



Engineers Are Square, Architects Are Spiral

Kate Simonen, RA, SE

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In the course of teaching structural design in the architecture program at California College of the Arts, I had a student who, despite her creativity and intelligence, was struggling with the analytical component of the class. One assignment she turned in looked at first like a jumbled mess of numbers, but I then realized that she had found the correct solution. Instead of laying out her work in an engineering-logic, linear fashion, she had worked the problem out in a series of short steps that spiraled toward the very center of the page, where she found the answer. Her solution was a physical manifestation of how her mind worked. People solve problems differently, I concluded, and we have to teach to many modes of learning.

Engineers may be square, but architects are spiral. They think differently, and as most complex structures are the result of their collaboration, their differences are a potential obstacle to structural creativity and innovation. I believe that these differences are fundamentally reinforced through pedagogy, so if we want to overcome them, we will have to change how we teach structural design to both professions.

The education of architects is quite different from that of engineers. Engineering education is structured linearly, providing students with increasing levels of knowledge and skill and waiting until all of it is obtained before asking students to “design.” Moreover, structural design problems are typically limited to the sizing of select elements or structural sections. Ambiguity and uncertainty are rarely encountered. Engineering students come to assume that the problems they will encounter in practice will have singular solutions—“right answers.”

Architectural education’s studio structure creates a much different learning environment. Students are asked to explore problems that are often ambiguous and uncertain, while learn-

ing the skills of their profession “on the job.” There are rarely “right answers” to their problems, only better or worse solutions. And in the midst of this, architecture students are often asked to take a condensed, watered down version of the engineers’ linear training in structural design.

Not surprisingly, these programs do not spark much interest in collaborative structural design in either profession. Both are introduced to the topic as a dry set of predetermined facts rather than an exciting means of understanding structural behavior. Structural design needs to be taught differently to each profession, but both should learn it as a real design discipline that reflects the realities of practice. Doing so is crucial, because the problem-solving methods learned affect the range of potential solutions that can be envisioned.

Analysis vs. design in engineering education

Although I received an excellent engineering education, we were not really taught structural design. Real structures only entered the curriculum after two years of structural engineering coursework. I was amazed to find that the beams I had analyzed had real life counterparts. With a master’s degree in structural engineering, I could analyze and size a predetermined beam or truss—and even a complex lateral system—but I couldn’t design them.

Looking back, I can recall only two of my teachers who were interested in teaching structural engineering as a design discipline. Professor Gerstle at Boulder and Professor Scordelis at Berkeley belonged to the post-war generation of engineers who learned structural design before the era of the computer. To simplify problems to a level where they could solve them, they had learned to visualize and

hypothesize structural behavior. So this is how they taught.

Both were captivated by the marvelous uncertainty of construction. When Professor Gerstle showed slides of Maillart’s bridges in construction, you could feel his excitement about the innovative potential of long spans. Through his lectures, I saw for the first time that as an engineer I would be directly involved in building these physical structures. Professor Scordelis described walking on top of a concrete shell, looking for cracks, and how he would find small cracks and make a note to add more reinforcing in those zones next time. It was a relief to realize that, even with complex analysis, there was still unknown behavior—and that intuition and experience were just as important to the realization of the project as analytical skill.

Analysis is important to engineering, and the more complex analysis that computers make possible creates many new opportunities for engineers. Yet, in capitalizing on them, engineering education has lost sight of design. The subject is presented through complex mathematical exercises, each with a correct answer. No one simplifies the problems anymore in order to think visually about them and hypothesize how a structure will behave—not when they can model the structure mathematically and make those predictions with exactitude. Consequently, students have forgotten about design and construction. They become experts in analysis, without fostering their creative imagination. They cannot design. Their architect peers, when exposed briefly to the same curriculum, lack the intuitive grasp of structural behavior that would extend their imagination in that direction and enable them to collaborate effectively in designing structures.

Bringing design back into the picture

Engineering education has largely abandoned visualization and approximation as methods of structural analysis. Graphic analysis of trusses or moment distribution, in which the final deflected shape is visualized, are examples of such methods, common before computer software for structural analysis came on the scene. They help students develop an intuitive understanding of structural behavior in a way that computer-based analysis does not. They need to be re-introduced, along with three-dimensional drawing. Without them, engineers have difficulty both imagining the complex interrelationships of a building and its structure and developing and presenting their ideas. More importantly, engineers need to appreciate that, as shapers of the physical world, they need to consider aesthetics and meaning just as much as strength and efficiency. Without this conceptual frame, they cannot engage in the dialogue necessary for creative collaboration.

The structural education of architects often leaves them feeling intimidated by knowing how little they know, and defensive about their ability to shape structure. The linear structures curriculum invariably means that they only master the most basic methods of structural analysis. Analytical skills *per se* are not so important for architects, however. They need to understand structural systems and concepts well enough to participate in their shaping.

To foster structural innovation, we need to begin the education of engineers and architects alike by developing their intuition and giving them problems they cannot solve without guesswork. This means abandoning linearity in favor of the “cyclical” teaching methods of the studio.

How structural design is taught at CCA

The structures class that I teach for architecture students at CCA focuses initially on understanding structural behavior on a conceptual level and then testing this understanding through the schematic design of complete structural systems. Using design charts (found in Allen and Iano, *Architects Studio Companion*, Wiley, 2002), students can estimate member sizes to a level accurate enough for schematic design. At the same time, they explore the possibilities for structure as an aesthetic generator and form giver. The goal is to bolster their confidence in their structural intuition and prod them to ask for more analytical tools—which they can use to test their hypotheses about a structure’s configuration.

In the second semester, we use analytical tools to understand structural behavior. I teach engineering analysis as a way of thinking as well as a design tool. My architecture students learn that predicting structural behavior requires precise analysis. Instead of giving them a condensed version of a typical linear engineering curriculum, I take them through a series of exercises that gives them an appreciation for engineering rigor and a better understanding of structural performance. I use graphic methods of analysis—a throwback to another era—because they provide a direct visual connection between the forces involved and their implications for form. (I use Zalewski and Allen, *Shaping Structures/Statics*, Wiley, 1998, for this purpose.) I am especially interested in having the students describe the results of their analysis clearly, so they come to see it as a tool that can help move the design forward.

There is a third focus—on the collaborative nature of building design. Education puts

great emphasis on individual performance, but designing a building—as an iterative and explorative process—depends on sustained teamwork. So, we not only create opportunities for collaboration, but also for mutual understanding. To be effective, students have to be confident they can put their ideas across and grasp the ideas of others. We ground our architecture students sufficiently in structural design so that its language and thought patterns are no longer foreign.

The real goal is to give architects the confidence to lead the design process, including the overall configuration of the building structure, effectively. They are able to discuss structural performance and possibilities and understand the relationship between force and form. They can understand the rigor and complexity of engineering computation and follow the results when engineers present them. There’s no feeling of inferiority or defensiveness because they can’t do that analysis on their own. Self-confidence and mutual understanding create the right framework for collaboration, freeing architects to ask the kinds of questions that spur innovation.

Things have to change for engineers, too

Structural engineering students also need to learn early in their education that it’s not all square. Like their architecture counterparts, they should be asked to solve problems they don’t yet know how to solve—forcing them to guess and estimate and to confront ambiguity. They need to be exposed early to the real world, where singular solutions are the exception. Start with large, open-ended problems, then cycle back to the complex math and mechanics of materials used to understand more advanced structural behavior. That way,

when they get back to those large, open-ended problems again, they can tackle them with all that acquired sophistication, just as in real life, but with creativity.

The issue of collaboration is equally true for engineers. Over-focused on math and science, they can be uncomfortable or intimidated by subjective discussions. The engineering curriculum needs to open enough that students can have a more liberal education. Studying architectural and structural history, learning to draw three-dimensionally, getting direct experience in building construction—these are steps that would help them understand the real world, the physical world, in which they will work.

Squares are good, and so are spirals. Buildings are created using both linear and circular problem solving. Innovation demands that we search for an unknown outcome. Linear thinking on its own is not enough. If the goal is structural creativity, then the teaching of architects and engineers has to change—developing intuition, not just specialized knowledge, encouraging exploration, and giving every student the confidence and desire to collaborate effectively. ●