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BOARD # 53: Pedagogical Bridges: Evaluation of Structural Education and Syllabi for Engineers and Architects Over Time

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ABSTRACT

Classes that teach building structures in engineering and architecture are often separated into distinct curriculum; however, the rules that govern structural behavior remain the same. While there are advantages to developing courses that meet the learning outcomes of specific disciplines, engineers and architects work together towards the same final product: a building. Understanding how their education in structures topics differs by profession and over time may be useful in improving their learning outcomes and shared understanding. In this research, we examine syllabi from engineering structures and architecture structures classes across five decades from five Universities in the United States. We identify and compare themes in the syllabi that highlight divergences by discipline and similarities in education. Curriculum models for integration of engineering and architecture education are suggested.

INTRODUCTION

While the nature of structural behavior has not changed in the last century, the way structural concepts are taught to designers is often reassessed by new instructors and accommodated for different disciplines. Not only do new textbooks emerge every few years, but syllabi are revamped, responding to a variety of new institutional and disciplinary criteria. While engineering students are expected to perform detailed, theoretical calculations for professional licensure exams, they may not always understand the application of the theory they learn in class. In contrast, structural design is only a small part of the knowledge demanded of architecture students but is nevertheless imperative for effective building design. In addition, the pre-requirements for many engineering and architecture classes have changed over time and vary between programs and universities. Although engineers and architects are expected to collaborate in future practice, their team efforts are often associated with conflict due to their diverging disciplinary goals [1]. Understanding how these disciplines were prepared to navigate structural concepts historically compared to current trends in their education may support better instruction in the future.

In this paper, we evaluate developments in structural education for engineering and architecture programs, looking at syllabi from the last 40 years at different Universities. We explore differences in the material included in structures focused classes for both engineers and architects and discuss the potential implications of these separate trainings on their careers and collaborations in the respective professions over time. While we acknowledge the reasons for separating engineering and architecture education, we speculate on ways to integrate aspects of building structures education. By being critical of past pedagogies, we can make informed changes in future teaching endeavors

CONTEXT

In our analysis, we consider the contexts of syllabi in coursework and briefly summarize how engineering and architecture professions split into their own disciplines. The history of these two topics is vast, but we focus on aspects that explain why curriculum differences exist.

What is a syllabus?

The course syllabus has evolved substantially since its early use in the late 1800s as an outline of lectures or course dates. The modern syllabus serves as a contract between the instructor and students, and contains expectations and responsibilities of both parties. It contains information specifically relevant to the course, such as learning objectives, program accreditation criterion, grading policies, assignments, exams, and procedures and policies regarding how incidences such as missed classes or exams will be handled [2]. It also contains standard information and resources from the University, such as policies for academic dishonesty, accommodations, mandatory reporting, and most recently guidance towards managing health and safety in the classroom due to COVID-19.

The split of engineering and architecture professions

While syllabi have been evolving within academia, the professions have entered the university through their own paths. Prior to the industrial revolution, building design roles were not differentiated by discipline. With advancements in material and technologies, expertise in specific design areas became necessary and responsibilities were distributed over time into the familiar disciplines defined today [1]. At the same time, universities began standardizing expectations for coursework and processes for earning degrees. As a result, the United States' system of higher education has face significant shifts in the last century. The Second Industrial Revolution (1870 – 1914) influenced engineering programs by transitioning from agricultural and small shop work to a stronger emphasis on specialized, discipline-focused training to meet the needs of a transforming society and workforce [3]. Events of the mid-1900s such as World War II and the Cold War that highlighted the importance of technology led to a larger surge in engineering and science education. The STEM (Science, Technology, Engineering, and Math) acronym was introduced by the NSF in 2001 to emphasize the need for more professionals in these fields [4]. Meanwhile, architecture took on its own narrative in schools of design, such as the Bauhaus in Europe, which set a model for apprentice-based, theory-heavy schools in the US, such as Frank Lloyd Wright's Taliesin. Designing a building was not just a technical skill, but an ideology on how people should live. Over time, the discipline of architecture found its own pedological goals separate from engineering within the 4-year university model. However, recent efforts have been made to re-synthesize disciplines in art and science by the 2018 Carl D. Perkins Career and Technical Education (CTE) Act in which the United States government legally recognized architecture as a STEM profession. A primary benefit of this Act is an increase in federal funding opportunities that architecture education can pursue [5].

Creating professional standards through accreditation

Moreover, in recognizing a need for professional recognition, the disciplines have defined their own expectations for education through program accreditation. Accreditation has become a driving force in university curriculum over time and is both similar and different for architect and engineering disciplines. For engineering programs, the Engineers' Council for Professional Development, originally founded in 1932, evolved to the Accreditation Board for Engineering and Technology (ABET) in 1980 [6]. However, they shortened their name to just ABET in 2005 to more accurately reflect their expanded scope, which included more fields in STEM. In 1997, they adopted Engineering Criteria 2000, which shifted evaluation from a "what is taught" mentality to a "learning outcomes" mentality through an outcome-based assessment. In addition, evaluation of programs is done by ABET Experts, including leaders from industry, academia, and government professionals, who visit campuses and review program materials.

Although it has its own separate accrediting body and disciplinary goals, the process for accreditation of programs in architecture follows a similar approach to evaluation. The National Architecture Accreditation Board (NAAB) oversees accreditation for Architecture programs in the US. Licensing architects was first introduced at the end of 19th century and an attempt to establish national standards in architecture education was made through the Association of Collegiate Schools of Architecture (ACSA) in 1912 [7]. After adopting and abandoning the use of standard minima, the NAAB was established in 1940. The most recent change to NAAB was in 2020 at new conditions for accreditation, emphasizing outcome-based assessment. Both engineering and architecture accreditation agencies have shifted to an outcome-based assessment, and they use a field of educators and practitioners to evaluate programs for their efficacy in their disciplines.

From briefly reviewing the histories and evolutions of engineering and architecture programs, it is evident that the relationship between the disciplines is regularly evolving. Advancements in technology, changes in the needs of society, and developments in the standards of the professions prompt revision of disciplinary education, thus making it important to assess the overlap of topics in their education.

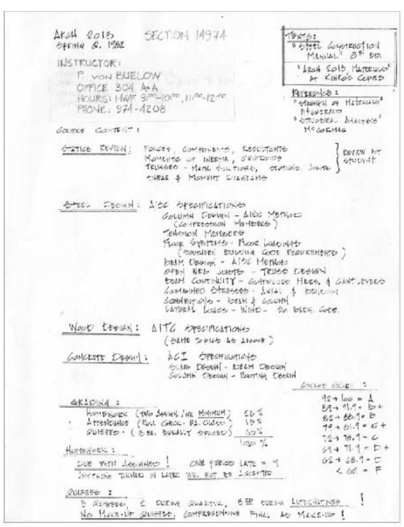
METHODS AND RESULTS

For this pedagogical investigation into structures-based curriculum, we considered differences and similarities between disciplinary programs and changes in the syllabi over time. We examined the instructor syllabi from both engineering and architecture structures classes from different Universities in the United States. For this research 14 syllabi were reviewed from 6 universities across 5 decades from 7 engineering and 7 architecture structures courses. The syllabi were grouped and evaluated by discipline, not sub topic material (for example structural analysis or statics in engineering) as we are interested in surveying their approaches as disciplines, rather than specific courses. As a research team, we examined the syllabi for their content, depth of detail, and tactile characteristics. The syllabi, as artifacts, provide brief insight to how structures education has evolved over time. Table 1 provides an overview of the syllabi reviewed.

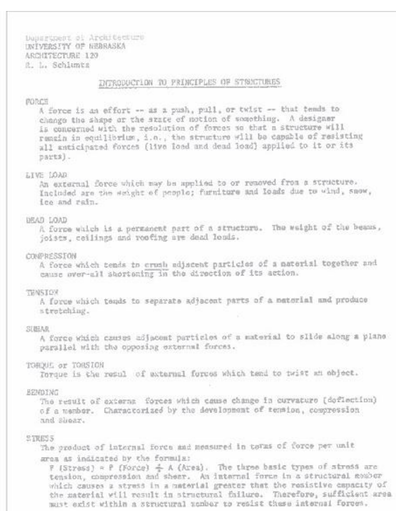
Table 1. *Summary of the syllabi reviewed, outlining their discipline, title, year, and institution.*

	ENGINEERING	ARCHITECTURE
Institution 1 *University of New Mexico*	Structural Analysis, 2010 Engineering Statics, 2022 Structural Analysis, 2023 Reinforced Concrete Design, 2024	Architecture Structures I, 2023
Institution 2 *University of Michigan*		Structures in Wood and Steel, 1983 Architecture Structures I, 1982 Architecture Structures II, 2023
Institution 3 *Nebraska*		Introduction to Principals of Structures, 1970's
Institution 4 *Texas Tech*	Statics, 2010 Structural Analysis, 2011	Building Technology II, 2020
Institution 5 *U of Tennessee*		Structural Design II, 1982
Institution 6 *Colorado School of Mines*	Advanced Structural Analysis, 2014	

There is also a difference in the use of documentation tools used to generate the syllabi over time as reflected in the medium of the syllabi. The earlier syllabi were written by hand and produced on typewriter while recent syllabi were typed on computers and were rarely printed out for distribution. Figure 1 shows a sample of 3 syllabi.



Handwritten
1982
for architects



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INTRODUCTION TO PRINCIPLES OF STRUCTURES

FORCE
A force is an effort -- as a push, pull, or twist -- that tends to change the shape or the state of motion of something. A designer is concerned with the resolution of forces so that a structure will remain in equilibrium, i.e., the structure will be capable of resisting all anticipated forces (live load and dead load) applied to it or its parts).

LIVE LOAD
An external force which may be applied to or removed from a structure. Included are the weight of people; furniture and loads due to wind, snow, ice and rain.

DEAD LOAD
A force which is a permanent part of a structure. The weight of the beams, joists, ceilings and roofing are dead loads.

COMPRESSION
A force which tends to crush adjacent particles of a material together and cause over-all shortening in the direction of its action.

TENSION
A force which tends to separate adjacent parts of a material and produce stretching.

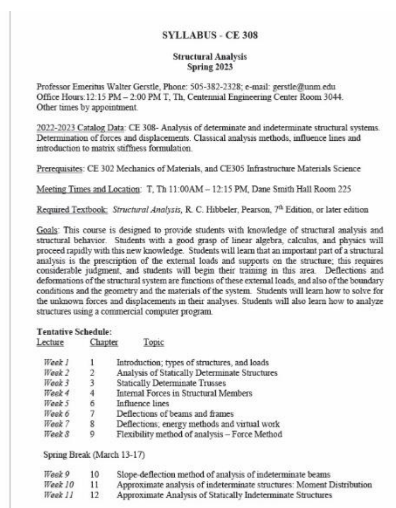
SHEAR
A force which causes adjacent particles of a material to slide along a plane parallel with the opposing external forces.

TORQUE or TORSION
Torque is the resul of external forces which tend to twist an object.

BENDING
The result of externa forces which cause change in curvature (deflection) of a member. Characterized by the development of tension, compression and shear.

STRESS
The product of internal force and measured in terms of force per unit area as indicated by the formula:
F (Stress) = P (Force) $\frac{.}{.}$ A (Area). The three basic types of stress are tension, compression and shear. An internal force in a structural member which causes a stress in a material greater that the resistive capacity of the material will result in structural failure. Therefore, sufficient area must exist within a structural member to resist these internal forces.

Typewriter
1970's
for architects



SYLLABUS - CE 308

Structural Analysis
Spring 2023

Professor Emeritus Walter Gerstle, Phone: 505-382-2328; e-mail: gerstle@unm.edu
Office Hours: 12:15 PM – 2:00 PM T, Th, Centennial Engineering Center Room 3044.
Other times by appointment.

2022-2023 Catalog Data: CE 308- Analysis of determinate and indeterminate structural systems. Determination of forces and displacements. Classical analysis methods, influence lines and introduction to matrix stiffness formulation.

Prerequisites: CE 302 Mechanics of Materials, and CE305 Infrastructure Materials Science

Meeting Times and Location: T, Th 11:00AM – 12:15 PM, Dane Smith Hall Room 225

Required Textbook: *Structural Analysis*, R. C. Hibbeler, Pearson, 7th Edition, or later edition

Goals: This course is designed to provide students with knowledge of structural analysis and structural behavior. Students with a good grasp of linear algebra, calculus, and physics will proceed rapidly with this new knowledge. Students will learn that an important part of a structural analysis is the prescription of the external loads and supports on the structure; this requires considerable judgment, and students will begin their training in this area. Deflections and deformations of the structural system are functions of these external loads, and also of the boundary conditions and the geometry and the materials of the system. Students will learn how to solve for the unknown forces and displacements in their analyses. Students will also learn how to analyze structures using a commercial computer program.

Tentative Schedule:

Lecture	Chapter	Topic
Week 1	1	Introduction; types of structures, and loads
Week 2	2	Analysis of Statically Determinate Structures
Week 3	3	Statically Determinate Trusses
Week 4	4	Internal Forces in Structural Members
Week 5	6	Influence lines
Week 6	7	Deflections of beams and frames
Week 7	8	Deflections; energy methods and virtual work
Week 8	9	Flexibility method of analysis – Force Method
Spring Break (March 13-17)		
Week 9	10	Slope-deflection method of analysis of indeterminate beams
Week 10	11	Approximate analysis of indeterminate structures: Moment Distribution
Week 11	12	Approximate Analysis of Statically Indeterminate Structures

Typed on computer
2023
for engineers

Figure 1. *Sample of 3 syllabi used in the assessment.*

Engineering and architecture curriculum have distinct disciplinary goals, requiring differences of instruction in their structural classes, however, some aspects of the structural courses, such as key concepts covered, are consistent regardless of profession. Table 2 shows a summary of the similarities and differences of characteristics from the syllabi. Themes from the syllabi were identified (including topics, depth, evaluation criteria, tools, and texts) and two dimensions of evaluation were considered: comparisons between the *disciplines* for each theme and changes over *time* in the syllabi that existed regardless of the profession.

Table 2. *Elements of structures focused classes organized by differences and similarities over time and by discipline*

THEMES		SIMILAR	DIFFERENT
content	discipline	---	✓ eng. more; arch. less
	time*	✓	---
evaluation criteria	discipline	✓ test, hw, etc.	---
	time	✓ test, hw, etc.	✓ "learning outcomes" not just topics
tools	discipline	---	✓ different rigor of struct. analysis tools
	time	---	✓ by-hand to digital
texts	discipline	---	✓ varies
	time	---	✓ no standard book

*in the table, "time" refers to changes over time

Content

Within the category of content, we identify the topics discussed and depth of their instruction. When teaching structural behavior to beginning design students, the basic ideas that support building mechanics have not changed over time. From a content analysis of topics mentioned on both the engineering and architecture syllabi across time, the terms "stress," "bending" (or "flexure"), and "beams" are used regularly used. In addition, the topics do not change by discipline, but the depth of each topic varies. Engineering curriculum has entire courses that focus on specifics of structural behavior, whereas architecture curriculum may address topics more broadly over 2-3 courses. It is generally assumed that the architecture classes use less math, but these conditions vary by instructor and program.

Evaluation Criteria

The forms of evaluation have not changed dramatically for either profession. Syllabi indicate a mixture of tests, homework, participation, and sometimes a project. However, stating the learning or performance objectives or outcomes in syllabi is evident in the last two decades. The older syllabi from before 2000 list the topics covered but are not phrased as active statements for what students should be able to do at the end of the semester. The active statements allow for clearer assessment of evaluation criteria, particularly in addressing accreditation criteria. One of the architecture syllabi lists the accreditation criteria being addressed in the class in order to meet accreditation requirements.

Tools

The evolution of tools and technologies has influenced the professions as both a means to solve complex problems and as information delivery methods. Structural analysis computer programs have provided simulation feedback for engineering that exceeds limitations of hand calculations. Digital tools such as SAP2000 and RISA2D were sometimes mentioned in the syllabi, however, they do not explain structural behavior and are not indicated as the primary teaching tools in the engineering structures courses. Similarly, the architecture structures class have their own structural analysis tool for their computer interface and they are sometimes mentioned in syllabi, but are not primary teaching tools. Karamba3D [8] is a structural analysis plug-in to Grasshopper, a parametric coding tool in the 3D modeling program Rhinoceros. Learning how to use tools in addition to learning the content of the class often exceeds the learning objectives listed on a syllabi.

There is also a difference in the use of documentation tools used to generate the syllabi over time as reflected in the medium of the syllabi. The earlier syllabi were written by hand and produced on typewriter while recent syllabi were typed on computers and were rarely printed out for distribution.

Texts

No class has used the same text as a required or suggested textbook. In the syllabi, they are often just listed as required or suggested with either no or limited information about expected reading assignments. Historically, textbooks were the primary resource for information outside of class lectures. Today, however, a multitude of online resources can also supplement course lectures. Future research can explore what influences the selection of a textbook and how they are utilized in teaching.

DISCUSSION

After reviewing the similarities and differences of syllabi characteristics from structures courses in engineering and architecture over time, we identify three themes that support their continued independence while also proposing opportunities for more integration.

- **The current common standard in structures education is to teach the material to engineers and architectures separately, which allows the same concepts to be discussed with varying depth to support disciplinary differences.** However, this method also reinforces traditional mindsets about the two fields that perpetuate into professional careers. We acknowledge that there are grounding reasons for why the two programs are taught separately as their design expertise varies. External influences from the education system in both disciplines (e.g., accreditation, credit hours) create unexpected challenges arbitrary to the topic material. While differentiating the disciplines’ structures classes has its advantages, there are potential deficiencies in collaborative understanding that become more apparent outside of the education system in professional settings.

- If the disciplines more consistently blended engineering and architecture education, at least in structures focused classes, **the disciplines may benefit from sharing their pedagogical diversities**. For example, architects commonly utilize precedent (the use of existing projects as items of study) in teaching [9], [10] which links design ideas to applications. Engineering education requires thorough coursework but often emphasizes theory absent application in real world example. As a corollary, architecture education generally de-emphasizes rigorously structured problem solving, such as stating given variables, required findings, and explicitly correct solutions. While there is evidence that open ended problem solving is valuable [11], when teaching basic structural behavior, establishing a strong understanding of the theory is necessary to develop the design. A class that blended the advantages of both disciplines may include multiple precedent examples to illustrate structural behavior and emphasize the application and value of all concepts introduced. By sowing the seeds in their education, there is the potential to establish an appreciation for each other's design complexity.

- **Allowing for options in blending the classes may be a way to overcome deficiencies when differentiating the disciplines.** We suggest a variety of types of programming that may facilitate cross-disciplinary integration of engineering and architecture across the university. We discuss these solutions as possibilities between two extremes: one of full administration integration in which the two disciplines are so blended that a third program emerges, and the other in which expertise in either discipline excludes consideration of the other. At this time, the authors do not think either extreme exist in the United States. Our list of solutions is not exhaustive but serves as a starting point for consideration.
    - *Combined departments:* Many universities have several sub-disciplines of building design housed in a single college (e.g., civil engineering with architectural engineering, architecture with construction management). One example includes Cal Poly's College of Architecture and Environmental Design which houses departments in both architecture and architectural engineering, allowing for the more fluid blending of students in structures-based classes [12]. This model for combining students in structures classes is close to ideal, however the departments are still distinct with different mission statements. We propose a department that produces students with aptitudes in both architecture and engineering that fully combines their education, not differentiating learning goals by discipline. Understanding the impact of such a program would require intensive study and broader changes to curriculum, accreditation requirements, and practitioner outcomes. We acknowledge the immensity of these limitations and consider more alternatives.
    - *Outsourcing Instruction:* Architecture students can be sent across campus to take lecture classes in an engineering department (or an instructor from engineering may come to architecture). This solution has been used historically as Mario Salvadori criticizes it in his 1958 lecture describing "the engineer who is a teacher of engineering very condescendingly accepts the horrible job of walking across

the campus, of entering the School of Architecture and of teaching Architects." and continues to suggest that this solution is not a favorable one [13]. While outsourcing instruction may reduce curriculum complexity and is one of the easiest to implement administratively, it still caters to the home discipline of the instructor, potentially limiting education of the architect.

- *Integrated Design Class:* Offering an integrated design class in which students from several disciplines work on a building design project over the semester prompts cross disciplinary collaboration. There has been discussion of interdisciplinary design thinking in architectural education, with many case studies suggesting the benefits and barriers in mixed design teams [13]. Primarily, the blending of diverse perspectives. Scaffolding shared disciplinary communication and design goals, from students and faculty, requires effort that must come first before working on the problem. One semester may not be enough time to achieve all of these objectives.
- *Instructor workshop:* Cross-campus discussion between educators of both engineering and architecture courses to discuss similarities and differences in curriculum and determine some alignment and shared goals. The American Institute for Steel Construction offers workshops for educators in architecture that teach structural steel [14] and workshops for engineers that teach structural systems [15]. While these workshops are valuable for the instructors and allow for overlap of ideas, the audience is still separated and we imagine a workshop that intends to overcome disciplinary barriers.
- *Cooperative experiences, student design organizations, and fellowships:* Design-oriented out-of-classroom experiences enable integration of students from different disciplinary areas to work on a shared design challenge, with mentors from different departments (e.g., NASA Minds Challenge).

Limitations

Although the authors attempted to acquire syllabi from a variety of teaching sources, this assessment is limited by the content found in selected syllabi. Review of additional syllabi may provide additional insight, In addition, this paper does not explore the efficacy of the classes on student learning outcomes, such as passing rate, rate of licensure, or job efficacy once in the profession. It also does not account for student or faculty perspective on syllabi. However, this work identified several topics for deeper investigation and serves as a starting point for exploring additional themes in structures education and syllabi development. Future work can expand on these ideas by seeking perspectives from students and faculty on the syllabi, whether the content knowledge is useful within professional work, and the effectiveness of a proposed hybrid course, department or degree.

CONCLUSION

This paper reports on syllabi from instructors of structural engineering and design from both civil engineering and architecture courses. We find that while the two fields share similarities in terms of the topics taught (e.g., stress, bending, beams), differences emerge in terms of the depth of instruction, the learning outcomes, tools and textbooks utilized. These differences may have grown over time due to the differing curriculum pathways, requirements for accreditation and professional licensure, and definitions of the roles of engineers and architects. We remark that while these differences have a positive role in aiding students within their discipline to learn and master a topic as needed, they lead to a divergence when both reach professional career states where they must learn to work with one another and communicate. A future education system which integrates designers and engineers within courses and programs may produce a workplace where shared language around structures can be built.

REFERENCES

[1] A. Saint, *Architect and engineer: a study in sibling rivalry*. London: Yale university press, 2007.

[2] J. Parkes and M. B. Harris, “The purposes of a syllabus,” *College teaching*, vol. 50, no. 2, pp. 55–61.

[3] American Society for Engineering Education and National Academy of Engineering, “The Engineering Mindset Report,” 2024. [Online]. Available: https://mindset.asee.org

[4] J. Hallinen, “STEM,” Britannica. Accessed: Jan. 15, 2025. [Online]. Available: https://www.britannica.com/topic/STEM-education

[5] N. P. Walsh, “Architecture becomes a STEM Subject in the United States,” ArchDaily. Accessed: Jan. 15, 2025. [Online]. Available: https://www.archdaily.com/908830/architecture-becomes-a-stem-subject-in-the-united-states

[6] ABET, “About ABET: At a Glance.” Accessed: Jan. 15, 2025. [Online]. Available: https://www.abet.org/about-abet/at-a-glance/

[7] NAAB, “NAAB: Our History.” Accessed: Jan. 15, 2025. [Online]. Available: https://www.naab.org/who-we-are/our-history

[8] C. Preisinger, “Linking Structure and Parametric Geometry,” *Architectural Design*, vol. 83, no. 2, pp. 110–113, Mar. 2013, doi: 10.1002/ad.1564.

[9] Ö. Akin, “Precedent-Based Learning: An Approach for Studio Pedagogy in the Early Years,” in *Practice of Teaching | Teaching of Practice: The Teacher’s Hunch*, ACSA Press, 2019, pp. 2–6. doi: 10.35483/ACSA.Teach.2019.1.

[10] H. Anay, “Creative use of Architectural Precedents in Design Education: A Framework for a Computational Model,” presented at the eCAADe 2006: Communicating Space(s), Volos, Greece, 2006, pp. 526–531. doi: 10.52842/conf.ecaade.2006.526.

[11] E. P. Douglas, M. Koro-Ljungberg, N. J. McNeill, Z. T. Malcolm, and D. J. Therriault, “Moving beyond formulas and fixations: solving open-ended engineering problems,” *European Journal of Engineering Education*, vol. 37, no. 6, pp. 627–651, Dec. 2012, doi: 10.1080/03043797.2012.738358.

[12] California Polytechnic State University, San Luis Obispo, “Cal Poly Colege of Architecture & Environmental Design.” Accessed: Feb. 20, 2025. [Online]. Available: https://caed.calpoly.edu/

[13] M. Salvadori, “Teaching Structures to Architects,” *Journal of Architectural Education*, vol. 13, no. 1, pp. 5–8, Mar. 1958, doi: 10.1080/10464883.1958.11102384.

[14] American Institute of Steel Construction, “Architecture Educator Workshop: Integration of Architecture and Structural Steel.” Accessed: Feb. 20, 2025. [Online]. Available: https://www.aisc.org/education/university-programs/architecture-educator-workshop/

[15] American Institute of Steel Construction, “Engineering Educator Workshop: Teaching Steel Design: Fundamentals of Behavior in a System Context.” Accessed: Feb. 20, 2025. [Online]. Available: https://www.aisc.org/education/university-programs/engineering-educator-workshop/