Initial Results of Introducing Design and Simulation Based Instruction in Mechanics of Materials

Dr. Christopher Papadopoulos, University of Puerto Rico, Mayaguez Campus

Christopher Papadopoulos is an Associate Professor in the Department of General Engineering at the University of Puerto Rico, Mayaguez (UPRM). He earned B.S. degrees in Civil Engineering and Mathematics from Carnegie Mellon University (1993) and a Ph.D. in Theoretical & Applied Mechanics at Cornell University (1999). Prior to coming to UPRM, Papadopoulos served on the faculty in the Department of Civil Engineering & Mechanics at the University of Wisconsin-Milwaukee (UWM).

Papadopoulos has diverse research and teaching interests in structural mechanics, biomechanics, appropriate technology, engineering ethics, and engineering education. He is PI of two NSF sponsored research projects and is co-author of Lying by Approximation: The Truth about Finite Element Analysis. Papadopoulos is currently the Program Chair Elect of the ASEE Mechanics Division and serves on numerous committees at UPRM that relate to undergraduate and graduate education.

Dr. Aidsa I. Santiago-Román, University of Puerto Rico, Mayaguez Campus
Dr. Genock Portela-Gauthier, University of Puerto Rico, Mayaguez Campus

Initial Results of Implementing Design and Simulation Based Instruction in Mechanics of Materials

Abstract

This paper describes results of the project "Leveraging Simulation Tools to Deliver Ill-Structured Problems: Enhancing Student Problem-Solving Ability in Statics and Mechanics of Materials", which is sponsored by the National Science Foundation and carried out in the Department of Engineering Science and Materials at the University of Puerto Rico, Mayagüez. In this project, design problems that require the use of relevant simulation tools are incorporated into the Statics and introductory Mechanics of Materials (MoM) courses; these problems further serve to vertically integrate the two courses. The subject of this paper is to describe the projects that have been developed for the MoM course. These projects engage students in the use of the structural analysis software SAP2000 and also design codes from ASCE, AISC, and AASHTO. Initial assessment results demonstrate that students enjoy the realistic feel of the projects and that they are able to complete the required tasks, but with a variety of execution and interpretive errors.

1. Introduction

The understanding that the essence of engineering is "to design" is well established[1], yet engineering education has often emphasized analysis at the expense of fostering creativity in design.[2] Nevertheless, many efforts have been made over the last two or three decades to change this trend, a partial review of which we have provided in a previous publication.[3]

Our project "Leveraging Simulation Tools to Deliver Ill-Structured Problems: Enhancing Student Problem Solving Ability in Statics and Mechanics of Materials" (NSF TUES Program, Grant #1044866) is one effort to introduce design into the earliest stages of the mechanics curriculum.[3] A strategy to accomplish this is to couple design problems by leveraging appropriate computer simulation tools that can be used as "sophisticated calculators"[4] so that students can make rapid design parameter changes to quickly test behaviors and outcomes. The project focuses on developing exercises and projects oriented toward the Civil Engineering/ Structural Engineering curriculum, and as such, students are further introduced to the use of design codes from ASCE, AISC, and AASHTO. The exercises and projects are delivered in the consecutive courses of Statics and introductory (sophomore level) Mechanics of Materials (MoM). The culminating project in Statics vertically integrates with MoM because it provides a preview of elementary stress analysis and also because the project context (the design of a steel signpost) forms the basis of further projects in MoM. Initial results from the implementation in Statics were published last year.[5]

With particular respect to MoM, other attempts have been made to implement design activities into this course.[6] In our case, we introduce the use of SAP2000 structural analysis software[7] as a design tool, and we continue to use the Excel spreadsheet as introduced in Statics.[5] Based on our review of papers published through ASEE Conferences and JEE, we found no prior examples in which SAP2000 is being implemented in the introductory MoM course; however, it has been utilized in more advanced structural engineering courses. In the MoM course (and to a very limited extent in Statics), we further incorporate the use of the design codes ASCE 7 *Mimimum Design Loads for Buildings and Other Structures* (2010)[8], the AISC *Steel Construction Manual* (2011)[9], and the *AASHTO LRFD Bridge Design Specifications* (2010).[10] We are aware of at least one other instance of implementing ASCE 7,[11] and two instances of implementing the AISC code[12,13] in introductory MoM, but the majority of instances occur in advanced structural analysis or design courses.

Many educators rightly raise questions as to whether commercial software and design codes (i) are too advanced for use in introductory MoM and/or (ii) offer occasions to bypass necessary theory and hand calculation.[3,4,5] As our project is in its early phase, we do not yet know what lessons we will learn that might edify these concerns. However, our approach is optimistic and is developed with care to anticipate such issues in advance. With respect to question (i), one technique that we use is "scaffolding",[14] in which partial information or structured templates are provided to students so that they can focus on key concepts. For example, we provide students with spreadsheets with pre-programmed cells.[5] In other cases, we provide students with a partially pre-programmed template in SAP2000, leaving them with a much reduced set of tasks to develop their models. We also have specially trained tutors to provide assistance to students with the design tasks. With respect to question (ii), simply put, we do not view the use of the computer as an excuse to avoid hand calculation. Rather, for reasons ranging from good solution validation practice to reinforcement of elementary concepts, we insist that students perform a variety of manual or spreadsheet calculations to verify the results from simulations in SAP2000. Overall, we believe that from a the perspective of "engineering culture", it is important to engage students at the earliest stage possible with the "real" tasks and habits of engineers and engineering analysts at the earliest possible stage in their careers. We intend that our project is an advance in eliciting such mature behaviors from students.

2. Description of Simulation & Design Projects in MoM

We expose students to simulation software and design codes in a sequence of four MoM projects that are completed in groups of 3-4. The following is a description of each project.

Project 1: This project is a re-visitation of a project initiated in the prior course in Statics, which is also part of our NSF project. In this Statics course, students were asked to design the dimensions of a hollow steel signpost to support a billboard, depicted in Figure 1. In MoM, this project is re-introduced immediately for the purpose of reviewing Statics and reinforcing the "tone" that the use of simulation is expected in the course – that is, that students are expected to answer questions as a result of their use of a software tool, which is here, the Excel spreadsheet.

With dimensions of the signpost and all loads specified – here, the dead weight of the sign, signpost, and wind loads specified from ASCE 7 (2010)[8] – the students were first asked to examine in detail the internal reactions in the signpost, and how they vary along its length.

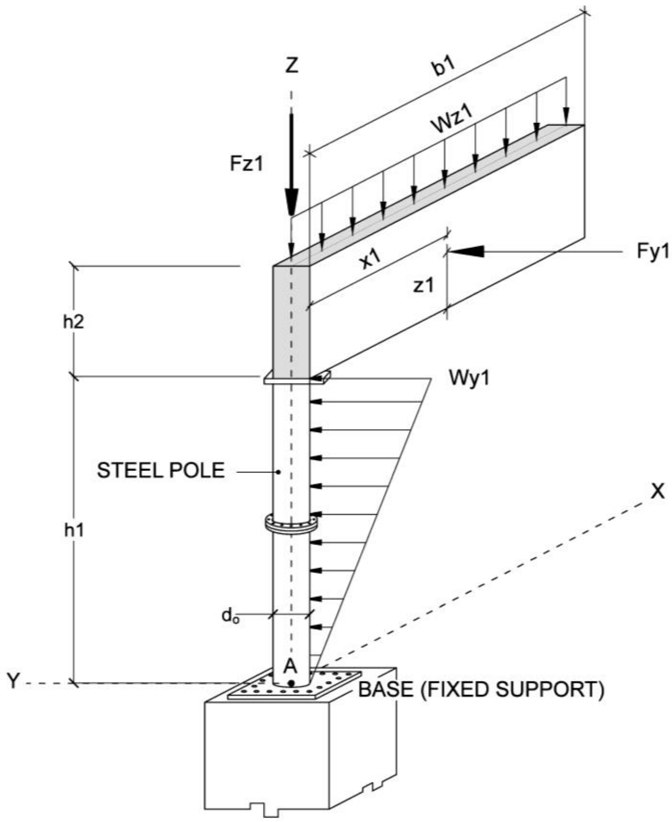

Figure 1. Signpost from Project 1.

The following questions were posed:

(Q1) *Calculate the values of all 6 reactions at the base, taking into consideration the self-weight of the pole*. Students are required to draw a 3D Free Body Diagram (FBD) of the entire system, write equations by hand, and solve the equations with an Excel spreadsheet.

(Q2) *Determine a formula for the internal reactions of the post in terms of the height "z"*. Students are required to draw a FBD of an appropriate section and to write a general formula for the internal reactions at an arbitrary height "z". In particular, their equations should recover the results obtained in (Q1) when z = 0.

(Q3) *Plot Reactions*. Using the equations from (Q2), students are required to develop a spreadsheet that calculates all six internal reactions at a minimum of 10 intermediate locations along the signpost and to generate six graphs that show the value of the each internal reaction with respect to the height "z".

(Q4) *Specify the height "z" at which the reactions appear to be greatest*. The key point here is that students are expected to answer this question based on their computed results, and not necessarily based on their (uncritical) intuition.

Project 2: This project builds off of Project 1 and assimilates concepts from early in the MoM course, such as tension, lateral shear, and bearing stress. Students are asked to design structural elements using the reactions previously obtained at the pole base (by the time this project is assigned, the results from Project 1 have already been discussed in class). In particular, the pole base (z = 0) is assumed to be attached to a steel plate that is connected to a concrete pedestal by steel anchors (Figure 2a).

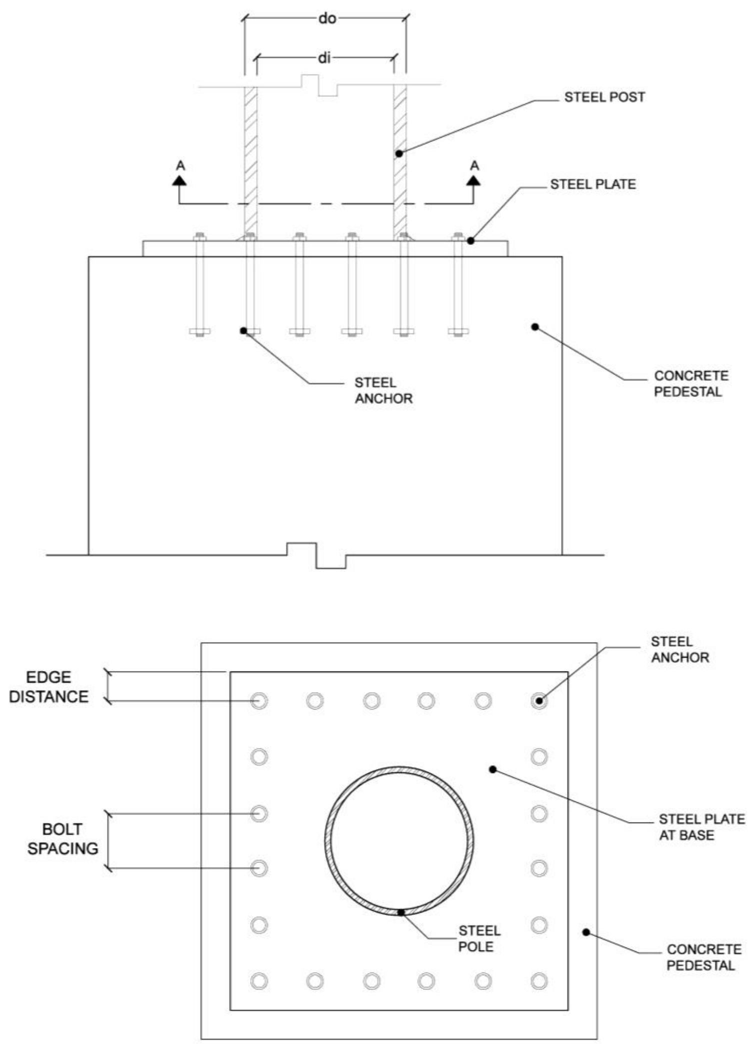

Figure 2a. Elevation (top) and Plan (bottom) views of Pole Base Connection, Project 2.

The following questions were posed:

(Q1-a) *Estimate diameter of the anchor bolts.* Students are provided with several working assumptions, including (i) the use of higher strength "Group B" ASTM A-490 bolts (Figure 2b), with threads excluded from the shear plane, i.e. "X-condition" (Figure 2e), as per AISC 2011;[9] (ii) specified plate width Wp = 52.5 in.; (iii) minimum anchor spacing of 3 in.; and (iv) specified edge distance of 1 ¼ in. With this information, students then use a pre-programmed spreadsheet to iteratively calculate the tension in each bolt based on the moment equilibrium at the base and the distance of each bolt from the central axis of the plate (Figure 2c).

ASTM Desig.	F_{nt}/Ω (ksi) ASD
Group A	45.0
Group B	56.5
A307	22.5

Figure 2b. ASTM allowable bolt tension (AISC, 2011)[9].

Mom. Max =	340.27	k-ft
Plate Width =	52.5	in
Edge Dist =	1.25	in
Bolt Rows =	5	
Row Spacing =	12.50	in
Total Tension =	81.66	Kip

Students enter basic data, including a choice of number of bolt rows.

The resulting maximum bolt tension can be iterated until equilibrium is achieved.

Bolt Row	Row Location [in.]	Dist. Centroid [in.]	Moment [k-ft]	Relative Force [K]	Iterative 65.3
1	1.3	25.0	1633.3	65.3	Difference
2	13.8	12.5	408.3	32.7	0.00%
3	26.3	0.0	0.0	0.0	
4	38.8	-12.5	0.0	-32.7	
5	51.3	-25.0	0.0	-65.3	
6	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.0	
8	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	0.0	
		Sum	4083.1		
		Value	4083.2		

Figure 2c. Excerpt of Excel Spreadsheet Template for bolt tension calculation. Cells in red are entered by the user; those in black are pre-programmed.

Finally, with the both tensions calculated, students determine the minimum required diameter based on the published tensile strengths and available diameters.

(Q1-b) *Estimate the plate thickness*. Using (i) published data for Available Bearing Strength at Bolt Holes for a standard hole type "STD" as per AISC 2011[9] (Figure 2d), together with

(ii) the bolt diameter and spacing from (Q1-a), and (iii) assumption that the tensile strength in the plate is 58 ksi, students determine the required plate thickness by balancing the approximate bearing force of the bolts on the projected cross sectional area of the bolt holes with the available tensile reaction of the cross sectional area between the bolt holes. The minimum allowable plate thickness is 3/16 in., regardless of the theoretical calculation.

Available Bearing Strength at Bolt Holes Based on Bolt Spacing
kips/in. thickness

Hole Type	Bolt Spacing, s, in.	F_u, ksi	Nominal Bolt Diameter, d, in.							
			5/8		3/4		7/8		1	
			r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
			ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
STD SSLT	$2^2/_3\ d_b$	58	34.1	51.1	41.3	62.0	48.6	72.9	55.8	83.7
		65	38.2	57.3	46.3	69.5	54.4	81.7	62.6	93.8
	3 in.	58	43.5	65.3	52.2	78.3	60.9	91.4	67.4	101
		65	48.8	73.1	58.5	87.8	68.3	102	75.6	113
Hole Type	Bolt Spacing, s, in.	F_u, ksi	Nominal Bolt Diameter, d, in.							
			1 1/8		1 1/4		1 3/8		1 1/2	
			r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
			ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
STD SSLT	$2^2/_3\ d_b$	58	63.1	94.6	70.3	105	77.6	116	84.8	127
		65	70.7	106	78.8	118	86.9	130	95.1	143
	3 in.	58	63.1	94.6	—	—	—	—	—	—
		65	70.7	106	—	—	—	—	—	—

Available Bearing Strength at Bolt Holes Based on Edge Distance
kips/in. thickness

Hole Type	Edge Distance L_e, in.	F_u, ksi	Nominal Bolt Diameter, d, in.							
			5/8		3/4		7/8		1	
			r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
			ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
STD SSLT	1 1/4	58	31.5	47.3	29.4	44.0	27.2	40.8	25.0	37.5
		65	35.3	53.0	32.9	49.4	30.5	45.7	28.0	42.0
	2	58	43.5	65.3	52.2	78.3	53.3	79.9	51.1	76.7
		65	48.8	73.1	58.5	87.8	59.7	89.6	57.3	85.9
Hole Type	Edge Distance L_e, in.	F_u, ksi	Nominal Bolt Diameter, d, in.							
			1 1/8		1 1/4		1 3/8		1 1/2	
			r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
			ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
STD SSLT	1 1/4	58	22.8	34.3	20.7	31.0	18.5	27.7	16.3	24.5
		65	25.6	38.4	23.2	34.7	20.7	31.1	18.3	27.4
	2	58	48.9	73.4	46.8	70.1	44.6	66.9	42.4	63.6
		65	54.8	82.3	52.4	78.6	50.0	75.0	47.5	71.3

Figure 2d. Available Bearing Strength at Bolt Holes, excerpt (AISC, 2011)[9].

(Q2) *Recalculate Anchor Bolt Diameters and Plate Thickness under Alternative Scenario*. Students are asked to recalculate the bolt diameters and plate thickness under a new scenario in which the pole is assumed to undergo impact due to a collision with a truck. Using an equivalent static force V = 400 Kip as per AASHTO 2010[10] that represents an isolated special load of truck collision at the bottom of the post, students were required to design the number and diameter of anchor bolts based on a the equivalent direct lateral shear strength resisted by the bolt cross sections (Figure 2e), and the plate thickness using similar reasoning as above. For this case, the maximum number of anchor rows is restricted to 4.

ASTM Desig.	Thread Cond.	F_{nv}/Ω (ksi) ASD
Group A	N	27.0
	X	34.0
Group B	N	34.0
	X	42.0
A307	–	13.5

Figure 2e. ASTM allowable bolt shear strength (AISC 2011)[9].

Project 3: In this project, students are asked to design of a truss that supports a floor (Figure 3a), using the computer software SAP2000 as the primary analytical tool. This project integrates various concepts learned in the first half of MoM, such as tension and axial displacement/strain, and introduces concepts that will be studied in future courses, such as structural displacements. The height and width of the truss are specified (HT = 6 ft., L = 15 ft.).

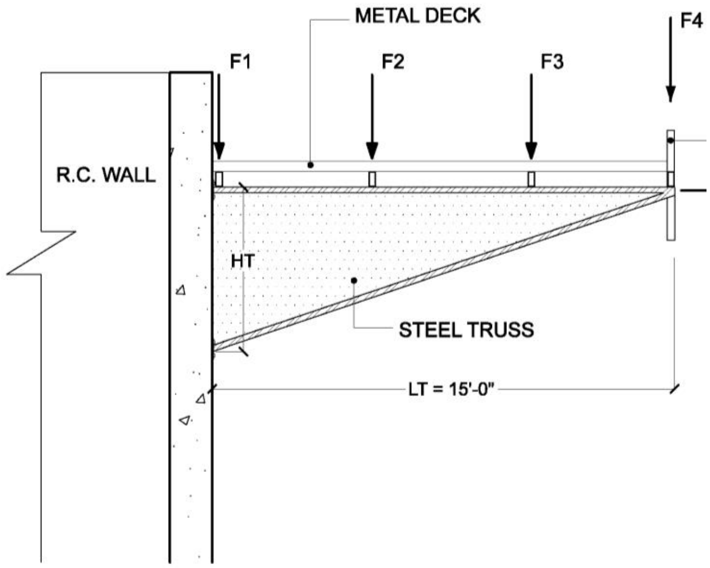

Figure 3a. Lateral elevation showing truss supporting a floor.

The truss is subjected to point loads F1 = 5 Kip, F2 = F3 = 9 Kip, and F4 = 10 Kip. These loads account for (i) the weight due to the floor and machines placed on the floor, (ii) other live loads on the floor, and (iii) loads imposed by secondary structural elements, such as those providing lateral stabilization to the system. The truss is to be assembled with square tubes (hollow structural sections "HSS", as specified in the AISC *Steel Construction Manual* (2011)[9] (Figure 3b), using 36 ksi steel.

Table 1-12 (continued)
Square HSS
Dimensions and Properties
HSS7-HSS4 1/2

Shape	Design Wall Thickness, t	Nominal Wt.	Area, A	b/t	h/t	I	S	r	Z	Workable Flat	Torsion J	Torsion C	Surface Area
	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}	in.	in.^{4}	in.^{3}	ft^2/ft
HSS7×7×5/8	0.581	50.81	14.0	9.05	9.05	93.4	26.7	2.58	33.1	4 3/16	158	47.1	2.17
×1/2	0.465	42.05	11.6	12.1	12.1	80.5	23.0	2.63	27.9	4 3/4	133	39.3	2.20
×3/8	0.349	32.58	8.97	17.1	17.1	65.0	18.6	2.69	22.1	5 5/16	105	30.7	2.23
×5/16	0.291	27.59	7.59	21.1	21.1	56.1	16.0	2.72	18.9	5 5/8	89.7	26.1	2.25
×1/4	0.233	22.42	6.17	27.0	27.0	46.5	13.3	2.75	15.5	5 7/8	73.5	21.3	2.27
×3/16	0.174	17.08	4.67	37.2	37.2	36.0	10.3	2.77	11.9	6 3/16	56.1	16.2	2.28
×1/8	0.116	11.56	3.16	57.3	57.3	24.8	7.09	2.80	8.13	6 7/16	38.2	11.0	2.30
HSS6×6×5/8	0.581	42.30	11.7	7.33	7.33	55.2	18.4	2.17	23.2	3 3/16	94.9	33.4	1.83
×1/2	0.465	35.24	9.74	9.90	9.90	48.3	16.1	2.23	19.8	3 3/4	81.1	28.1	1.87
×3/8	0.349	27.48	7.58	14.2	14.2	39.5	13.2	2.28	15.8	4 5/16	64.6	22.1	1.90
×5/16	0.291	23.34	6.43	17.6	17.6	34.3	11.4	2.31	13.6	4 5/8	55.4	18.9	1.92
×1/4	0.233	19.02	5.24	22.8	22.8	28.6	9.54	2.34	11.2	4 7/8	45.6	15.4	1.93
×3/16	0.174	14.53	3.98	31.5	31.5	22.3	7.42	2.37	8.63	5 3/16	35.0	11.8	1.95
×1/8	0.116	9.86	2.70	48.7	48.7	15.5	5.15	2.39	5.92	5 7/16	23.9	8.03	1.97
HSS5 1/2×5 1/2×3/8	0.349	24.93	6.88	12.8	12.8	29.7	10.8	2.08	13.1	3 13/16	49.0	18.4	1.73
×5/16	0.291	21.21	5.85	15.9	15.9	25.9	9.43	2.11	11.3	4 1/8	42.2	15.7	1.75
×1/4	0.233	17.32	4.77	20.6	20.6	21.7	7.90	2.13	9.32	4 3/8	34.8	12.9	1.77
×3/16	0.174	13.25	3.63	28.6	28.6	17.0	6.17	2.16	7.19	4 11/16	26.7	9.85	1.78
×1/8	0.116	9.01	2.46	44.4	44.4	11.8	4.30	2.19	4.95	4 15/16	18.3	6.72	1.80
HSS5×5×1/2	0.465	28.43	7.88	7.75	7.75	26.0	10.4	1.82	13.1	2 3/4	44.6	18.7	1.53
×3/8	0.349	22.37	6.18	11.3	11.3	21.7	8.68	1.87	10.6	3 5/16	36.1	14.9	1.57
×5/16	0.291	19.08	5.26	14.2	14.2	19.0	7.62	1.90	9.16	3 5/8	31.2	12.8	1.58
×1/4	0.233	15.62	4.30	18.5	18.5	16.0	6.41	1.93	7.61	3 7/8	25.8	10.5	1.60
×3/16	0.174	11.97	3.28	25.7	25.7	12.6	5.03	1.96	5.89	4 3/16	19.9	8.08	1.62
×1/8	0.116	8.16	2.23	40.1	40.1	8.80	3.52	1.99	4.07	4 7/16	13.7	5.53	1.63
HSS4 1/2×4 1/2×1/2	0.465	25.03	6.95	6.68	6.68	18.1	8.03	1.61	10.2	2 1/4	31.3	14.8	1.37
×3/8	0.349	19.82	5.48	9.89	9.89	15.3	6.79	1.67	8.36	2 13/16	25.7	11.9	1.40
×5/16	0.291	16.96	4.68	12.5	12.5	13.5	6.00	1.70	7.27	3 1/8	22.3	10.2	1.42
×1/4	0.233	13.91	3.84	16.3	16.3	11.4	5.08	1.73	6.06	3 3/8	18.5	8.44	1.43
×3/16	0.174	10.70	2.93	22.9	22.9	9.02	4.01	1.75	4.71	3 11/16	14.4	6.49	1.45
×1/8	0.116	7.31	2.00	35.8	35.8	6.35	2.82	1.78	3.27	3 15/16	9.92	4.45	1.47

Table 1-12 (continued)
Square HSS
Dimensions and Properties
HSS4-HSS2

Shape	Design Wall Thickness, t	Nominal Wt.	Area, A	b/t	h/t	I	S	r	Z	Workable Flat	Torsion J	Torsion C	Surface Area
	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}	in.	in.^{4}	in.^{3}	ft^2/ft
HSS4×4×1/2	0.465	21.63	6.02	5.60	5.60	11.9	5.97	1.41	7.70	—	21.0	11.2	1.20
×3/8	0.349	17.27	4.78	8.46	8.46	10.3	5.13	1.47	6.39	2 5/16	17.5	9.14	1.23
×5/16	0.291	14.83	4.10	10.7	10.7	9.14	4.57	1.49	5.59	2 5/8	15.3	7.91	1.25
×1/4	0.233	12.21	3.37	14.2	14.2	7.80	3.90	1.52	4.69	2 7/8	12.8	6.56	1.27
×3/16	0.174	9.42	2.58	20.0	20.0	6.21	3.10	1.55	3.67	3 3/16	10.0	5.07	1.28
×1/8	0.116	6.46	1.77	31.5	31.5	4.40	2.20	1.58	2.56	3 7/16	6.91	3.49	1.30
HSS3 1/2×3 1/2×3/8	0.349	14.72	4.09	7.03	7.03	6.49	3.71	1.26	4.69	—	11.2	6.77	1.07
×5/16	0.291	12.70	3.52	9.03	9.03	5.84	3.34	1.29	4.14	2 1/8	9.89	5.90	1.08
×1/4	0.233	10.51	2.91	12.0	12.0	5.04	2.88	1.32	3.50	2 3/8	8.35	4.92	1.10
×3/16	0.174	8.15	2.24	17.1	17.1	4.05	2.31	1.35	2.76	2 11/16	6.56	3.83	1.12
×1/8	0.116	5.61	1.54	27.2	27.2	2.90	1.66	1.37	1.93	2 15/16	4.58	2.65	1.13
HSS3×3×3/8	0.349	12.17	3.39	5.60	5.60	3.78	2.52	1.06	3.25	—	6.64	4.74	0.900
×5/16	0.291	10.58	2.94	7.31	7.31	3.45	2.30	1.08	2.90	—	5.94	4.18	0.917
×1/4	0.233	8.81	2.44	9.88	9.88	3.02	2.01	1.11	2.48	—	5.08	3.52	0.933
×3/16	0.174	6.87	1.89	14.2	14.2	2.46	1.64	1.14	1.97	2 3/16	4.03	2.76	0.950
×1/8	0.116	4.75	1.30	22.9	22.9	1.78	1.19	1.17	1.40	2 7/16	2.84	1.92	0.967
HSS2 1/2×2 1/2×5/16	0.291	8.45	2.35	5.59	5.59	1.82	1.46	0.880	1.88	—	3.20	2.74	0.750
×1/4	0.233	7.11	1.97	7.73	7.73	1.63	1.30	0.908	1.63	—	2.79	2.35	0.767
×3/16	0.174	5.59	1.54	11.4	11.4	1.35	1.08	0.937	1.32	—	2.25	1.86	0.784
×1/8	0.116	3.90	1.07	18.6	18.6	0.998	0.799	0.965	0.947	—	1.61	1.31	0.800
HSS2 1/4×2 1/4×1/4	0.233	6.26	1.74	6.66	6.66	1.13	1.01	0.806	1.28	—	1.96	1.85	0.683
×3/16	0.174	4.96	1.37	9.93	9.93	0.953	0.847	0.835	1.04	—	1.60	1.48	0.700
×1/8	0.116	3.48	0.956	16.4	16.4	0.712	0.633	0.863	0.755	—	1.15	1.05	0.717
HSS2×2×1/4	0.233	5.41	1.51	5.58	5.58	0.747	0.747	0.704	0.964	—	1.31	1.41	0.600
×3/16	0.174	4.32	1.19	8.49	8.49	0.641	0.641	0.733	0.797	—	1.09	1.14	0.617
×1/8	0.116	3.05	0.840	14.2	14.2	0.486	0.486	0.761	0.584	—	0.796	0.817	0.633

Figure 3b. Table of square tubes (HSS), excerpt, (AISC, 2011).[9]

To enable the students to create and analyze a model truss, a prepared template in SAP2000 containing discrete node points for elements and loads is provided to the students (Figure 3c). Thus, with this template, students can readily insert truss elements with a minimal amount of instruction, rather than being required to build an entire model from scratch.

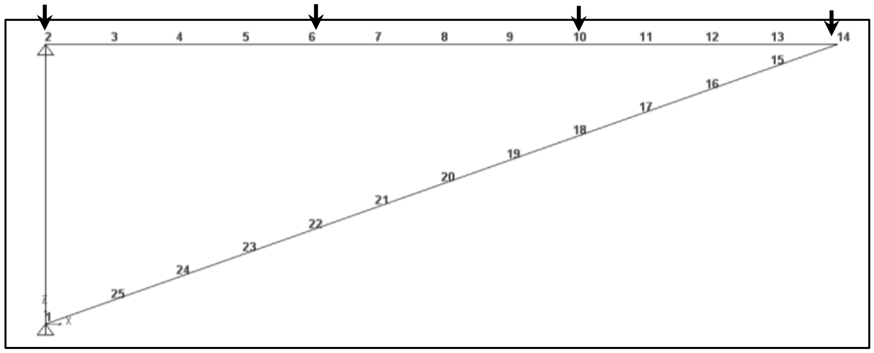

Figure 3c. Standardized node points for SAP2000 truss template, Project 3.

The following questions were posed:

(Q1) *Build Initial Model*. Using the SAP2000 template, the students build a truss of their choosing, including the size of the tubes and their nodal endpoints. The following additional constraints were imposed: (i) select square hollow structural sections with external widths from 2 in. through 6 in.; (ii) select wall thicknesses from 3/16 in. through 3/8 in.; (iii) assume pinned supports in joints connected to the wall; (iv) use one tubular section type for all exterior elements and one tubular section type for all interior elements; and (v) internal elements should have a width smaller than the outside elements.

(Q2) *Check internal member forces*. Students are asked to perform a manual analysis of the truss joints using the Method of Joints to check the internal member forces calculated by SAP2000, and to verify that members satisfy maximum stress limits. Assume in this case that Joint 1 has a roller and Joint 2 has a hinged support.

(Q3) *Maximum Displacement Constraint*. Students are now asked to consider an additional design constraint in which the maximum displacement cannot exceed 0.22 in. Using the SAP2000 model, they are asked to check if the original design exceeds this value, and if so, they should modify the truss. Students are then asked to explain why they decided to use the proposed system.

Project 4: This project complements Project 3. The same floor is considered, but here students should design a steel cantilevered beam (see Figure 4a), rather than a truss, to support the floor (i.e., using the same data provided in Project 3).

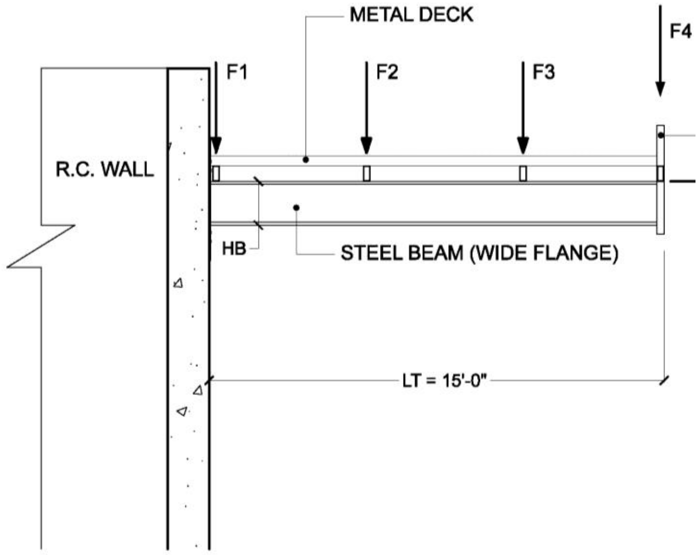

Figure 4a. Lateral elevation showing cantilever beam supporting a floor, Project 4.

The beam should consist of a standard W (wide flange) I-beam, selected from the tables provided by the AISC *Steel Construction Manual* (2011)[9] (Figure 4b).

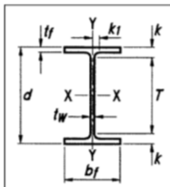

Table 1-1
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Distance Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335[c]	98.5	44.0	44	1.03	1	1/2	15.9	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290[c]	85.4	43.6	43 5/8	0.865	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.36	2 7/16	1 1/4		
×262[c]	77.2	43.3	43 1/4	0.785	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.20	2 1/4	1 3/16		
×230[c,v]	67.8	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16	↓	↓
W40×593[h]	174	43.0	43	1.79	1 13/16	15/16	16.7	16 3/4	3.23	3 1/4	4.41	4 1/2	2 1/8	34	7 1/2
×503[h]	148	42.1	42	1.54	1 9/16	13/16	16.4	16 3/8	2.76	2 3/4	3.94	4	2		
×431[h]	127	41.3	41 1/4	1.34	1 5/16	11/16	16.2	16 1/4	2.36	2 3/8	3.54	3 5/8	1 7/8		
×397[h]	117	41.0	41	1.22	1 1/4	5/8	16.1	16 1/8	2.20	2 3/16	3.38	3 1/2	1 13/16		
×372[h]	110	40.6	40 5/8	1.16	1 3/16	5/8	16.1	16 1/8	2.05	2 1/16	3.23	3 5/16	1 13/16		
×362[h]	106	40.6	40 1/2	1.12	1 1/8	9/16	16.0	16	2.01	2	3.19	3 1/4	1 3/4		
×324	95.3	40.2	40 1/8	1.00	1	1/2	15.9	15 7/8	1.81	1 13/16	2.99	3 1/16	1 11/16		
×297[c]	87.3	39.8	39 7/8	0.930	15/16	1/2	15.8	15 7/8	1.65	1 5/8	2.83	2 15/16	1 11/16		
×277[c]	81.5	39.7	39 3/4	0.830	13/16	7/16	15.8	15 7/8	1.58	1 9/16	2.76	2 7/8	1 5/8		
×249[c]	73.5	39.4	39 3/8	0.750	3/4	3/8	15.8	15 3/4	1.42	1 7/16	2.60	2 11/16	1 9/16		
×215[c]	63.5	39.0	39	0.650	5/8	5/16	15.8	15 3/4	1.22	1 1/4	2.40	2 1/2	1 9/16		
×199[c]	58.8	38.7	38 5/8	0.650	5/8	5/16	15.8	15 3/4	1.07	1 1/16	2.25	2 5/16	1 9/16	↓	↓
W40×392[h]	116	41.6	41 5/8	1.42	1 7/16	3/4	12.4	12 3/8	2.52	2 1/2	3.70	3 13/16	1 15/16	34	7 1/2
×331[h]	97.7	40.8	40 3/4	1.22	1 1/4	5/8	12.2	12 1/8	2.13	2 1/8	3.31	3 3/8	1 13/16		
×327[h]	95.9	40.8	40 3/4	1.18	1 3/16	5/8	12.1	12 1/8	2.13	2 1/8	3.31	3 3/8	1 13/16		
×294	86.2	40.4	40 3/8	1.06	1 1/16	9/16	12.0	12	1.93	1 15/16	3.11	3 3/16	1 3/4		
×278	82.3	40.2	40 1/8	1.03	1	1/2	12.0	12	1.81	1 13/16	2.99	3 1/16	1 3/4		
×264	77.4	40.0	40	0.960	15/16	1/2	11.9	11 7/8	1.73	1 3/4	2.91	3	1 11/16		
×235[c]	69.1	39.7	39 3/4	0.830	13/16	7/16	11.9	11 7/8	1.58	1 9/16	2.76	2 7/8	1 5/8		
×211[c]	62.1	39.4	39 3/8	0.750	3/4	3/8	11.8	11 3/4	1.42	1 7/16	2.60	2 11/16	1 9/16		
×183[c]	53.3	39.0	39	0.650	5/8	5/16	11.8	11 3/4	1.20	1 3/16	2.38	2 1/2	1 9/16		
×167[c]	49.3	38.6	38 5/8	0.650	5/8	5/16	11.8	11 3/4	1.03	1	2.21	2 5/16	1 9/16		
×149[c,v]	43.8	38.2	38 1/4	0.630	5/8	5/16	11.8	11 3/4	0.830	13/16	2.01	2 1/8	1 1/2	↓	↓

[c] Shape is slender for compression with F_y = 50 ksi.
[h] Flange thickness greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with F_y = 50 ksi.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

Figure 4b. Excerpt from table of W-Shapes (AISC, 2011).[9]

The following questions were posed:

(Q1) *Select initial beam*. Students are asked to select the lightest possible W (wide flange) beam that is capable of supporting the specified loadings, without exceeding the maximum allowable bending stress (36 ksi, with a factor of safety of 2.4). Students are required to provide spreadsheet that can take as inputs basic parameters of the beam dimensions and the given loadings, and provide as output the maximum bending stress.

(Q2) *Verify and modify design*. Students are asked to verify that their design satisfies the constraints by including the self weight of the beam in the calculations, in addition to the given loadings. If the maximum bending stress is exceeded, students must iteratively select another W-Shape until the condition is satisfied.

(Q3) *Build SAP2000 Model and Check Displacement Criterion*. With the experience of Project 3, students are able to build a basic beam model in SAP2000, including the specification of the W section designed in (Q2) and the imposed loads. They are asked to run the analysis and verify the maximum displacement. If this value exceeds 0.22 in., they must redesign the beam to find the lightest possible one that meets both the displacement and yield stress criteria.

(Q4) *Manual Check*. Using a provided table of displacement equations for beams for the cases of a concentrated load (external loads) and a distributed load (self-weight), students are asked to create a spreadsheet that uses these equations to estimate the maximum displacement, and to compare this result with that obtained with SAP2000.

(Q5) *Check Shear Stress Requirement*. As a final step, students are asked to check that the beam satisfies the allowable stress τ_a = 12 ksi. They should also perform this check by creating a spreadsheet based on the equation τ = VQ/It.

(Q6) *Comparison*. Once a final design for the beam is selected, students are asked to choose one of the systems (truss or beam) to support the roof. Cost estimates are provided for each structural system per pound of steel (but not construction labor).

3. Assessment

A detailed 29-question survey was given to students at the end of the semester to inquire about students' attitudes as a result of their experience in the MoM course. The survey is provided in the Appendix. To date, 5/20 enrolled students have completed the survey. Some key results are as follows:

- Students generally felt that the projects engaged them with real-world engineering problem-solving, and that such projects should be continued as part of the class (Qu. 1.1 and 1.2).

- Students had mixed feelings on whether the training that we provided them to use SAP2000 was sufficient, but most of them indicated that overall they like using it and would try to use it in future problem-solving situations (Qu. 2.1 and 2.9).
- When asked openly to comment on the advantage of using SAP2000 in design (Qu. 2.2), 2/5 students indicated that the computer is useful to make quick adjustments to refine the design; all students indicated that this functionality was a positive feature when specifically asked about this issue (Qu. 2.8).
- Students generally perceived that the course required higher than average effort, but that the effort was "worth it" (Qu. 4.1).

We also reviewed the results of each project. The projects were complete by 10 groups, each consisting of 3-4 students. The main findings are summarized as follows:

Project 1. Students had more difficulty than we anticipated in determining the internal reactions as a function of height along the pole. Only 2/10 groups were able to provide credible graphs and equations for all six internal reactions. There appear to be three primary reasons for this:

- Students have not mastered the concept of making an arbitrary cut in a system and selecting an appropriate subsystem for the governing free body diagram. Specifically in this case, students would make a cut at an intermediate point in the signpost, but then remained confused about whether to use the top or bottom section, including whether the sign should remain attached to the top section and whether the weight of the sign should transfer to the bottom section. Many students were further confused when told that both the top and bottom sections could be used, despite the fact that they could recite the law of Action-Reaction; they seemed to have in mind that only one or the other would be correct.
- Perhaps in relation to the previous issue, several students had difficulty accounting for the self weight of the section of the post (as a function of z) that remained in their selected FBD.
- Several students had difficulty with the algebra to compute forces, centroids, and moments resulting from trapezoidal loadings (corresponding to the wind pressure) and self weight (from the signpost) that exist on a given subsystem, perhaps due to the fact that the variable "z" appeared rather than a concrete number.

Project 2. This project was the students' first encounter using professional design manuals, and it is not surprising that they had some difficulty adjusting to the use of tables when they were perhaps expecting everything to take the form of an algebraic formula. Four of the ten groups submitted projects with generally satisfactory results. Based on the written works and student questions, the primary difficulties appear to be as follows:

- In general, students had difficulty envisioning the situations described in the code. For example, the standard diagram of bearing stress from the textbook is not provided in the table for allowable bearing strength in plates. Students are left to interpret that what is meant is the total lateral force applied to the bolts divided by the total projected lateral surface of the bolts inside the bolt holes.

- Several students had difficulty understanding the logic of using the theoretical continuous bending stress distribution to determine the corresponding equivalent tensions in bolts located at discrete distances away from the neutral axis of the pole. However, in several of these cases, we witnessed the students understanding emerge after playing with the prepared spreadsheet and studying the results.

Project 3. This project was the students' first exposure to the use of SAP2000. Most students appeared to learn the basics of how to operate the software itself. The main problems that emerged were more conceptual in nature, and are as follows:

- Failed constraints: 2/10 groups did not attempt alternatives when their design failed to satisfy the specified maximum stress constraints at (Q2).
- No design improvements: 6/10 groups did not update the design to improve efficiency once the design satisfied the limiting constraints, either from (Q2) and (Q3).
- Poor manual calculations: 4/10 groups had difficulty performing manual calculations from the SAP2000 model. In particular, a common difficulty was that given the two endpoints of an element from SAP2000, they could not determine the angle or slope of the member for use in manual calculation.

Project 4. This project was the students' first exposure to the topic of analytical determination of beam deflections, and also provoked them to qualitatively compare the performance of a truss with that of a beam. The major difficulties from this project are as follows:

- No spreadsheet: 5/10 groups did not attempt a spreadsheet to summarize the manual calculations for bending stresses or beam deflection.
- Incorrect shear calculation: 5/10 groups had difficulty properly estimating the maximum shear force in the beam. This appears to originate with difficulties applying the equation τ = VQ/IT.
- Incorrect deflection verification: Although the instructor provided the general equation for the deflected beam under the cases of (i) uniform load (to represent self weight) and (ii) a single point load, 4/10 groups had significant problems understanding how to apply these equations and to superimpose the results. Hand calculations were compared with output from SAP2000, errors in the hand calculations distorted or invalidated these comparisons.
- Incorrect bending stress: 3/10 groups developed incorrect estimates of maximum bending stress because they incorrectly calculated the maximum bending moment in the beam. From the tables provided, they used the equation for maximum moment for the simply supported beam rather than for the cantilevered beam.

4. Discussion and Conclusions

We regard the results of the student performance in the MoM class as moderately successful. Broadly speaking, students did not appear to be overwhelmed by the required tasks and logistics to run SAP2000 and the use of design manuals. In fact, based on the results of the survey questions 1.1, 1.2, 2.1, and 2.9, students generally were interested by this approach and felt that the instruction was at least adequate to enable them to use these methods. Moreover, we believe that the early exposure to these approaches is a key to their future success in subsequent classes and eventually in their professional careers.

About half of the groups were consistently able to execute the complete required design steps and obtain reasonable results. On the other hand it is disappointing that in a number of cases, fundamental concepts from both Statics and MoM – theory of FBD's, geometry of diagonal truss members, and difficulty with the shear stress equation – were at the root of a large number of errors.

Specifically with regard to an aspect of simulation, it is interesting to compare the results of survey questions 2.2 and 2.8 with actual student behavior in the projects. In Question 2.2, students were asked to respond to an open-ended question about their perceived advantages of using SAP2000. Two of the five respondents commented that they could use SAP2000 to quickly update models and refine results. In Question 2.8, all respondents agreed that this was an advantage when the issue was specifically raised. In the performance of Project 3, only 4/10 groups performed design improvements using SAP2000 after a feasible solution was reached. This suggests that the use of a simulation tool as a design tool is a new idea for students to grasp, and this is likely a consequence of a steady diet of closed-ended textbook problems.

On the whole, we believe that our approach is both within reach of students' abilities and accelerates their exposure to use of simulation in design. Based on the results thus far, an immediate improvement that the instructors will make is to provide the introductory training in SAP2000 at an earlier stage of the course to allow students more time to adapt to the new methodology, and hopefully to use it maturely as a design tool. In the long term, we plan to track student performance of our students in subsequent courses to determine if they outperform other students in design oriented problems and tasks.

We also plan to make further improvements in the content of the modules themselves. Further refinements can be made to reflect richer design scenarios. For example we will explore the development of additional states to consider in the analysis of the steel plate, such as yielding due to tension, fracture due to tension and block shear rupture. We also plan to build in realistic fabrication and construction costs that might occur in a real structure.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1044866. The authors gratefully acknowledge this support.

Bibliography

1. Dym, C.L., A.M. Agogino, O. Eris, D.D. Frey, and L.J. Leifer. "Engineering Design Thinking, Teaching, and Learning", *Journal of Engineering Education*, Vol. 94, No. 1, January 2005.

2. MacNamara, S. “Trans-Disciplinary Design Teaching for Civil Engineers and Architects: Lessons Learned and Future Plans”. *Proceedings of the ASEE Conference and Exposition*, Vancouver, BC, 2011.
3. C. Papadopoulos, A. Santiago Román, G. Portela Gauthier, R. Marín Ramírez, P. Pacheco Roldán. “NSF Poster: Leveraging Simulation Tools to Deliver Ill-Structured Problems: Enhancing Student Problem-Solving Ability in Statics and Mechanics of Materials”. *Proceedings of the ASEE Annual Conference and Exposition*, San Antonio, TX, June, 2012.
4. J. Papadopoulos, C. Papadopoulos, and V. Prantil. “A Philosophy of Integrating FEA Practice throughout the Undergraduate ME/CE Curriculum”. *Proceedings of the ASEE Annual Conference and Exposition*, Vancouver, Canada, June, 2011.
5. C. Papadopoulos, A. Santiago Román, G. Portela Gauthier, and A. Ponce. “Leveraging Simulation Tools to Deliver Ill-Structured Problems in Statics and Mechanics of Materials: Initial Results”. *Proceedings of the ASEE Annual Conference and Exposition*, Atlanta, GA, June, 2013.
6. Bucciarelli, L. “Learning By Design – What Have We Learned?”, *Proceedings of the ASEE Conference and Exposition*, Milwaukee, WI, 1997.
7. Computers and Structures Inc.. SAP2000 v.15, 2013.
8. American Society of Civil Engineers. *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10), 2010.
9. American Institute of Steel Construction (AISC). *Steel Construction Manual*, 14th Ed., 2011.
10. American Association of State Highway and Transportation Officials (AASHTO). *LRFD Bridge Design Specifications*, 5th ed., 2010.
11. Estrada, H. “Analysis of Wind Loads On Buildings And Signs: A Computer Program Based On Asce 7”, *Proceedings of the ASEE Conference and Exposition*, Salt Lake City, UT, 2004.
12. Delatte, N., R. Sutton, W. Beasley, and J. Bagaka's. “Assessing The Impact Of Case Studies On The Civil Engineering And Engineering Mechanics Curriculum”, *Proceedings of the ASEE Conference and Exposition*, Honolulu, HI, 2007.
13. Estrada, H. “Using The AISC Steel Building Case Study In A Structural Engineering Course Sequence”, *Proceedings of the ASEE Conference and Exposition*, Honolulu, HI, 2007.
14. Impelluso, T. “Distance Learning And Cognitive Load Theory To Improve Traditional And Non Traditional Student Learning Of Computer Programming For Mechanical Engineers: Quantitative Assessment”. *Proceedings of the ASEE Conference and Exposition*, Austin, TX, 2009.

Appendix

The following table provides the survey questions and corresponding answer types. The survey is grouped into four parts. Part 1 deals specifically with the projects. Part 2 deals specifically about the experience using SAP2000. Part 3 deals with impressions about the nature of engineering design. Part 4 deals with general issues such as effort required.

Qu.	Question Statement	Answer Type
1.1	In general, what concepts or skills do you think your instructors wanted you to learn with the projects and special assignments?	Free Response
1.2	React to the following statement: “The projects and special assignments engaged me with realistic engineering problems and design considerations”.	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree

1.3	React to the following statement: “The projects and special assignments required me to think creatively and/or to discover ideas and information that were not explicitly given”.	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
1.4	React to the following statement: “The projects helped me to learn basic concepts of Mechanics of Materials”	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
1.5	To what degree were you prepared to do these projects based on what you learned in your previous course in Statics?	Very Prepared Somewhat Prepared Neutral Somewhat Unprepared Very Unprepared
1.6	Which of the following statements reflects your view on how your project/special assignment group functioned?	In my group all members we worked on all parts of the projects/special assignments together and with about equal effort. We had excellent meetings in which we brainstormed ideas, commented on other people's ideas, and corrected each others' errors. In my group, each member was assigned a separate part of the project/special assignment. We met frequently and had excellent meetings in which we brainstormed ideas, commented on other people's ideas, and corrected each others' errors In my group, each member was assigned a separate part of the project/special assignment. Although we did not meet frequently, we had at least one final meeting in which each member reviewed all answers and final edits were made as a group. In my group each member was assigned a separate part of the project/special assignment. The final project/assignment was put together by cutting and pasting the differerent parts and we were not able to have a final meeting for everyone to review all of the final answers.
1.7	Which of the following statements reflects your view on how your working within your group for the projects and/or special assignments affected the quality of your work?	As a result of working in my group, my overall quality of work was improved beyond what I could have accomplished by myself As a result of working in my group, my overall quality of work was about the same as it would have been if I had worked by myself As a result of working in my group, my overall quality of work was lowered compared to what I could have accomplished by myself
1.8	The level of difficulty of the projects and special assignments was	Very Difficult Somewhat Difficult Neutral Somewhat Easy Very Easy
1.9	Please provide further comments about the projects and special assignments that you think the instructors should know, including how they did or did not benefit you, how appropriate the topics were, and how they could be modified.	Free Response
2.1	As a result of the introductory seminar on the use of SAP2000 that was given early in November, how well prepared were you to use this software in the projects and special assignments?	Very Well Somewhat Well Neutral Somewhat Poorly Very Poorly

2.2	List what you think are both the advantages and disadvantages of using SAP2000 in this or a similar course.	Free Response
2.3	React to the following statement: "Because I did not have to do calculations by hand, SAP2000 allowed me to focus my attention on understanding the concepts and interpreting the results".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
2.4	React to the following statement: "When I used SAP2000 I felt uncomfortable because I felt that I should have been doing the calculations by hand instead".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
2.5	React to the following statement: "When I used SAP2000 I felt uncomfortable because I felt that I was using a lot of functions without understanding what I was doing".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
2.6	React to the following statement: "SAP2000 allowed me to solve my problems in an efficient and organized manner".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
2.7	React to the following statement: "Even though SAP2000 performed the calculations automatically, the process to enter the data use the appropriate functions was very difficult and caused me great frustration".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
2.8	React to the following statement: "I thought it was really cool that when I used SAP2000 I could create a structure, and then I could change the design of the structure to see how the problem results would change"	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
2.9	React to the following statement: "In future classes, I intend to use SAP2000 as often as possible, even if the professor does not require it, because it is very advantageous for solving structural engineering problems".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree I did not use SAP2000 enough to answer this question
3.1	Explain what you think "engineering design" means and involves.	Free Response
3.2	React to the following statement: "As a result of this class, I have increased my understanding of why computer tools are essential to the engineering design process".	Strongly Agree Somewhat Agree Neutral (neither agree nor disagree) Somewhat Disagree Strongly Disagree
3.3	Explain why you think that using computer simulation tools are an essential part of the engineering design process (or, if you disagree, explain why not).	Free Response
3.4	Please give a specific example of how you used a computer simulation to assist you with a design problem or question in this class.	Free Response

3.5	Suppose you are an engineer who is using a commercially available computer software to solve an engineering design problem. After the computer generates the answer, what, if anything, should you do to check that the answer makes sense?	Free Response
3.6	If an engineer uses an approximation to solve a problem, is that an indication that the engineer is skillful or an indication that s/he lacks sufficient understanding of the 'real' problem?	Free Response
3.7	In addition to using computer software, what other tool or resource does a professional engineer use or consult when developing a structural design?	Free Response
4.1	Which statement best describes the effort required in this class compared with other typical 3-credit engineering, math, or science courses?	This class required higher than average effort, but I learned a lot and the effort was worthwhile and/or I would choose this type of class again This class required higher than average effort, and even though I learned a lot, the effort was too great and I would not take this type of course again This class required higher than average effort, but I did not learn a lot because the course was too advanced and I could not keep up This class required average or below average effort, but I learned a lot and I would take this class again This class required average or below average effort; I did not learn very much and I would not take this class again
4.2	Which aspects of the course most tended to increase to your workload?	Difficulty of assignments The amount of assignments The amount of material in the course I was unprepared and was always behind Other
4.3	Please list and explain what you think are the most important things that you learned in this class that will have a lasting influence on your future studies and career preparation.	Free Response
4.4	Please provide any additional comments that you would like your instructor to know about this course and/or your experience in it.	Free Response