CONSIDERATION

In addition to the format of the course, several smaller teaching skills have been adopted over the years that work well in the design class. It has been found to be very helpful to open each class with an open-ended short (less than five minute) period where homework questions or points that were unclear from the last lecture can be quickly addressed. Contacting students regularly (email and on-line posts are used in this class, but blogs are also relevant), as well as responding quickly to student emails, providing timely feedback, and getting students actively engaged with each other have all proved to be worth the effort. Over time, these likely save time by avoiding repetitive questions or students getting lost to the point where significant effort is required to catch them back up.

Any chance to bring in samples of what they are designing (bolts, small connections, shear studs, welding electrodes, washer types) and demonstrations (foam beams and columns) is always worthwhile and these are often commented on as positive aspects on semester course evaluations.

During homework and exams, I have found it useful to get students to admit that they have made mistakes rather than covering it up. For instance, on homework and exams, when a student identifies an incorrect number, (such as working a problem by two methods and not obtaining the same solution), they are given extra credit if they reason through why one is likely correct but acknowledge the uncertainty. However, when a student provides extemporaneous work hoping to obtain credit for eventually including a relevant equation, deductions should be taken for each non-relevant type of equation presented. It has been fulfilling to see that students in the class are consistently able to answer exam questions that stretch the context beyond what is covered in class. Exams usually include a closed book short answer section on general concepts or deeper understanding, with three numerical problems. At least one of these problems typically appears significantly different than the structure used in class (examples have included a geotechnical excavation support, pipeline support structures, bridge components, etc.) in order to see whether students can extrapolate the information they have used. In these ways, the exams are intended to evaluate a fairly equal amount of quantitative and qualitative information. Students typically are more adept at one or the other, with about ¼ of the class able to present both effectively.

While problem based learning may seem to be a natural progression from the way that this course is taught, the instructor has only used this course as a basis for students becoming ready for such a method. The follow up Advanced Topics in Steel Design is taught as a hybrid instruction and semester project course.

ALUMNI AND CURRENT STUDENT FEEDBACK

Student feedback has been collected in two ways on this class, a recent on-line survey distributed to alumni and questions added to end of course surveys for a period of six years.

In 2019 an anonymous online survey was sent to graduates from the 22 years that the instructor has taught the class, and obtained 184 responses (21 % response rate of all enrolled students), with yearly percent of total enrollments responding and cumulative responses plotted in Figure 3. Of the respondents, 42.4 percent (78 respondents) indicated that they have designed steel structures in their career. Student's self-perception of preparedness in structural steel design for the workforce and graduate school are shown in Tables 1 and 2, respectively. Average ratings (on a 1 to 4 scale, with 4 being better prepared than peers) were 3.3 for both questions, indicating student self-perception as being overall better prepared than their peers from other institutions. Results were similar whether the alumni had designed steel structures or not. When asked about the effectiveness of specific components of the course (Table 3), students rated the reference building components of the course (reference building, construction documents and field trip) as effective to very effective. It is not clear why some components were rated as Not Applicable by a large number of students. While early versions of the class did not include a reference structure and not all students go on the field trip this does not account for all of these responses.

FIGURE 3
SURVEY RESPONSE RATES
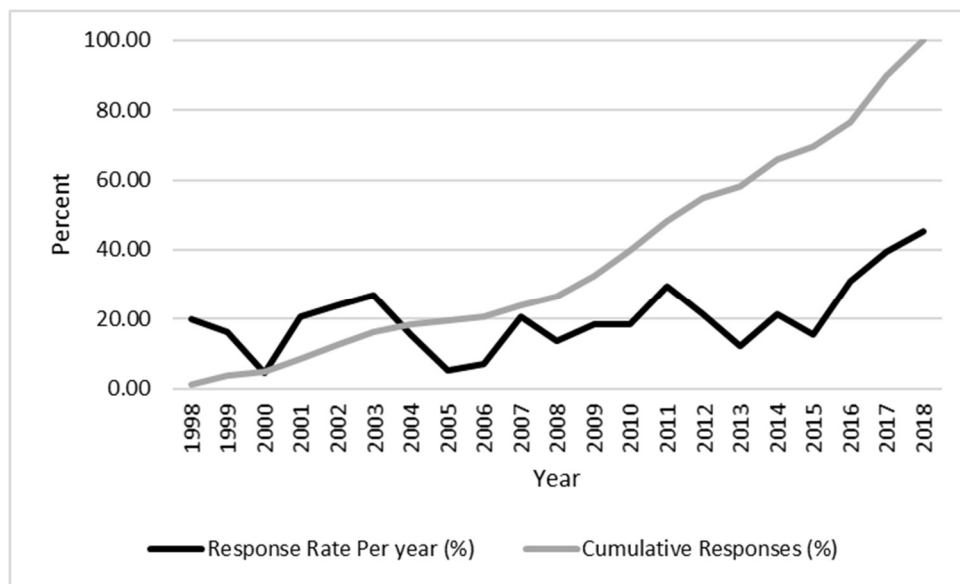
TABLE 1
PREPAREDNESS FOR WORKFORCE

	Compared to other engineers starting at my company, I feel that I was		
	Answer Choices	Responses	
4	Better prepared for structural steel design.	21.74%	40
3	Slightly better prepared for structural steel design.	33.15%	61
2	Slightly worse prepared for structural steel design.	1.63%	3
1	Worse prepared for structural steel design.	0.54%	1
	Not Applicable.	42.93%	79

TABLE 2
PREPAREDNESS FOR GRADUATE SCHOOL

	If you took graduate courses after taking CEE434, Compared to other graduate students in my program, I feel that I was		
	Answer Choices	Responses	
4	Better prepared for structural steel design.	14.13%	26
3	Slightly better prepared for structural steel design.	22.83%	42
2	Slightly worse prepared for structural steel design.	2.72%	5
1	Worse prepared for structural steel design.	0.54%	1
	Not Applicable.	59.78%	110

TABLE 3
PERCEIVED EFFECTIVENESS OF COURSE COMPONENTS

Rating	Use of reference building	Use of construction documents (structural and architectural drawing sets)	Use of AISC Manual	Field trip of construction site
1 - Not Effective	0.00%	1.09%	0.54%	0.54%
	0	2	1	1
2	1.63%	2.17%	0.00%	2.17%
	3	4	0	4
3	11.96%	11.41%	5.43%	9.78%
	22	21	10	18
4	22.83%	22.28%	21.20%	15.22%
	42	41	39	28
5 - Very Effective	35.33%	40.22%	66.85%	31.52%
	65	74	123	58
Not Applicable	28.26%	22.83%	5.98%	40.76%
	52	42	11	75
Weighted Average	4.28	4.27	4.63	4.26

For a five-year period (2008 to 2012) end of semester questions were added to the standard university survey assessments to evaluate course specific objectives. These questions changed in 2010 and are provided below. Survey results are presented in Tables 4 and 5. For all years the rating scale was 5 – Fully achieved, 4 – Mostly achieved, 3 – Partially achieved, 2 – Barely achieved, 1 – Did not achieve.

For 2008 and 2009 students were asked to assess the following statements:
1a) An understanding of the design process and methods of handling uncertainty in design.
2a) A familiarity with project documents (drawings).
3a) An understanding of the basic behavior of beams, columns, tension members and basic connections and combined force members.
4a) An understanding of relevant AISC Steel Construction Manual Specification and Design Aids.
5a) An awareness of the role of research and uncertainty inherent in developing Specification provisions.

6a) The ability to design beams, columns, tension members and basic connections and combined force members.
7a) The ability to perform both technical and non-technical literature reviews
8a) The ability to communicate ideas effectively through written and mathematical means.

TABLE 4
END OF YEAR ASSESSMENTS 2008-2009

	Year	
	2008	**2009**
Question	**Avg (StDev)**	**Avg (StDev)**
1a	4.6 (0.50)	4.5 (0.64)
2a	4.5 (0.69)	4.2 (0.85)
3a	4.8 (0.39)	4.5 (0.64)
4a	4.6 (0.69)	4.5 (0.58)
5a	4.5 (0.70)	4.3 (0.84)
6a	4.7 (0.53)	4.5 (0.61)
7a	4.6 (0.62)	4.4 (0.75)
8a	4.7 (0.61)	4.5 (0.70)
Responses/Total enrollment	29/37	52/60

For years 2010 through 2012 the statements were modified to align with specific sections of a typical steel design course.
1b) Students have gained a familiarity with project construction drawings.
2b) Students can use ASCE 7 to develop loads on a structure.
3b) Students can analyze basic structures and arrive at member forces.
4b) Students can design beams for bending and shear.
5b) Students can design columns.
6b) Students can design tension members.
7b) Students can find technical and non-technical materials related to a design topic and report on a related contemporary topic.
8b) Students have a familiarity with the provisions of the Steel Design Manual

TABLE 5
END OF YEAR ASSESSMENTS 2010-2012

	Year		
	2010	**2011**	**2012**
Question	**Avg (StDev)**	**Avg (StDev)**	**Avg (StDev)**
1b	4.1 (0.78)	4.3 (0.75)	4.5 (0.62)
2b	4.1 (0.83)	4.4 (0.74)	4.5 (0.62)
3b	4.3 (0.79)	4.5 (0.67)	4.6 (0.54)
4b	4.4 (0.75)	4.7 (0.53)	4.7 (0.50)
5b	4.3 (0.76)	4.5 (0.63)	4.6 (0.58)
6b	4.2 (0.80)	4.3 (0.75)	4.5 (0.66)
7b	4.2 (0.81)	4.3 (0.72)	4.4 (0.65)
8b	4.6 (0.69)	4.7 (0.59)	4.8 (0.49)
Responses/Total enrollment	65/68	43/53	47/56

The end of year assessment data indicates that students have a confidence in their abilities upon completion in the course, not only in specific design tasks, but in some of the professional skills alluded to in statements 5a, 7a, 8a and 7b. This is supported by the alumni data indicating that these students ended up thinking that they were better prepared than their peers for the workforce and/or graduate studies. In addition, individual comments included on end of year student teaching evaluations regularly highlight the use of "real world" applications as a significantly positive aspect of the class. The class and instructor are regularly rated very highly.

CONCLUSION

A method that has been found to be effective for teaching a Design of Steel Structures course has been described with the intent that others can adopt some of the ideas and intents implemented. The use of a reference structure that is under construction provides context and directly reinforces the applicability to consulting practice and current topics. The structure is regularly interleaved into the class assignments and discussions throughout the semester. This has been found to be a stimulus to student motivation in the class and student comments have highlighted the appreciation for "real world" examples in class surveys. A mixture of calculations and reflection on the meaning and relevance of results is included on assignments as well as exams and effectively identifies students who have internalized the course content versus those who may be effective at identifying correct methods and calculations but cannot explain how the theory and calculations relate to one another, or cannot properly apply concepts to new situations. Conscious efforts to link class content to previous classes in the curriculum as well as future electives and careers are included to promote awareness of life-long learning. The methods described are specific to a course in the Design of Steel Structures, but the basic concepts could be applicable to any design course.

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