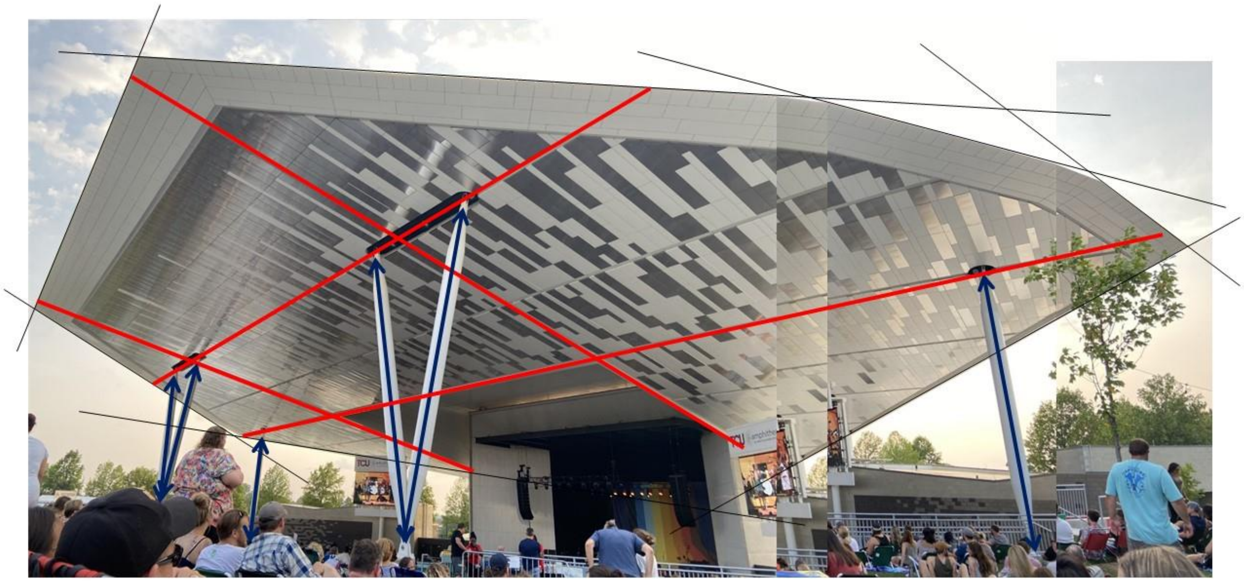


The TCU White River Amphitheater, Indianapolis, Indiana, Studio Axis, 2020.

Towards a Phenomenology of Teaching Architectural Building Structures

César A. Cruz, Ball State University

Teaching building structures in the context of an undergraduate architecture curriculum often privileges narrowly-focused, quantitative, engineering-based methods that relate to discrete building components (i.e., the analysis and sizing of individual structural elements such as a beam, column, or truss). In reference to this conference's theme, this is akin to the concrete being subsumed by the abstract, what is readily apparent by the unseen, *the blatant by the latent.* In these situations, the potential pitfall is for students and instructors to be so consumed with the calculations typically employed in these courses (for example, calculating a bending moment, moment of inertia, section modulus, centroid, or slenderness ratio, to name just a few) that they fail to also see building structures in more wholistic ways. This situation is what one student described as "I can do structures. I just don't understand structures." This should not happen in our courses. Instead, the goal in a structures class should be for students to become adept across a spectrum that encompasses technical details and calculations, as well as the logic that governs the overall system and its individual components.

This paper argues for a greater balance between the latent and the blatant. Furthermore, the way forward is to draw inspiration from phenomenological principles and methods. This paper discusses, first, an overall strategy that would help in reaching the proposed balance, including the major class activities that support this teaching program. Second, there is the theoretical foundation for this pedagogical approach. Third are student responses to these classes.

The method

The principal method employed in a balanced structures course focuses on contextualizing what students do (engineering calculations) with what they can see (examples of actual structures). Such contextualization occurs in a number of ways, but mainly through the reinforcement of overarching structural principles that students hear about, see, and engage with throughout the semester in key projects, homework assignments, and in-class problems.

The main set of principles of this method describes how a whole structural system comes together, and they consist of the following seven points:

1. Organizational strategy
2. Modularity and rhythm
3. Orientation
4. Alignment
5. Spacing
6. Shape, size, and hierarchy
7. Lateral stability

To clarify, these are the definitions that I employ with my students. The broadest perspective we may apply upon a structural system is its ***organizational strategy***, which is the geometric pattern (usually represented in a plan view) that guides the placement of line-forming, horizontal spanning systems (such as beams and trusses), and the key connecting points between structural components of different orientations (for example, beam to girder, or beam to column).[1,2] Second, structures typically employ ***modularity and rhythm***, which is to say the use of a repeated structural unit, such as a column bay or structural bay, that when employed in a repeated manner throughout a building can simplify structural planning and even go so far as to impart a certain aesthetic upon the building. Third, ***orientation*** refers to both the general direction that a structural element takes (typically, horizontal vs vertical) as well as the direction that elements take in relation to one another.[3] Fourth, ***alignment*** is the purposeful coinciding of two or more structural elements, such as a column on top of another column, a girder in line with a column, or beams joining with a truss at the right node or joint. Fifth, ***spacing*** is the well-considered interval between repeated, discrete structural elements. Spacing is a consequence of what structural elements span in between two other structures, such as a set of beams between trusses, or a girder between two columns. Sixth, a structure's ***shape, size, and hierarchy*** relate how large or small a structural component will be based upon a number of factors, among them material strength, a structural component's location within an overall structural system (i.e., near the top of a building or closer to its foundation), how great a load it is tasked with carrying (e.g., roof loads versus floor loads), as well as to some key physical dimension. In terms of the latter, consider the sizes of a beam, truss, or arch in relation to their spans, a column to its tributary area, or a wall to its tributary width, among many other examples. And seventh, every building, no matter how tall or short, large or small, must contend with ***lateral stability***, that is, its ability to maintain its shape and remain anchored to its foundation (i.e., preventing overturning or sliding) when resisting wind forces and earthquake forces (though in terms of the latter much less frequently and to much more varying degrees than wind loads). The structure behind Chicago's Pritzker Pavilion illustrates these principles even at a glance, see Figure 1.

Figure 1. I encourage my students whenever they find themselves in Chicago to walk behind Frank Gehry's Pritzker Pavilion to get an object lesson in structures, particularly the full seven-point model, albeit in a highly unorthodox manner.

These seven points aim to do what many others in the past have articulated so as to help others see architecture through new eyes.[4] The ways to accomplish this new perspective are several. The current semester, a Structures 1 course in the Spring of 2022, is the most refined version, so I will detail that model. I start the semester with a broad overview of structures, of which the seven points are a key component, though others' views are included as well (i.e., Vitruvius, Schodek, Roth, and the Swiss architect Peter Zumthor). Next, the students and I undertake a walkthrough of select campus buildings where we can see and discuss these varied principles, usually at one of our university's sports facilities, see Figure 2 on the next page. We then move into a block of instruction on rules of thumb, in which students can relate structure sizing to easily grasped dimensions, such as a truss's span or a wall's unbraced height, as well as more nuanced dimensions such as tributary area or tributary width.

Up to this point in the semester we have merely engaged in lectures, discussions, readings, walkthroughs, and the simple calculations related to rules-of-thumb sizing. This has occupied the first three weeks of the semester, and we have yet to engage in the engineering-based curriculum of a traditional structures course. Once we do, the semester is divided into instructional blocks of 3-5 weeks devoted to force vectors, concurrent force systems, beams, and trusses. In any case, once we enter into more quantitative topics, the students have an initial but evolving mental picture of a whole structural system. Thus, a discrete structural element such as a beam is not an abstraction lacking a connection to the world at large. Instead, that beam is a component within a larger building narrative. Students understand that such a beam is a representative sample of one of dozens if not hundreds of beams that may reside within a building. And as we engage in engineering-based calculations, several class activities remind the students of how their various math problems relate to "real structures". The main class activities that I rely on are historical precedents, contemporary case studies, and a semester project.

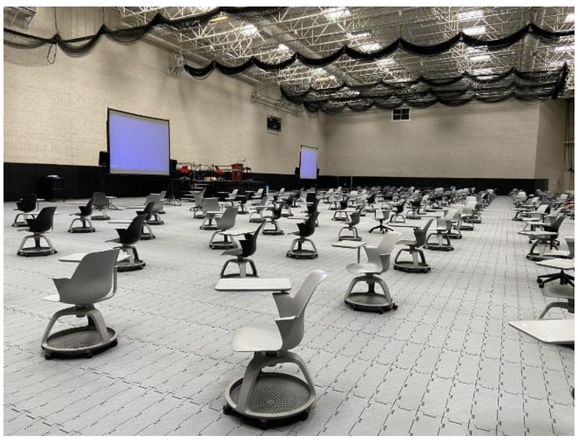


Figure 2. A favorite place to demonstrate simple structural systems to students is one of our university's student recreational facilities. In Spring 2021, this indoor soccer field conveniently served as our socially-distanced lecture hall for a class of 71 structures students. Principles could be demonstrated in real time during the lectures.

Historical precedents and contemporary case studies

Every class lecture that focuses on traditional engineering methods and calculations includes a historical precedent or contemporary case study (i.e., an illustrative example) of that day's subject or task at hand. Most often this occurs at the beginning of class with 1-3 PowerPoint slides. In a brief discussion, students are expected to process the image and my short explanation, then weigh in with their own observations and questions. Other times I insert this sort of short discussion in the middle or end of class, as a quick break or winddown from a technical subject or mathematical procedure. In a class lasting one hour and fifteen minutes, this can take approximately 2-3 minutes or as much as 10-15. However long it takes, the intended effect is this: to continually intertwine accessible representations of physical structures with the facts, figures, calculations, and minute details of building structures.

Historical precedents are especially appropriate to this teaching style because the ideas that underpin the seven-point model first emerged out of a recurring analysis of Pierre Koenig's Case Study House 22 in Los Angeles. Case Study House 22, also known as the Stahl House, is an L-shaped, midcentury modern, glass-box house that overlooks Los Angeles from a bluff high above Sunset Boulevard. The house was made most famous through a series of black and white photographs by Julius Shulman. Through photographs and drawings of that iconic house, I initially showed students five points that characterized the structure:[5]

(1) the square and rectangular *modules* that comprise the spaces and placement of columns
(2) the *rhythm* that the columns and beams present on the pool facing side
(3) the *hierarchy* of structural sizing demonstrated by relatively short spanning elements (the roof's steel deck and beams) and more substantial load bearing structures (the long, cantilever girder that runs both lengths of the L-shaped house)
(4) the shifting horizontal and vertical *orientations* of the deck, beams, girders, and columns
(5) the *spacing* in between the hierarchical elements listed in point three above

As I returned to the Stahl House from one semester to another, and as I applied these first five principles to different historical precedents, other principles and combined ideas (e.g., shape, size, and hierarchy) emerged, which then led to the current seven-point model. Over time my classes have applied the perspective of the whole structural system to many other historical precedents – whether through very brief discussions or full-scale structural analyses – to works such as the Pompidou Center, various buildings and projects by Mies van der Rohe, and even Laugier's primitive hut. But are such important principles limited to the simple rectilinear forms and diagonal lines of the historic precedent alone? Of course not.

Beyond just historical precedents, students' perspectives on what makes a viable structural system also benefit from many contemporary case studies of, for example, Frank Gehry, Zaha Hadid, Norman Foster, Thomas Mayne, Santiago Calatrava, Rem Koolhaas, Shigeru Ban, and others. The key lesson to be gained from works closer in time to us is that no matter how unorthodox a building an architect designs today – whether that building employs, for example, expansive curved planes, or wildly angular geometries – those foundational structural principles that orient my classes govern in those buildings, too, see Figure 3. The student (or instructor) need only look beneath the surface of those buildings to see (albeit applied in very creative or unconventional ways) an organizational strategy, module and rhythm, etc. Such revelations in a student's mind make a lasting impact on their understanding of structures, as we will see later in student responses to this program.

Figure 3. Standing astride both historical and contemporary notions of architecture, Marina City along the Chicago River is an accessible example of ordinary structural principles that are singularly reinterpreted into iconic buildings and structures, particularly in the two buildings' organizational strategy, and modularity and rhythm.

Major class assignments that aim at a more balanced teaching program

After the regular offerings of historical precedents and contemporary case studies, and the occasional building walkthrough, there are a small number of class assignments that reinforce the fundamental principles evident in a building structure. The major assignment is the design of an entire structural system that must address a number of structural-spatial challenges. Students must design a structure that incorporates at least three of the following:

- A cantilever
- A multi-story building
- A long span (greater than 60 feet)
- Curved surfaces or line-forming elements
- An axis or axes at an acute or obtuse angle or angles
- A double-height or multi-story interior volume
- Angular, jagged, or wedge-shaped geometries
- Non-rectilinear building corners, or non-parallel exterior walls
- Geometric volumes – of equal or different shapes – stacked, merged, offset, and/or rotated
- An experimental structure based on an innovative use of a lightweight, structurally efficient system such as a truss, spaceframe, diagrid, suspension structure, shell, etc.

This project allows students to pursue their own formal and spatial interests in architecture, no matter how unorthodox or daunting, and resolve them structurally. Each student's three chosen criteria are seen as structural challenges and a means to an end. No attention is paid to anything that is not structural – the building's doors, windows, curtain walls, or support facilities. All that matters is the bare structure, as if the building were under construction and the structure were fully exposed. However, the structure must be resolved into, among other things, a framing plan, a rendered perspective of the entire structure, and the calculations necessary for the sizing of three structural components, see Figure 4 on the next page.

The execution of this assignment is time consuming, as it necessitates 2-3 working sessions throughout the semester to refine each student's scheme. As students grapple with juggling the beams, trusses, long spans, cantilevers, and sharp angles within their buildings, for example, issues related to building grids, alignment, and spacing, etc. inevitably enter into each conversation with students.

When large classes (e.g., greater than 36 students) are faced with this project, the working sessions invariably encroach upon lectures on other topics. Under these circumstances a balanced schedule is stretched thin. With the smaller classes of a graduate curriculum (less than 10 students), managing this project in accord with all necessary topics is much easier. Graduate students can also fit in a major precedent study as a midterm project and the structural design as a final project.

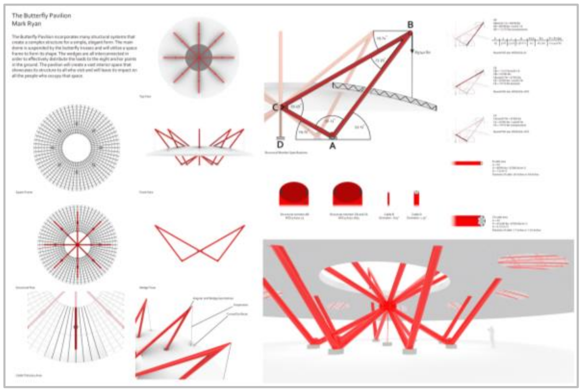


Figure 4. A highly unusual combination of a radial organization, suspended structures, and truss action in one student project. The aesthetics of the pavilion had to be reconciled with calculated structural sizing.

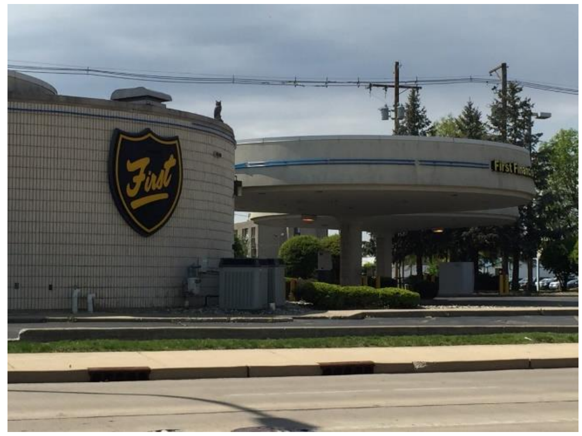
Currently underway this semester is a new project that is directly related to the seven-point structural model. Students must analyze the structure of a building that they can readily visit, photograph, take measurements, sketch in place, etc. The objective is to recognize and document the seven structural characteristics that underpin the course. As this project is currently conceived, we will not require in-class working sessions. Students will submit two draft boards throughout the semester. Then they will receive feedback comments online, while overarching comments for the class will be shared during the lectures. The desired outcome is to direct students to understand what they see, and to continue on a journey of learning about structures, even outside of the classroom.

The theoretical foundations

In associating these teaching methods to phenomenology through this conference paper's title and introduction, much clarification is in order. Classes such as these proposed structures courses – i.e., multiple courses at the undergraduate and graduate levels – are not focused on phenomenological methods such as Edmund Husserl's bracketing or Martin Heidegger's etymological analyses. Instead, the teaching of the class is influenced by phenomenological thinking in general as well as selected concepts. First, let's establish a working definition that broadly encapsulates the ideas at hand.

When we consider the many individuals who in ways large and small, directly or indirectly, have contributed to the field of architectural phenomenology, it is evident they are neither addressing one single issue nor coming to the same conclusions on a number of issues. To that end, one definition for architectural phenomenology is the following: the theory and practice of architecture that concerns itself with (1) subjective experience, (2) sensorial experience, (3) bodily experience, and (4) notions of place. To cite some examples, Heidegger's later works have had a great influence upon notions of place, though the architect Adam Sharr also has shown that those same writings by Heidegger dealt just as much with the philosopher's subjective experiences.[6] The geographers Ed Relph and Yi-Fu Tuan, and the archeologist Christopher Tilley have likewise written at length on notions of place as understood by various cultural groups around the world and even across eras, in the case of Tilley including prehistory. On the other hand, whereas the philosopher Maurice Merleau-Ponty resided in the sphere of bodily experiences, the focus of the architect Juhani Pallasmaa has been on sensorial experiences, particularly sight and touch. In his designs, the architect Peter Zumthor transcends all four listed categories – memory and past experiences, the senses and the body, and designing in response to and in accord with landscapes and cultural influences.

The four-part definition for architectural phenomenology above begins to explain the thinking behind the proposed teaching strategy of this paper. The desired balance in a structures curriculum relies first on bolstering students' subjective experiences. The recurring exposure to and discussions revolving around historical precedents and case studies starts to build a mental reference library in students' minds. These instructional moments are not in direct physical contact or interaction with structures themselves. However, many of Heidegger's most famous insights likewise resulted from similar mental exercises in response to a van Gogh painting, the imagery in a Holderlin poem, or the watchful eyes of the portrait of the poet Johann Hebel. What such mental exercises help the student to do is to make sense of what they see in a variety of contexts. It begins in a lecture hall with a set of images of exposed structures or buildings under construction. The lessons that begin there are intended to extend to a better understanding of the works of their favorite architects, to each student's studio project, and to the engineering problems they will work out in class.



Figures 5 and 6. Images of a now defunct branch of the First Financial Bank of Danville, Illinois. The cantilevered drive-up service stations offer strong hints of radial organizations, imposing vertical and horizontal cantilevers, and the unseen strength of steel reinforcement in concrete. The hints of structural logic abound all around a student's world.

A key aspect of this reference library growing in a student's mind is that it is grounded in the lifeworld, which as *Lebenswelt* is one of the earliest phenomenological principles formulated by the discipline's acknowledged founder Edmund Husserl. The contemporary environment behavior researcher David Seamon explains that "the lifeworld is the everyday realm of experiences, actions, and meanings typically taken for granted and thus out of sight as a phenomenon." Furthermore, he asserts that it is both an individual and collective phenomenon. Seamon goes on to say, "A major phenomenological aim is […] to recognize how much of human life, both in its ordinary and extraordinary aspects, incorporates a lived complexity of which we are normally unaware." Lastly, individual and collective lifeworlds are intertwined with places, particularly buildings.[7]

Following along the lines of David Seamon, what this rebalancing of the blatant with the latent aims at is an introduction of the structural lifeworld into the students' consciousness. The seven-point model of a wholistic building structure is evident in our everyday lives, thus it is a part of each of our lifeworlds. As I often remind my students, before they first enrolled in Structural Systems 1 they were probably unaware that structures were all around them. Now is the time to start noticing them. I often encourage them to take notice of, for example, an exposed ceiling structure by telling them to "Look up!" Yes, it is true that a building's structure is all too often hidden within its walls or ceilings. Nevertheless, examples of exposed structures, or at the very least hints of a structural logic, abound, see Figures 5 and 6. They can often be seen at your local place of worship, a sports facility, a concert venue, a national retail store, your city's main airport, even your favorite restaurant. Students need only begin to notice them as a heretofore unforeseen part of their lifeworld.

An important aspect of the lifeworld paradigm is an apparent (some would argue inherent) tension between it and the technological paradigm that pervades modern and contemporary life. This tension is often expressed through the quantitative-qualitative duality, which is sometimes expressed in terms of abstract-concrete or space-place. In the minds of phenomenologists, the quantitative-qualitative duality implies a great imbalance in the world today between the two terms.[8] According to hallmark of a scientist or researcher is to distance themselves from real world phenomena by taking measurements and carrying out calculations as a means of making an abstract representation of a subject, in order to finally study and understand it.[9] To address this perceived imbalance, the field of phenomenology asks us to step outside the scientific bubble that encompasses us and be open to other insights into our world, insights gleaned through closer engagements with the world. In phenomenology, then, there is a constant tension between a qualitative view of the world and a quantitative, scientific, or technological one because, according to phenomenological philosophers, technology can disassociate us from the world around us by mediating our perceptions of the world. The scientific and technological paradigm forms a barrier between us and real personal contact with the world. Thus, they alter our perceptions of the world, from the concrete "here-and-now" of more direct personal experiences with places, people, and things to the distant and far removed paradigm of abstract and quantitative thinking. Phenomenology's attempts at bridging these divides is, of course, at the heart of this paper.

Student responses to these teaching approaches

As an instructor, my pursuit of continuous improvements are shaped in large part by my students' end-of the semester course evaluations. To that end, those evaluations have been beneficial in assessing the teaching strategies outlined in this paper.

A common student observation has been directed at the intended linking of course lessons to recognizable examples of built works. One student said that the instructor "puts structures into real world perspectives." Another student cited "the material we learn and how realistically it is applied" as a strength of the course. A third student added, "Nothing we did felt like busy work, everything had a clear purpose." Among the highest praise was the student who commented that the instructor "pushes us to see the structural world differently. I have applied his class to my studio projects and have a deeper understanding of architecture."

The semester project likewise received mostly positive reviews for its intended purposes. A student remarked, "The semester project helped me understand structural systems in a real-world manner." Another student responded, "I feel like I have a good understanding of how to apply the calculations we learned to a real building," adding that the semester project "takes the content of the course and makes us demonstrate that we can apply it to a design. The project is straightforward and of an appropriate scope for the course."

The major drawback cited by students was the times allotted in class to working on the semester project, which reduced the times we may have had to reinforce other topics. Two surprising responses were, first, "My only complaint about the semester project is that its working sessions took so much time away from being in class," and second, "I felt like the semester project took away from some important concepts that we could have gone over more. […] The checkpoints were nice because it made sure we were thinking about our project and not just procrastinating the entire thing, however, I am now nervous for next year's structures course." Though surprising when first read, these comments have been essential to the semiannual restructuring of my undergraduate structures courses. Thus, to cite one example, there is the change to the semester project during the current semester of Spring 2021, i.e., no in-class working sessions.

It bears repeating that in attempting to strike a balance between the qualitative and quantitative, all that is normally taught in an undergraduate structures course receives its due attention. Students in a first-semester structures class still receive weeks of instructions on vector forces and concurrent force systems, beam support reactions, vertical shear, bending moments, section moduli, and trusses and their external and internal forces, among other topics. This still occupies the majority of the time in class. It is merely and regularly supplemented with how those concepts and calculations work in buildings either commonplace or highly unusual in terms of design.

In the end, the efforts directed at a much more balanced approach to teaching structures has begun to show merit. Though students struggle at first to demonstrate the desired principles in their own work, they can be coached to a high level of success. The desired outcome is this charge to our students: Don't just think like an engineer, think like a designer.

End Notes

[1] The terms line-forming, surface-forming, horizontal-spanning, vertical supports, and lateral stability system are taken from Schodek's *Structures,* a work which has informed much of the thinking behind this paper. In his textbook, Schodek also presents building characteristics that presaged the seven-point model presented here. His categories include geometry, stiffness, one-way and two-way systems, materials, and primary structural units and aggregations. See Schodek, *Structures*, 4-8, 11-12.
[2] The grid is, of course, the most common organizational strategy. However, students should keep in mind that a grid is not an inviolable ordering system. Also, neither is a strictly square or rectangular grid the only option in structural and spatial planning. To best serve a designer, a grid must remain flexible and widely applicable to a variety of architectural demands. To this end, a grid may be radial, skewed, tapered, or at an acute or obtuse angle to another grid. The grid should also accommodate spaces and volumes within a building, which is to say that not every point and line within a grid has to represent a physical object within that building.
[3] A structure's orientation is typically though not exclusively horizontal or vertical. Consider a cluster of columns that rise at angles other than ninety degrees. The more unusual the angle, the less that they resemble a traditional, vertical column. In such unusual circumstances, I revert to the more general term of vetical support. Another important lesson for students is that orientations vary predictably from one supporting element to the next, and to

the next, and so on. For example, a steel deck is supported from below by a beam at a 90 deg orientation to the steel deck's orientation. The beam will transfer its loads to girders that again lie 90 deg to the beam (thus parallel to the deck's orientation). The girder then relies on a vertical column, of which the latter is now 90 deg vertically to the horizontal girder.

4 Think of the Vitruvian triad, and Sempner's tectonic and stereotomic. Leland Roth leveraged the Vitruvian triad into a highly accessible understanding of structures in his work of architectural history *Understanding Architecture*, in which he devotes a chapter, titled "*Firmitas*", to historical building structures (i.e, the wall, post and lintel, frame, truss, arch, vault, etc.). More closely aligned to the structures classroom, consider again Schodek's surface-forming and line-forming elements; and horizontal spanning systems, vertical supports, and lateral stability. From Ambrose and Tripeny, a structures student can also formulate the interconnected workings of building frames and their subcomponents: joists, beams, girders, columns, etc. See Roth, *Understanding Architecture*, 18-43; Schodek, 12; and Ambrose and Tripeny, *Simplified Engineering*, 166-184.

5 These five points were first applied to the Stahl House in the Summer 2020 semester, though the house had appeared in my structures courses many times before then.

6 In his book *Heidegger's Hut*, the architect Sharr relates how many of Heidegger's works that have become highly influential within architectural phenomenology have a direct correlation to the German philosopher's experiences in his cabin retreat in the Bavarian woods. See Sharr, Adam. *Heidegger's Hut*. Cambridge, Massachusetts: The MIT Press, 2006.

7 See Seamon, "Architecture, Place, and Phenomenology," 248.

8 Phenomenologists have described the divide in the quantitative-qualitative duality in stark terms. In an indirect reference to the perceived imbalance between the two concepts in the duality, Heidegger termed the problem "the radical inhumanity of today's adulation of science" and "the mechanization of man." *See Heidegger, "Zeichen," 211, and "Das Wohnen de Meschen," 219.* Christopher Tilley likewise cast blame upon an undercurrent of modernity and the twentieth century with what he called a "white hot positivism coupled with functionalism." See Tilley, *A Phenomenology of Landscape*, 7. Christian Norberg-Schulz, a prolific writer and long-time proponent of Heidegger's influence upon architecture, stated it thus in the 1980s, "After decades of abstract, 'scientific' theory, it is urgent that we return to a qualitative, phenomenological understanding of architecture. It does not help much to solve practical problems as long as this understanding is lacking." See Norberg-Schulz, *Genius Loci*, 5-6.

9 See Heidegger, *The Question Concerning Technology*, 127-128. This sentiment recurs in many of Heidegger's other works – not cited here - that have famously shaped architectural phenomenology.

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