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Introducing Students to Interdisciplinary Perspectives of Building and Urban Design

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Introducing Students to Interdisciplinary Perspectives of Building and Urban Design

Introduction

A major challenge in engineering education is the effective integration of societal and environmental constraints with engineering design fundamentals. This paper describes a new course developed that aims to introduce four factors that affect design, construction and management of the structures we live and work in—*Safety*, *Sustainability*, *Style* and *Society*—from qualitative and quantitative perspectives. Central questions discussed in the course are: *What are our expectations for safety in the built environment? What are the impacts of buildings on the natural environment? What is the interplay between style, sustainability and safety in building design?* The course is intended for students with interests in building design and use, including engineering and non-engineering majors, with a focus on engaging freshman students. Unlike more traditional engineering courses, the curriculum applies concepts from architecture; structural, environmental and building systems engineering; urban development; economics; and public policy, with the goal of holistically examining building design, its influences and its impacts. The course aims to strengthen students' ability to analyze and communicate ideas about building design across multiple disciplines and to explore how integration of dimensions of sustainability and social issues can lead to novel solutions to traditional engineering problems.

This paper details the curriculum and innovative instructional techniques developed for the semester-long seminar-style course at a large public university, including the design of laboratory activities, writing assignments, class discussion activities, and a term project. Students were also introduced to a variety of professions related to buildings through field trips and guest lectures, enabling the course to address challenges associated with emergency management, city planning, and low-income housing. While the activities described here were created for use in this holistic, semester-long course, they could also be used as modules to incorporate societal or sustainable thinking in other courses on building design. To facilitate adaptation by others, the complete assignment sheets and grading criteria for the key assignments are provided online. The final section of the paper assesses the curriculum in terms of student achievement of learning objectives, and changes in student perceptions of building design and sustainability during the course. The assessment is based on the first offering of the course and examines (a) feedback from students during university-administered course questionnaires, (b) examples of student work, and (c) a pre- and post-survey on student perceptions about buildings.

Course overview

This course aims to introduce students to qualitative and quantitative perspectives of four factors that affect design, construction and management of the structures we live and work in. These four factors, *Safety*, *Sustainability*, *Style* and *Society*, comprised the four principle modules of the course. The course explores the modules separately, as well as their interconnectedness. In addition, the course focused on drawing as a language for communicating building design and performance. The class was organized as a weekly 2.5 hour seminar course to allow time for field trips, laboratory activities, and class discussion, which were designed to strengthen students' ability to analyze and communicate ideas about building design across disciplines. Weekly readings shaped the focus of each week's class. A list of the course learning objectives, as described in the syllabus, are provided in Table 1. The primary topics addressed in the class under each of the main modules are listed in Table 2.

Table 1. Course learning objectives.

No.	Course Learning Objective (abbreviated "CO")
1	Understand challenges (technical, social, etc.) to building "better" buildings
2	Describe physical, social, economic and environmental impacts of natural hazards on buildings
3	Describe how building design has changed over time to respond to needs of society
4	Apply simplified methods of structural analysis
5	Compute building energy performance
6	Conduct basic life-cycle environmental assessments of buildings
7	Create a conceptual design for a building that meets goals of safety, sustainability, style and society

Student performance was assessed according to the following guidelines: 20% in-class participation; 20% responses to short writing prompts; 12% submission of "problem sets;" 28% submission of reports on findings from laboratory experiments; and 20% term project. Students were encouraged to work in groups of two or three for the lab reports and term project, but submitted problem sets and writing assignments individually. These assignments are described in detail in the sections below.

In the first offering of the course, seven students enrolled. One student was a business school major, but the rest were were engineering (or pre-engineering) students, despite our interest in attracting a more diverse student enrollment. Two of the seven students were women and most were freshman. The authors of this paper are the faculty instructor and the graduate teaching assistant. A website compiling many of the materials used in the class is available at www.abbieliel.com/educational-materials.

Curriculum and instructional techniques

Laboratory assignments

Eiffel Tower

The first laboratory assignment was part of the *Safety* module, and examined a scaled model of the Eiffel Tower. The purpose of this laboratory was to examine the reactions at the base of a structure that is subjected to a point load. The point load created a concentrated force intended to represent a distributed wind pressure.

In this lab, student worked with a model of the Eiffel tower constructed with K'Nex, shown in Figure 1. The K'Nex structure was built by graduate students (using photos of a previous Eiffel Tower structure built at Princeton University and a lab assignment developed by Prof. Sarah Billington at Stanford University. In the lab, students measured the key dimensions of the structure, including height and span of the base of the tower (Figure 1a). Then (in Figure 1b), they applied a weight, which was connected via a pulley system to the side of the tower such that it applied a lateral load. A data acquisition system (Figure 1c) was used to measure the reaction loads under each foot of the tower. Students were asked to compute the total vertical and overturning moments at the base of the tower.

Table 2. Overview of class topics for each module.

Module	*Safety*	*Sustainability*	*Style*	*Society*
Class Topics	• Structural engineering & effects of loads on structures • Natural disasters, risks and methods of risk assessment • Hazards and risks in our community	• Sustainability and green building design • Metrics of building environmental impact • Life-cycle analysis of buildings	• Evolution of building form • Representations of buildings, space and meaning • Role of architect and architectural theories	• Building design and urban development • Linkages between buildings and economic development • Adaptive reuse

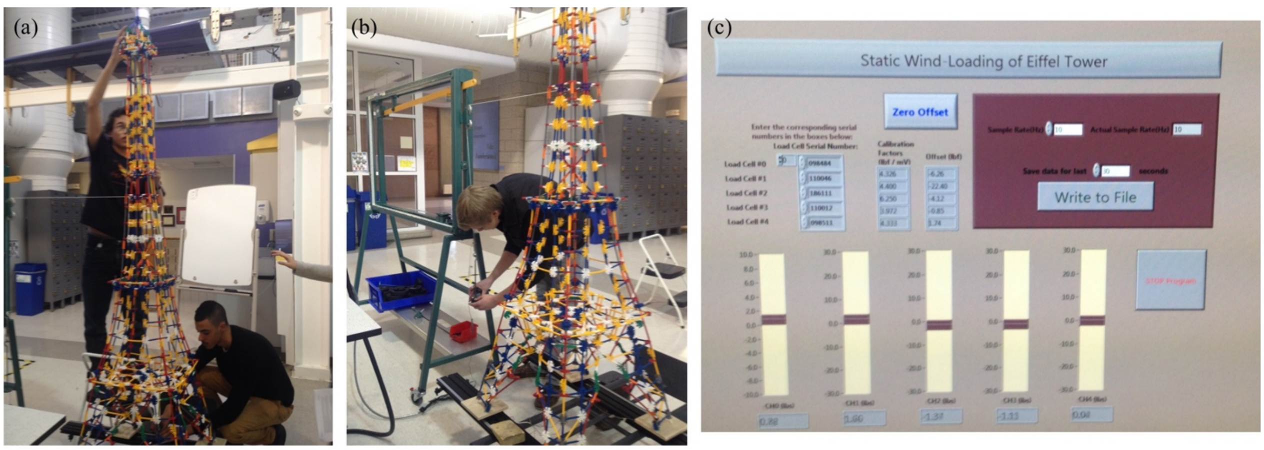
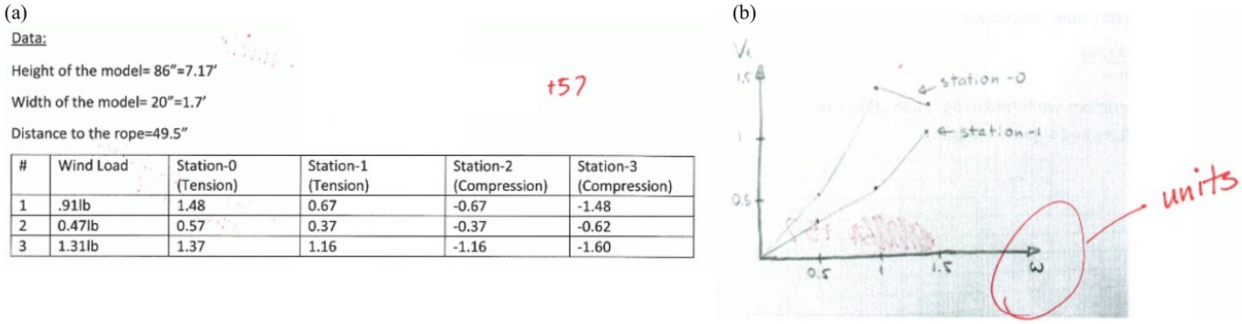


Figure 1. Photos from Eiffel Tower laboratory activity, showing (a) students verifying dimensions of the structure, (b) a student hanging weights from a pulley to create the static representation of the wind loads, and (c) computer interface with load cells used to measure reactions.

In the lab report, students reported measurements from the lab, and compared these values to hand calculations. Figure 2 provides examples of some of the data collected and of student work. Students were also asked to comment on uncertainty in their findings and discrepancies between the laboratory results and their hand calculations. In general, students were very successful at measuring and computing the required quantities from the laboratory assignment. However, the verification with hand calculations was more difficult, especially for those who had not yet taken statics.

LEED Evaluation of Campus Building

The second lab is oriented toward the second of the major course modules: *Sustainability*. The purpose of this laboratory is to assess the performance of a campus dormitory, based on the Leadership in Energy and Environmental Design (LEED) rating for Existing Buildings: Operations + Maintenance. At the time of its construction, the dormitory was the first one of its size in the U.S. to receive a LEED platinum rating. In this lab, the class assessed the LEED platinum rating, surveying the building to determine whether it deserved the high-performance rating based on its as-built features and current operations and maintenance.



Data:

Height of the model= 86"=7.17'

Width of the model= 20"=1.7'

Distance to the rope=49.5"

#	Wind Load	Station-0 (Tension)	Station-1 (Tension)	Station-2 (Compression)	Station-3 (Compression)
1	.91lb	1.48	0.67	-0.67	-1.48
2	0.47lb	0.57	0.37	-0.37	-0.62
3	1.31lb	1.37	1.16	-1.16	-1.60

Figure 2. Examples from students' Eiffel Tower lab reports, showing (a) data collected and (b) plots (with instructor annotations).

Students were asked to conduct a visual inspection of the building interior and exterior, to utilize an online campus tool documenting building energy/water usage for the building, and to conduct basic calculations for energy and water savings relative to conventional construction. Photos from the inspections are provided in Figure 3. Students were given a reduced checklist of LEED credits to check, since not all of the information that the U.S. Green Building Council requests of building owners and operators during LEED certification could be easily gathered over the course of a class period. Students were also informed about other features of the building that might not be obvious in their visual inspections, including daylight sensors, CO_2 monitors, heat recovery and the use of low volatile organic compound paints and sealants.

Figure 3. Photos from student evaluation of LEED credits of campus dormitory: (a) exterior physical inspection, (b) student reviewing data about the filtered water available for filling water bottles in the building, and (c) use of online campus computer tools to review energy and water usage.

In the lab reports, students described which LEED credits they found the building earned, according to their individual assessment from the inspections, online computer tools, and other research. Interestingly, students reached significantly different conclusions, depending on the detail of their level of analysis and on the information sources they used. For some students (such as the student quoted here), the exercise provided a chance explore the subjectivity and weighting of LEED credit systems:

> I would rate it as a LEED platinum building. This isn't a definitive statement because the score that I ended up giving it based on my observations was a 54, which would put it at a silver rating. However, there were 27 points I didn't count which would make it impossible to reach even a gold rating. That being said, assuming that all 27 points that I didn't count were given to the building, then it would be given 81 points, which would make it a platinum rating.

For others (such as the student cited below), the exercise allowed them to think critically about the supposed sustainability of the dormitory in which they lived and studied.

> I would not even certify this building. I would give it a 34. It falls way short (emphasis his) in the energy savings depicted above…The amount of energy saved is much lower than projected. That was its worst area.

Concrete shell structures

In the third laboratory activity, students built concrete shell structures using the concept of purely tensile and compressive structures. This activity was part of the *Style* module, and intended to encourage students to think about the concept of form from multiple perspectives, stretching students to consider artistic as well as functional considerations in their design and construction. This laboratory assignment was based on the work of structural artist Heinz Isler. Students at Princeton University had previously used similar techniques to build structures for an exhibit on structural art at the Princeton Art Museum.[1]

In this course, students were asked as a pre-lab assignment to sketch the structure they wanted to build (Figure 5a). Then, they spent the lab time building the frame and constructing their structure. This process is documented in Figure 4. After waiting for the structures to dry, the final product was revealed in Figure 4d with accompanying drawings, an example of which is shown in Figure 5b. The laboratory report asked students to document the decisions they made regarding the design, form, and function of the structure.

SimCity

The final laboratory activity examined the interrelationship between building design and urban planning and infrastructure, in the *Society* module. This lab used a popular video game, SimCity. (Due to complications with how our campus computer labs are set up, we used an older version of the game with outdated graphics. It would be better to utilize the new version if licensing/server issues can be resolved.) Students were asked to build a city in SimCity that responded to citizen requests, withstood natural disasters, and remained financially solvent.

Students were asked to design a city (see Figure 6 for one example), and help it grow for at least 50 years. In the lab report, they documented the growth of the city with screenshots and notes, documenting their city's terrain and environment and the overall trajectory of growth and development. In addition, students were asked to enact several different policies (increasing property taxes, legalize gambling, etc.) and record their effects on the city. For example, one student observed interdependencies between policy making and infrastructure development, and between power and water infrastructure systems, writing:

> The city grew a lot earlier in the game…at the beginning I had extremely low property taxes to encourage growth, and used much larger zone additions in contrast to the mid-level taxes and low additions I utilized later. The early strategy was great for increasing size, but also caused extreme fluctuations in the demands of the citizens, causing many abandoned buildings. The main challenges were that after the coal plant blew up, I switched to renewable energy. While this energy was pretty cost effective and clean, it was not 100% reliable, which caused small power shortages from time to time. This would then disrupt water supply as well.

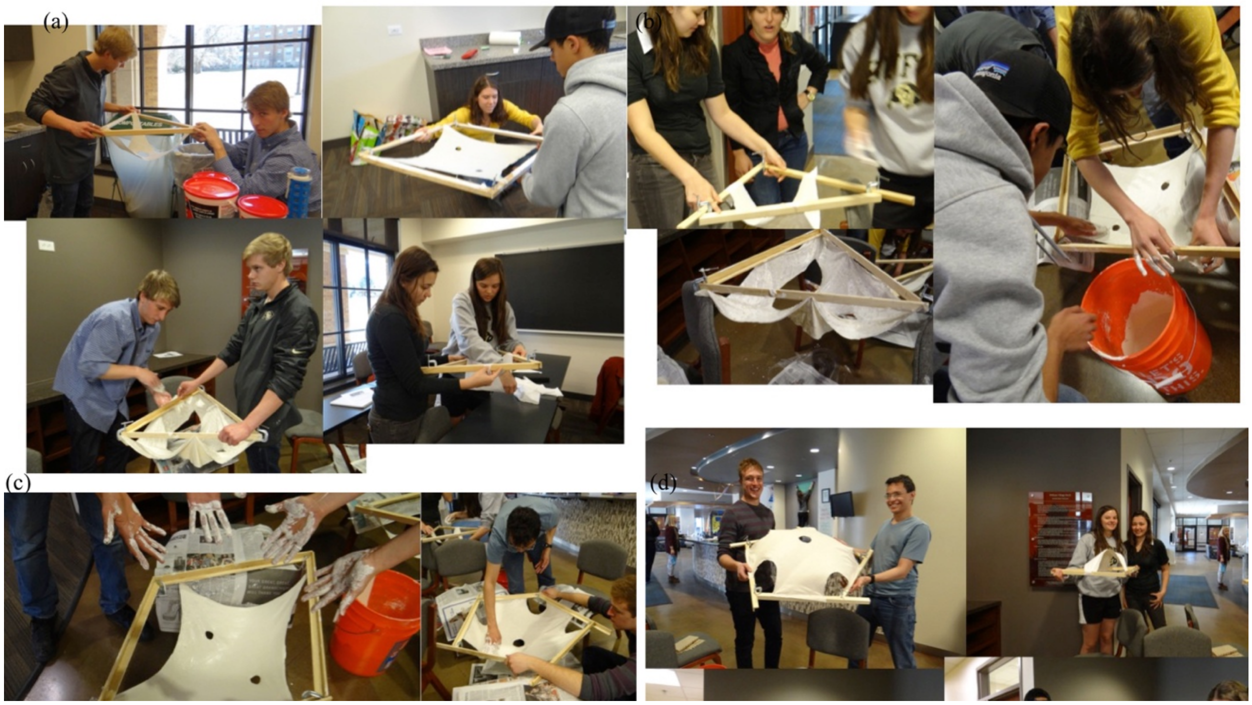


Figure 4. Construction of concrete shell structures in the lab, showing students (a) designing the formwork for their structure, (b) hanging fabric, (c) applying plaster, and (d) showing off their completed (dried) structures.

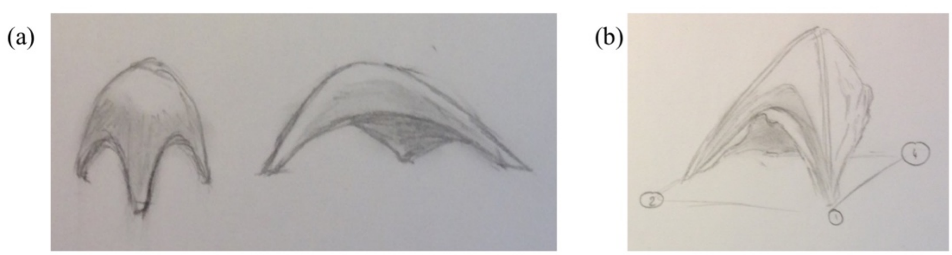


Figure 5. One student's drawing of the structure (a) before the lab and (b) based on the completed structure.

Since games necessarily are simplifications of the urban environment, we also asked students to address inconsistencies between the game and "reality" in their reports. Students observed a variety of places the game was overly simplified, including, the following:

> In reality, it would be more difficult to tell what the people want. In the game, the little bar graph shows which areas (residential, commercial, industrial) need growth and which need to be cut back. In real life, things like this would not be so cut and dry, and even if they were, it would be much more difficult to enact changes so quickly.

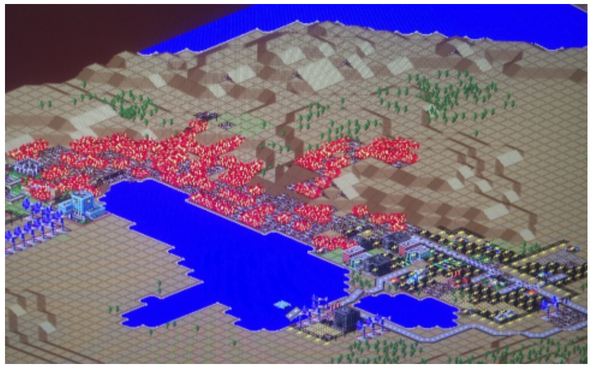


Figure 6. Screenshot of one student's "city", showing a fire burning in part of the city.

Reading and writing assignments

The reading and writing assignments are described in Table 3, showing the diversity of perspectives students were exposed to over the course of the semester. The reading and writing assignments are presented together because, in many cases, the writing assignment used a portion of the reading assignment as a prompt. Students were asked to submit the writing assignments via a web portal to permit easy detection of plagiarism and inappropriate referencing with an online tool.

The challenges and successes of writing assignment submissions are illustrated here through some examples. The first two writing assignments combined analysis of case studies in forensic engineering (writing assignment 1) and building regulations (writing assignment 2), with personal opinions and reactions to the case, offering time for reflection of some of the concepts explored in the class. This combination (sometimes more elegantly achieved than others) is exemplified by this submission to the forensic engineering assignment:

> These improvements are relatively inexpensive from an economical point of view… the state will definitely not be happy with these extra expenses, so this is controversial… the construction team could be at a high risk of losing their engineering license and the media will most likely stir up some harsh and unnecessary labels to them…

This student is reflecting on many of the case study's key ideas, but struggling to articulate his ideas clearly. This student, like others, was reluctant to offer his own opinion, fearing he was searching for a right or wrong answer, and focused on repeating the opinions he had read. In answering the second writing assignment, another student reflected on the difficulty of regulations related to sustainability, with a bit more clarity, and adding some information from his own experience:

> I believe the biggest thing the county… could change with regards to sustainability is making it a bit easier to implement new and different ways of being sustainable. How difficult it is to run a gray water system is a perfect example of where our codes are failing us.

The third and fourth writing assignments asked students to rely more heavily on their own experiences and integrate those experiences with ideas discussed in the class. When asked to reflect on his previous experiences with drawing, Student A wrote:

I took an engineering drawing course last year, but that course mostly covered the use of Revit and how to read building blueprints not much to do with handwritten drawings. Besides that class, I think that the last drawing class I took was in middle school where the most memorable thing that I did was draw myself riding a pterodactyl while James Bond super-villain henchmen shot at me with cats launched from crossbows and then my teacher yelling at me because I was supposed to be drawing a flower (I was a strange child). I never really had much feelings one way or the other regarding drawing. It was always kind of like math where it was just a means to an end.

Table 3. Reading and writing assignments.

Module	*Safety*	*Sustainability*	*Style*	*Society*
Reading Assignment	• One of the selected chapters from *Why Buildings Fall Down,* Levy & Salvadori. • Selections from *The Tower and the Bridge* about the Eiffel Tower, Billington. • Chps. 1-2 from *Developments in Structural Form*, Mainstone. • Selected news articles on recent local flooding. • Chapter 2 of *Disaster by Design*, Mileti.	• *Green Building in North America,* chps. 2-4. • *Green Building and LEED Core Concepts 2009*, pages 1-24. • "Economic Benefits of Green Buildings", Ries *et al.* • "Life-Cycle Assess-ment of Office Buildings", Junnila *et al.* • "Environmental Life-Cycle Analysis", Ciambrone.	• Excerpt from *The Tower and the Bridge*: "Discipline and Play: New Vaults in Concrete", Billington. • "Understanding Creativity", Hines. • "Commuitarianism and Emotivism: Two rival views of ethics and architecture", Bess. • "Europeans Biuer! Dali and La Corbusier conquer New York", Koolhaas.	• Excerpt from Sustainable Urbanisation "Informal Settlements – Clinging to Existing buildings" • 2013 Shelter Report from Habitat for Humanity - Affordable Housing for Strong Communities
Writing Assignment	*Forensic Engineering.* Choose one of the building failures that is described in the chapter you just read. You have been identified as an expert on buildings by your local mayor. Your task is to write a short memo to the mayor explaining (a) why this building failed and (b) how this type of failure can be prevented in the future.	*How do local govern-ments promote green building?* One of our guest speakers discussed the work of the County Sustain-ability Examiner during class. In the first paragraph, summarize the work that his office does and the goals behind their work. The second paragraph should focus on what you think our County is doing well with regard to sustainability. The third paragraph should focus on what you think our County could improve. Be specific.	*Position Paper.* In your reading, Hines argues that "Drawing is the language of the engineer." In one paragraph, explain what he means by this statement. In a second paragraph, describe your own experiences with drawing. Have you taken courses in drawing? Did you like to draw when you were a child? Do you incorporate drawings in your assignments for other classes? What kinds of drawings? Do you agree with the statement that drawing is a language for engineers? *A picture is worth a thousand words.* Create a SketchUp model of a building of your choosing. Your submission should include a) a picture of the building, b) 3-4 screenshots of your SketchUp model, and c) a description of the building and what you are trying to present in you SketchUp model (you could choose to focus on engineering aspects, architectural aspects, landscaping, etc.).	

The "Picture is worth a thousand words" assignment asked students to develop a SketchUp (computer) drawing of a building and describe that building, in order to encourage participants to think more critically about space and representations of space. One submission is excerpted below, showing how the student is relying on his background and familiar places to explore concepts of space (Figure 7):

> The building is a depiction of my house back home… I was really just trying to get a feel for the general shape and design of my house. It was interesting because I know the inside of my house really well, but when it came to the shape of the actual building, it was unsure. So the main goal was just to get a general experience of the outer appearance of a building that I know the inner appearance of so well.

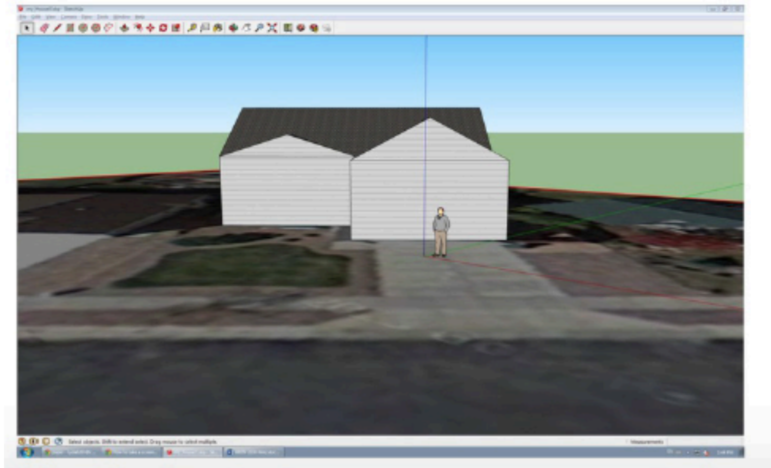


Figure 7. Student SketchUp drawings submitted with writing assignment.

Problem sets

Two of the course modules, *Safety* and *Sustainability*, lent themselves to calculation oriented assignments or problem sets. In the first assignment, students learned basic statics equations, how to idealize a structure for the purpose of calculations and the concept of a "factor of safety." Computations were based on two real structures, the Tower Bridge in London, and the CN Tower in Toronto. This assignment was inspired from similar materials used at Princeton and Stanford Universities. In the second assignment, students used an environmental life-cycle impact calculator software tool for buildings, *Athena Impact Estimator.*[2] These calculations were based on a dormitory on campus (the same one evaluated in lab). After predicting baseline environmental impacts, considering product manufacturing, building construction, maintenance, and all related transportation activities, students were also asked to conduct a sensitivity analysis looking at how factors like exterior wall type, window type and location impacted the results.

The ease with which students approached the problem sets depended largely on their familiarity with the computational techniques in the class and maturity in the university academic setting. Although several lectures were devoted to some of the quantitative principles, a number of students spent significant time in office hours to improve their understanding of these topics. Those students with more background in physics, statics and thermodynamics were able to complete the assignments more quickly.

Other class activities: Field trips, guest speakers and class discussion

Table 4 describes the field trips and guest speakers included in the course. These activities were designed to take advantage of interesting local projects and also to familiarize students with different careers that engage with the built environment, including emergency managers, real estate developers, computer scientists (who design GIS/3D spatial mapping and imaging programs), local policy makers, and architects. Selected photos from the fieldtrips are provided in Figure 8. Although these activities were some of the highlights of the course according to student reviews, they are not emphasized here, as these opportunities would necessarily be different if the course were offered in a different location, or at a different time.

Table 4. Field trips and guest speakers for the course.

Module	*Safety*	*Sustainability*	*Style*	*Society*
Field Trip	Visit to local Office of Emergency Management. The visit focused on recent flooding events in our community, and the OEM's response (Figure 8a).	Visit to a National Lab that is a LEED-certified green building, and where they conduct green building research (Figure 8b).	Visit to a local redevelopment project. This project has involved adaptive reuse of a historic building. The visit also focused on the challenges of development in a former industrial area (Figure 8c).	Local history walking tour (Figure 8d). The tour focused on the urban growth of the city, and architectural developments.
Guest Speakers/ Topic	Instructor in environmental engineering, "Effect of flooding on indoor and outdoor air quality."	County sustainability examiner, "Sustainability Initiatives in our County"	Instructor of architecture, "The architect and building form" Local computer scientist, "Introduction to *SketchUp*"	Professor of architecture, "the Bungalow and the History of the Evolution of Building Form" Director of communi-cations, local Habitat for Humanity affiliate
Class Discussion/ Activities	• What is your favorite building? • Why are communities and buildings vulnerable to natural hazards? • How can this vulnerability be reduced? • Drew maps of vulnerability of the US to different kinds of hazards (Figure 9) • Ranked risks of different activities and compared to actual risk	• What is the meaning of sustainability? How does sustainability apply to building design? • Brainstormed life-cycle environmental and other impacts of building new manmade islands off the coast of Brazil (Figure 10)	• Artistic, cinematographic, literary and musical representations of buildings • What is architecture? • What makes buildings aesthetically pleasing? • What are the important architectural theories impacting building design?	• Case study of the Citycorp center: its design and redesign (supported by a Slate podcast)

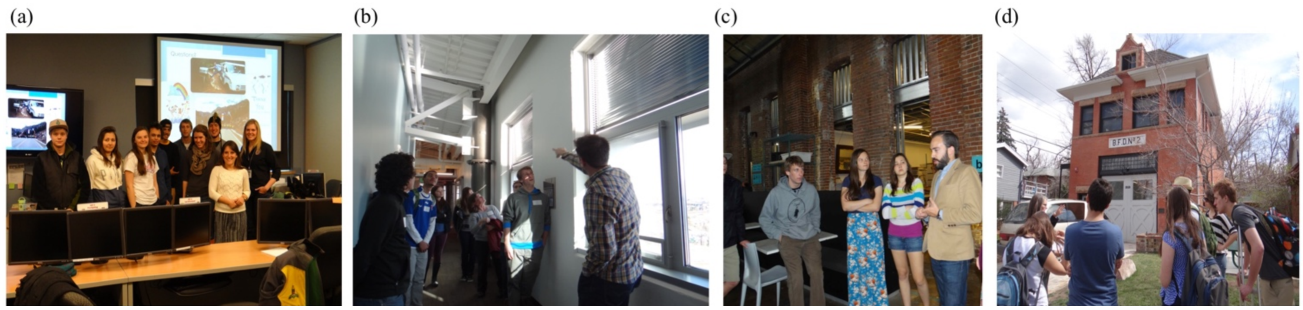


Figure 8. Photos from class field trips at: (a) Office of Emergency Management, (b) national lab, (c) local redevelopment project, and (d) local history walking tour.

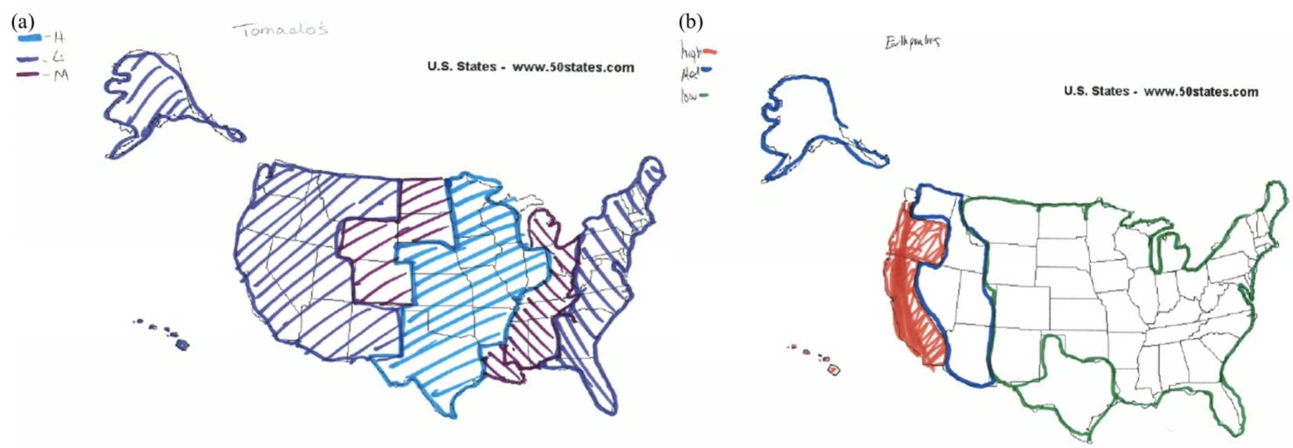


Figure 9. Student-drawn maps of risk due to (a) tornadoes and (b) earthquakes in the U.S. We then compared these to maps of risk developed by professionals and discussed perceptions of risk.

The final row of Table 4 also provides examples of some of the in-class activities and discussions that formed part of the class time. These activities were intended to force students to think critically about the material being presented, test their intuitions about risk and energy efficiency, and foster understanding of some of the challenging aspects of building and urban design.

Term Project

The class culminated with a term project. This project related to a new branch library to be built in our city. Students were asked to work in groups of 2 or 3 to develop a conceptual design for the branch library, at the site already chosen by the City.

The conceptual design submission integrated the material from the four course modules. These submissions included a community needs statement (Why do we need a new library? Who are the users? etc.), a site plan, a depiction of the exterior of the building, a sustainability plan, a floor plan and a structural plan. Students were not asked to design any elements for the structural plan, but to do enough calculations to demonstrate that the design was feasible through estimation of loads and rough checks of member sizes. The primary deliverable was a 20 to 25-minute presentation by each group. Students' physical submission included the presentation slides and supporting documentation, as well as a two-page letter to the client describing how the proposed design satisfies the goals of safety, sustainability, style and society. Examples of the approach taken by the three teams are provided in **Error! Reference source not found.**.

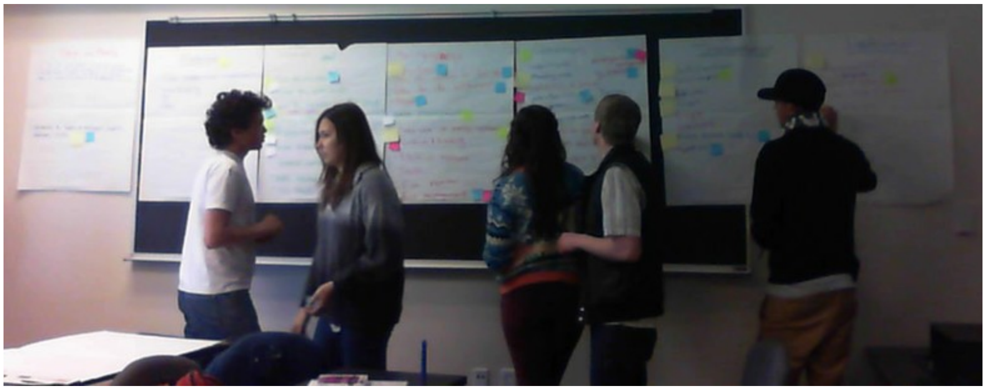


Figure 10. Students brainstorming life-cycle impacts of manmade habitable islands off the coast of Brazil.

(a)
(c)
(b)

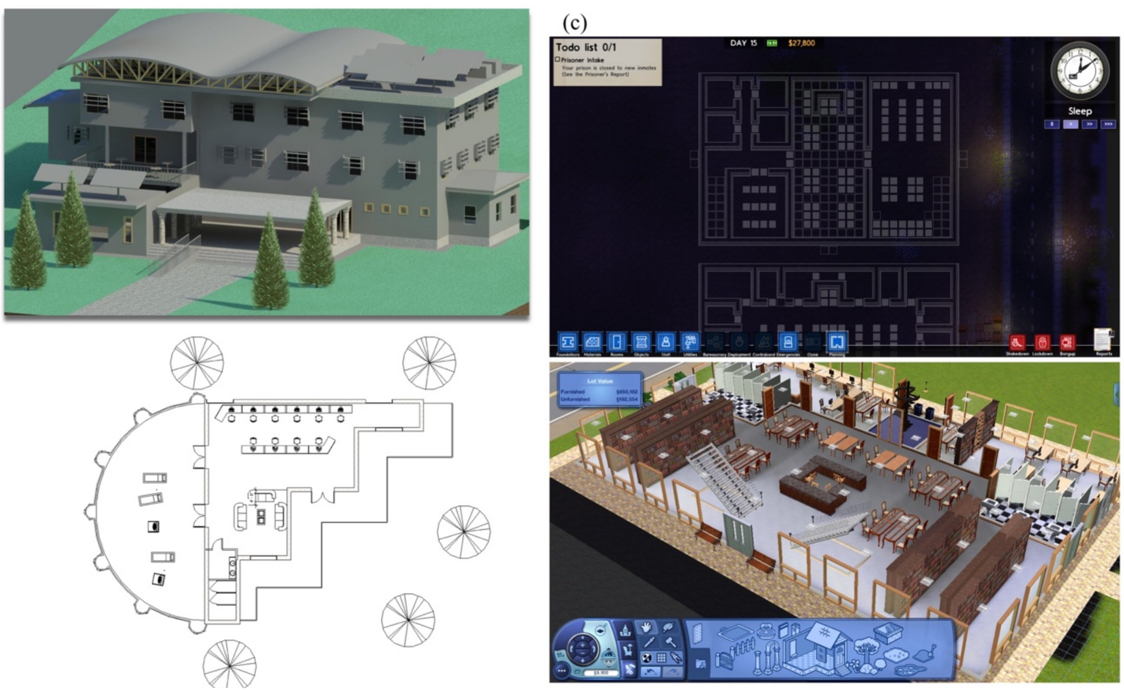


Figure 11. Illustrations of student library designs showing (a) 3D rendering from group A, (b) floor plan submitted by group B, and (c) screenshots from a video walkthrough created by group C. Group C repurposed the videogame Sims to image and imagine spaces for the assignment.

Assessment of Curricular Design

In order to assess the content of the course, and the effectiveness of the course design and course material for achieving the learning objectives, we utilize results of university-administered course questionnaires, student responses from a pre and post-survey of perceptions about building performance and examples from student work, focusing especially on the work presented in the culminating term project.

University-Administered Student Survey Results

Results from university questionnaires administered at the end of the semester are summarized in Table 5. These ratings show that students gave the course high ratings in the most general categories (course overall and instructor overall), both in absolute terms and relative to other courses in the civil engineering department and the college of engineering. Students also reported high levels of improved understanding of the profession they plan to enter, preparation for their chosen career and that they learned a lot, although they rated the intellectual challenge of the course as about average. Only two of the students elected to provide written feedback to the instructor on these forms. These written comments were:

1) This was a really great class, really interesting and hands-on, it was a nice change in pace from other classes and I still feel like I learned a lot.
2) Prof was great. Really interesting and fun class.

Table 5. Summary of student responses to university-administered course evaluations.

Item	*Rating (out of 6.0)*	*Percentile in comparison to department / college of engineering*
Course overall	5.7	99 / 95
Instructor overall	5.9	90 /94
Instructor effectiveness at encouraging interest	5.7	99 / 99
Intellectual challenge of the course	4.4	50 / 37
How much you learned in course	5.6	90 / 95
This class improved my understanding of the profession I plan to enter	5.7	N/A*
My confidence to succeed as a student was enhanced	5.2	N/A
This course prepared me for my chosen career	5.0	N/A

*These questions are not considered in the statistics, because they are only asked on some course surveys at our university.

Student Work and Grades

These university-administered course questionnaires, however, do not directly examine student progress toward the course learning objectives described above. To investigate how well student achieved various learning objectives, the term project grades for the three groups are reported in Table 6. These grades are provided for the overall project, including presentation and submission. For the purpose of this assessment, the work is also scored separately by the project content related to each of the four major modules. The overall term project grades indicate that the students achieved good progress toward the overarching and integrative course goals of understanding challenges to building "better" (CO 1) and creating a conceptual design for a building (CO 7). (See Table 1 for numbering of course objectives.) However, there was some variation in project performance related to the different modules. Most groups indicated strong performance in their quantitative and qualitative thinking about *Sustainability*, as exhibited by their final project. This module was the focus of three of the learning objectives. In the *Safety* aspects of the project, two of the groups did very well, and the other one did fairly poorly, indicating especially a struggle with Course Objective 4 (apply simple methods of structural analysis). The term projects showed middling performance on the *Style* and *Society* modules, but these modules were less heavily weighted in the course objectives.

The average student earned a B in the class. A complete breakdown of the grades, by type of assignment is given in Figure 12. These results show that grades on writing and problem sets were lower than grades on other assignments, but the grade variation between students is significantly greater than the variation between types of assignments. In particular, some students did poorly on the problem sets (which relates especially to the most quantitative Course Objectives 4, 5 and 6); in fact, one student neglected to turn in either of the problem sets in complete form. However, some of these same students did well on the labs, some which were also quantitatively oriented. Some students also struggled with the writing assignments, which were oriented especially toward course objectives 1-3. There are insufficient data based on these seven students to further disaggregate the results by gender or other characteristics of the students.

Table 6. Authors' ratings of different aspects of term projects from the three groups (+++ = Excellent to + = Poor).

Group	*Overall Grade (CO 1,7)*	*Safety (CO 2, 4)*	*Sustainability (CO 2, 5, 6)*	*Style (CO 3)*	*Society (CO 3)*
A	85	+	+++	++	+
B	94	+++	++	++	++
C	96	+++	+++	++	+++

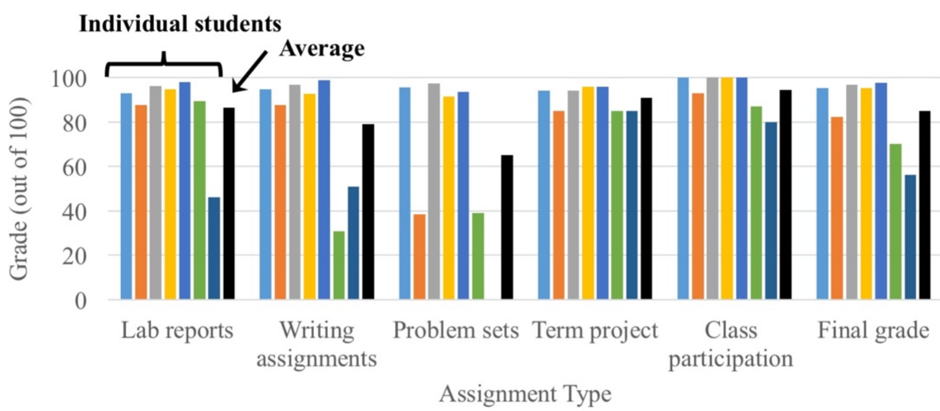


Figure 12. Students' grades in the class, separated by types of assignments.

Survey: How do students perceive buildings and building investment decisions?

To examine how student perceptions of different aspects of building design and performance had changed over the course of the semester, students were asked to participate in a Building Preference survey designed for this purpose. The survey consists of three questions. Each relates to the purchase of a building, but the buyer and the situation differs. In the first (Q1) case, the survey taker is asked to suppose that they are buying a home. In the second (Q2), they are asked to imagine they are advising their parents about the purchase of a building they will use for their small business. The third question (Q3) reads, "Suppose you are advising your boss about the purchase of a new manufacturing facility. Since you work for a major company, you know this purchase will be covered in the local news media." For each of these three scenarios, the students are given eight bins with different building features that relate to the concepts explored in the course, as illustrated in Figure 13. The survey taker is then asked to distribute ten gold coins among the bins to mark which qualities are judged to be most important in the context of the scenario given. Multiple coins can be placed in each bin, but no fractional coins are allowed, and the coins allocated must sum to ten. The same survey (same scenarios) was administered at the start and end of the course. Although there is no right or wrong answer, the survey is designed to help us understand what students think is important for building design and investment decisions.

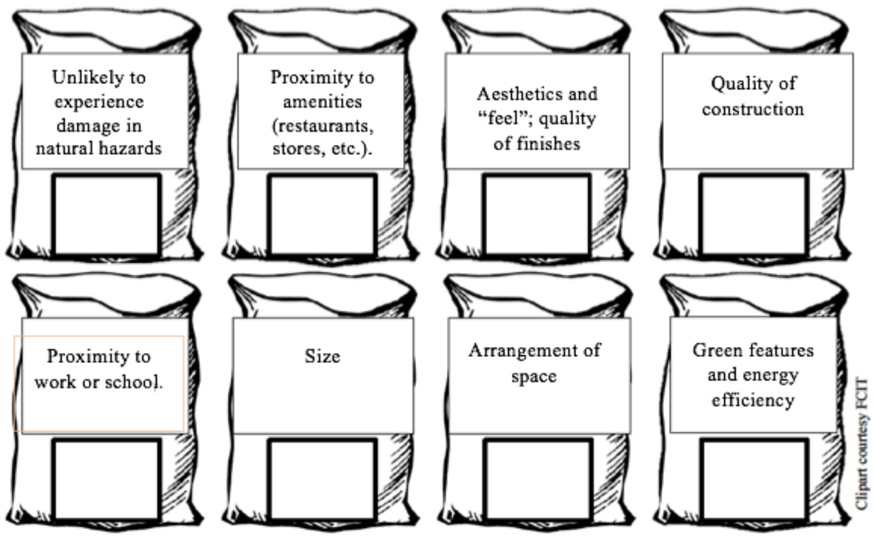


Figure 13. In the building preference survey, students were asked to allocate gold coins to each of these bins based on their preferences for the scenario given.

Figure 14 plots the average student response to the three questions. Although individual answers changed, there are not significant differences in the response between the start and end of the semester on average, especially when examining the second and third scenarios. The most notable shift was with the first and second scenarios, for which the post-survey showed that students placed more value on avoiding damage from hazards and disasters than they had previously. This result is interesting because this module is also where the problem sets and the labs caused the most difficulty They also increased the coins allocated toward quality of construction, proximity to work and school, size and arrangement of space, with a slight decrease in the preference for green features. These results appear to indicate a change in thinking during the course about disaster impacts, and other features of a building, particularly spatial arrangements (both within the building and of the building within the community), as it pertains to a home (Q1). However, the students did not seem to apply this thinking to the other two scenarios (Q2 and Q3). In addition, the reason for the decrease in coins allocated toward green building is not clear, but may relate to the fact that most students had a strong interest in sustainability and green technologies entering the course, so this is something they were already thinking about. The results for Q3 also seem to indicate that the students perceive different and narrower priorities for a manufacturing facility rather than a home or a small business. These perceptions did not change significantly over the course of the semester.

More work is needed to validate this survey as a tool for understanding how students perceive different aspects of building performance. The course enrollment was small (n = 7), making it difficult to identify statistically significant trends. In addition, the order of the course material (with modules going from *Safety* to *Sustainability* to *Style* to *Society*) may have influenced the post-course results, which seemed to emphasize issues related to the *Style* and *Society* modules.

In the future, we plan to link the second or third scenarios more closely to examples the students are familiar with from field trips, guest speakers, etc. to explore how those experiences impact these perceptions. In its current form, Q2 and Q3 seem to have been more abstract and removed from their everyday life for students early in their college career, so future revisions will explore other scenarios about building design/maintenance/management with more relevance to these students.

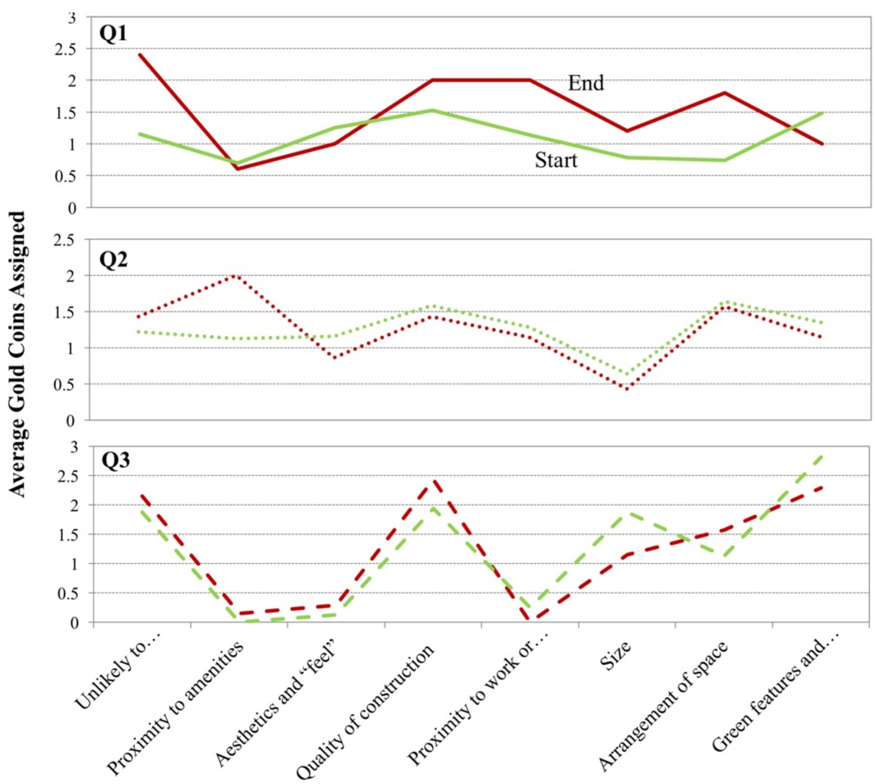


Figure 14. Student responses to building preferences survey for the given scenarios, at the start and end of the semester. (The completion captions for the items on the x-axis are provided in Figure 13).

Conclusions

This course aims to provide students with an interdisciplinary and integrated perspective of four key features of building design: *Safety*, *Sustainability*, *Style*, and *Society*. This course introduces students to the idea that engineering design of buildings, and the organization of communities, and cities is highly integrated with and constrained by societal and environmental influences. The classwork and assignments asked students to analyze buildings both qualitatively and quantitatively. This paper summarizes the curriculum and assignments developed for the course. In addition to providing a template for an interdisciplinary class, the concepts in this course could be integrated into upper-level engineering courses to encourage students to interrogate the environmental, economic, social, and political implications of engineering decision-making in design.

Course evaluations, student surveys and student work were used to evaluate the materials and course organization. Students self-reported high levels of learning and gave the course high scores in university-administered course evaluations. The term project and survey also showed development in thinking, particularly about the natural hazards portion of the course. By the end of the semester, students also demonstrated a holistic approach to building design. However, the assessment is limited by the small class size, as the results from the small sample of students did not produce statistically significant trends, and the lack of academic diversity among the students. In addition, the small class size meant that individual students' motivation and enthusiasm (or lack thereof) influenced the entire class.

In the future, we would consider re-arranging the order of the course to see how student learning changed if the course of the modules was different, such as separating the *Style* and *Society* modules, *i.e. Style, Safety, Sustainability,* and *Society.* Furthermore, we plan to refine and enhance measurements of student learning over the course of the semester through the building preference survey and other tools. In the next offering we hope to recruit a larger number of students, and students from different disciplines, to investigate the influence of student gender, background and interests on their experience in the course.

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