A Lesson in Abstraction

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THE QUESTION OF THE DIGITAL MODEL

The digital model is both a simple tool of intuitive design thinking used to devise spatial compositions and the base layer of increasingly complex computational practices imbued with layers of contingent information. It has replaced paper as the primary venue of architectural communication, regardless of a user's level of experience, specific purpose, or degree of sophistication.

The ubiquity of the digital model begets complacency toward its implications, which include a significant threat to the logic of the traditional architectural design process established in the Renaissance and upheld throughout centuries of disciplinary change. The extent to which the threat poses a crisis is an open question, and architectural education today has an opportunity (if not a responsibility) to confront that question head-on, so as to produce a generation of practitioners cognizant of the stakes.

After a generation of adaptation, and amid a steady stream of innovation that continually (and productively) destabilizes day-to-day practice, the logic of the digital model itself—the framework onto which innovations are applied—is taken for granted. Despite the persistence of increasingly tiresome digital-verses-analog debates, the discipline has yet to reflect critically on the basic nature of the digital model. That inquiry must begin at the most foundational level—the first year of the education of the architect.

The project outlined in this paper is a central component of a new foundation design pedagogy currently under development at the University of North Carolina at Charlotte. It introduces students to the digital model in a manner that lays bare how contemporary design tools are both alike and unlike traditional ones, and it challenges students to wrestle with the relevance of historical practices in an era of relentless innovation.

The description of the project included here is to be deployed in the second iteration of the new program in academic year 2019/2020. Illustrations are drawn from the first iteration in academic year 2018/2019. This is an ongoing experiment in architectural education being conducted in a transparent manner. Students understand that the curriculum is dynamic, not settled, and that their work is contributing to pedagogical and disciplinary research.

SEEING ARCHITECTURE

The logic under threat by the digital model is a matter of abstraction. In his treatise on architecture, Alberti dismisses the relevance of both linear perspective and realistically rendered physical models to the architectural design process, contending that architecture cannot be developed and evaluated by practitioners through modes of visualization rooted in experiential realism, despite the fact that buildings are habitually consumed and evaluated by users in those ways.[1] According to the logic, practitioners produce beautiful buildings only after examining the underlying conditions that produce architectural beauty in analytical modes of visualization (historically, orthographic drawings and analytical physical modeling).

While devised within a culture that valued classical ideals, this understanding of the design process is applicable to all architecture and compatible with any idea of beauty, which is why the methods associated it long outlasted the aesthetic assumptions of the Renaissance. The logic, at it core, assumes only that architecture cannot be evaluated during the design process through pictorial modes of visualization. The design of buildings requires an analytical vision.

The digital model threatens that assumption not because it resides on a screen, but rather because of the ingrained habits that designers bring to the screen, as well as the interfaces and procedural shortcuts developed to accommodate those habits. The digital model, in fact, has the capacity to be the epitome of the analytical method promoted by Alberti, as it may optimize the management of parametric variables and the production of analytical graphics, allowing designers to complete weeks of work in mere hours.

Designers, however, tend to use the digital model more intuitively than analytically, and to look at it primarily through a roving pictorial camera. On the one hand, to use the digital model as something other than an optimal version of a traditional method makes sense—surely the digital and computational age is about something other than efficiency and speed. On the other hand, that "something" cannot be reduced to the mediation of resistance and the glorification of visual immediacy. The digital model—again, the base layer and primary venue of current and future design practices—is capable of more. How may it break the mold of the traditional design process in qualitatively valuable ways?

To answer that question requires the development of a different sensibility toward the digital model, one that somehow reinterprets the Albertian ideal of analytical abstraction in a progressive manner that resists nostalgia and addresses the essential difference between the base layer of the digital model (how it looks like a building) and the additional layers of computational information housed within it (how it facilitates practice, construction, and use). This project is an initial step toward a new consciousness of how the digital model allows us to look at architecture.

THE PROJECT

The project reinterprets a design exercise with a long history in foundation design curricula: the creation of occupiable space through the carving of voids within the solid mass of a cube. In this case, design occurs within Rhinoceros, a common entry-level digital modeling program; however, the majority of the process involves the construction of two-dimensional multi-view drawing sets located on a single plane of the three-dimensional workspace. At first, and throughout most of the three stage project, the modeling program is used as a drafting program. Eventually, the project concludes with the construction of digital models—a coda that considers differences between multi-view drawing and digital modeling. Throughout the process, hand sketching is encouraged as a way to generate and develop ideas, but only to a limited extent, so that the constraints of the digital environment steer the process.

THE VALUE OF POINTS

Each stage of the project consists of two rounds, one that proceeds according to the laws of descriptive geometry and one that proceeds according to the laws of projective geometry. Both mathematical disciplines assume that geometric parameters of objects and environments are reducible to a set of three-dimensional coordinates—points. To gain a full understanding of those parameters requires the construction of drawing sets in which the same points appear in views of different coordinate planes (xy, xz, yz) and, in the case of projective geometry, also in a perspectival construction. Both the digital model and computational thinking more broadly share the same point-based logic that underlies these geometries. In digital and computational environments, points determine architectural geometries, and this project develops literacy in the spatial language of points.

The overall project begins with a set of exercises that introduce the mathematical laws of descriptive geometry and projective geometry. In specified initial views, students plot sets of points, connect them with lines, and then execute acts of projection to create additional views that visualize the same points and lines from different orientations. Different exercises mandate different processes for the initial plotting of points, as well as different variables and degrees of complexity, so as to develop a high degree of proficiency in the basic mathematical laws of point-based drawing.

A mantra introduced in these exercises steers the entire project: two lines define one-and-only-one point; two points define one-and-only-one line. This basic law of Euclidean geometry, already familiar to students, is applied to a basic set of operations in each type of geometry that correctly locate corresponding points and lines in multiple views. The mantra strives to demystify the process and to reassure students that, no matter how complex or layered operations become, all points and lines are located in exactly the same way—as foreign and intimidating as the overall project may seem, it requires only a simple set of rules, a basic set of operations, and patience.

The exercises also codify a set of terms. Different views of the cube are referred to by their coordinate planes: plan cuts and views are xy cuts and views; section cuts and elevations are xz or yz cuts and views, depending on their orientation. Students are already familiar with plan, section, and elevation, and the specificity of this language intends to reframe that knowledge through the point-based logic.

The exercises also introduce a graphic sensibility for the entire project. Points, lines, and construction/cutting lines are color-coded for mathematical clarity, as opposed to experiential realism, not unlike a wireframe view of a digital model. Examples of coding are provided in demonstration materials, but students are encouraged to experiment with different strategies, so as to a develop an analytical language for their drawing sets, at once individualized and objectively clear.

STAGE ONE: DESCRIPTION AND PROJECTION

In the descriptive geometry round of the first stage, design begins with the plotting of points (according to a set of parameters) on three xz cuts through the cube. Lines that connect the points in each of the three cuts are interpreted as edges between mass and void. The y-coordinates of the xz cuts are then determined (again according to

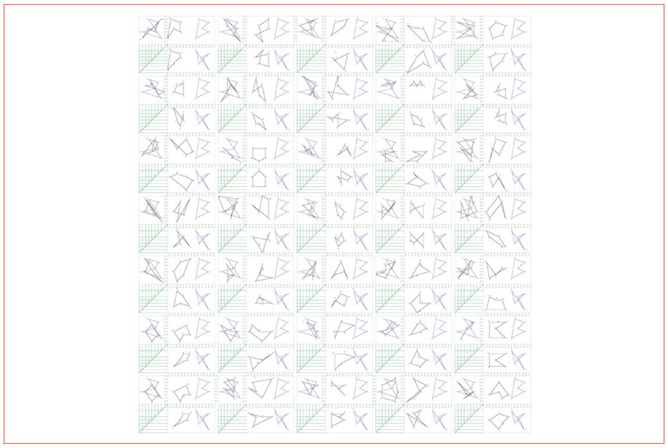

Figure 1. Stage 1, descriptive geometry exercise, Kelly Byas.

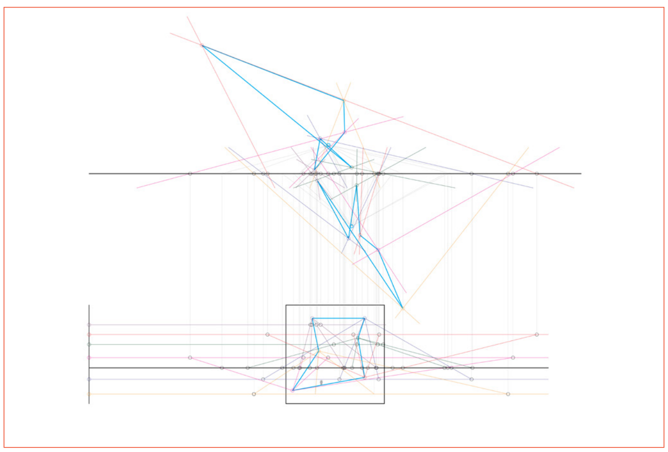

Figure 2. Stage 1, projective geometry exercise, Daniel Lynch.

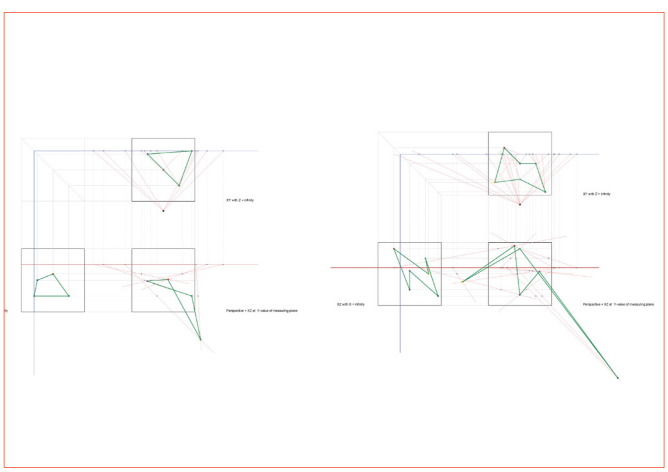

Figure 3. Stage 1, projective geometry exercise, Carl Debrosse.

a set of parameters), so that a manual lofting procedure may occur: lines between corresponding points in the three cuts are drawn to define a volume. Then, six new drawings are constructed: three xy cuts, and three yz cuts. At the conclusion of the stage, the mass of the cube and the void of the carved volume are described by nine projectively-aligned drawings: the original set of three xz cuts and the subsequent set of three xy cuts and three yz cuts.

In the projective geometry round of the first stage, design begins with the plotting of points (again according to a set of parameters) on a single xz cut through the cube. Lines that connect the points in each of the three cuts are again interpreted as edges between mass and void. The plane on which the points are plotted is considered the measuring plane of a linear perspective (often called the picture plane). Two determinations follow: the value of the y-coordinate of the measuring plane, which sets its location within the cube; and the location of the viewing point (often called the station point) in all three axes, which sets both its position in xy views and the location of the horizon line in xz views. Points and lines are then plotted in an overhead xy view and a elevational yz view.

The next step involves the construction of a regulating grid through the cube. The coordinates of the initial points on measuring plane and those of the viewing point are used to generate regulating lines in xy, xz, and yz views; horizontal and vertical lines are projected through each point in each view. These regulating lines in two-dimensional views represent the edges of regulating planes, resulting in a three-dimensional regulating grid that slices the volume of the cube into segments. After the construction of this base grid, additional regulating planes may be generated either within the orthographic views and/or the perspectival construction. For example, diagonals may connect points to each other and/or to the edges of the cube may, resulting in diagonal regulating planes. New regulating planes may also adhere to existing proportions and rhythms of the base grid, or they simply appeal to the aesthetic impulses of the designer. Regardless of intention and method, a high density of regulating planes is encouraged so as to facilitate the next step.

As in the first round of this stage, the generation of the carved volume within the cube involves a manual lofting procedure, in this case multiple acts of tracing the lines of the regulating grid across multiple views. Literal acts of projection between views are no longer necessary because the regulating grid, the construction of which required those acts, already appears in all views. The points that define edges between mass and void on the measuring plane are lofted in both directions toward points of intersection within the regulating grid. Lines between points may be drawn in any view and then traced into the other views, and students are encouraged to loft both in xy and yz views and within the perspectival construction, so as to analyze the sometimes surprising relationships between orthographic/measurable and

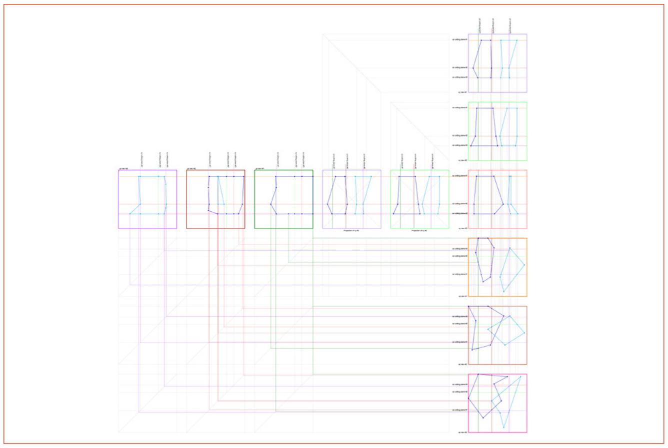

Figure 4. Stage 1, manual lofting, Kennedy Sweeney.

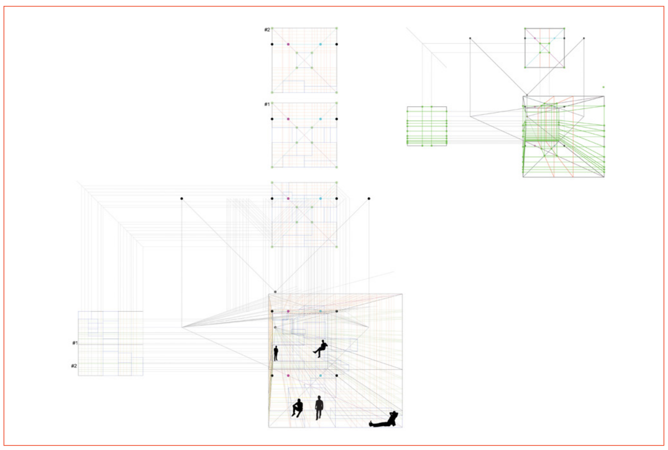

Figure 5. Stage 1, regulating grid, Olivia Gregson.

perspectival/distorted views.

The use of the regulating grid results in a more nuanced design process compared to the manual lofting operation in the first round. In this round, a single point on the measuring plane may be lofted to more than one point in each direction, and different points on the measuring plane may be lofted to different depths within the cube. In short, there is more available data in this round, and the resulting volumes are inevitably more complex. While complexity is encouraged, an unyielding requirement is that solids and voids must be closed—basic physics must be obeyed.

To fulfill presentation requirements (two xy cuts, two yz cuts, two xz cuts, and a perspectival construction) more acts of projection are necessary. The operations necessary to build this set of drawings are covered in the initial exercises: 1) how to trace points from xy and yz views into a perspectival construction; 2) how to trace points from a perspectival construction into xy and yz views; and 3) how to extract xz views other than the measuring plane from a perspectival construction.

STAGE TWO: APPLIED LEARNING

A primary challenge of the first iteration of the project concerned the retention and reapplication of the mathematical laws of descriptive geometry and projective geometry. After the initial exercises and the first stage of the project, both of which were supported by step-by-step demonstrations, students (almost without exception) were unable to apply already-learned operations toward less structured methods and objectives. Especially troubling was a widespread inability to follow the logic of the mantra: two lines define one-and-only-one point; two points define one-and-only-one line.

Asked to develop the cubes from Stage One with more design intention but through the same point-based drawing method, students struggled with basic operations and repeatedly asked how to find specific points and lines. Countless repetitions of the mantra and reminders of specific operations did not stop the questions, and it became clear that the project confronts a fundamental problem of education in general—how to teach intellectual agility and critical thinking.

The second iteration of the project institutes two changes in this stage independent of the overall objectives to address that issue: the tone of the instruction will be less accommodating of students' asserting that they don't know what they have already learned (i.e., more tough love); and the process will include a daily regimen of in-class small-group workshops, in which students help each other "figure it out" while instructors roam and give prompts and help as necessary.

The top-down model of instruction that includes step-by-step demonstrations is common in foundation design curricula, following an assumption that beginning students need to be told exactly what to do and how to do it in order to produce quality work. Meanwhile, other types of procedural pedagogies are increasingly common in other levels of curricula. These models of teaching are valuable, but need to be balanced with non-scripted processes and peer-enabled learning. This stage of the project has revealed itself as a perfect opportunity to deploy those tactics so as to develop applied learning and a different type of knowledge-building.

The primary theme of this stage is design intention. In the first stage, the abstraction of the method, to a certain degree, alienates the designer from the results of the operations that carve the cube, especially compared to the agency enjoyed in hand drawing and physical modeling. In this stage, students edit existing designs and are given more freedom to explore spatial qualities. Fine tuning is discouraged in favor of bold exploration. Inspiration for design development comes primarily from two sources: in-class lectures and discussions on hierarchy, circulation, light, and other foundational themes; and analog-based precedent studies conducted in a parallel and coordinate course.

The significant restriction of the point-based multi-view drawing method remains in place, foregrounding a struggle inherent to any design process between an idea in one's head and the limitations of a specific method. Tools and methods enable and restrict, and design is always a function of that dialectic. The objective is to balance resistance with intention.

The operations of design development focus on adding data to the

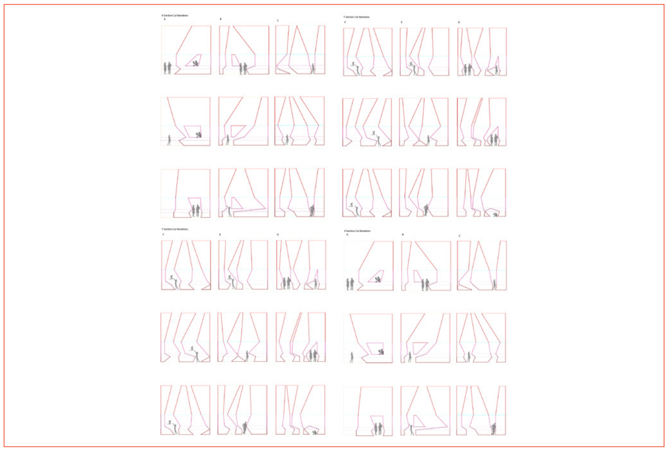

Figure 6. Stage 2, design iterations, Rebecca Seagondollar.

cubes without overriding any of the existing data. In other words, the DNA of the designs evolve and perhaps even mutate, but the original species does not go extinct. Adding data may occur through adding points to existing views and/or through generating new views that redirect the original manual lofting procedure. New views may mirror, invert, or rotate an existing view in a different orientation, so as to retain more of the original DNA, or they may force a mutation.

A design challenge of this stage is to work with the existing cubes instead of "starting over" with a new idea—a common problem in all levels of design education. To address that issue, the logic of iteration is introduced as a means to design development. Continuing the DNA analog, students are encouraged to consider how a new design may be a non-identical twin, a parent, an offspring, or even a distant cousin of the original. How may an idea or a spatial condition be transferred and modified without being lost?

STAGE THREE: THE PROBLEM OF VISUALIZATION

The first iteration of the project ended after the first two stages. The third stage described here is an addition to the second iteration project in response to an issue that plagued the first: students (and, at times, instructors) struggled with the difficulty of visualizing the designs of the cubes. Even the addition of perspectival constructions in the second rounds of each stage failed to mediate the abstraction of the point-based drawing-set method. In group discussions, some students admitted to constructing digital models in Rhinoceros in order to help them to understand what they were doing in the drawing sets, sparking passionate debates within the course and the school. Colleagues not involved in the course, for example, suggested the addition of physical modeling alongside the drawing sets to help students overcome the difficulties of the abstraction.

The response of the authors is to double down on the premises of the project, insisting not only that the value of the method outweighs the frustration associated with it, but also that the tediousness of the method has its own hidden assets; however, adjustments to the process and the rhetoric associated with the project are necessary to better manage the difficulty and tedium.

It is important, for example, to explain and reiterate that point-based line drawing is a mode of visualization with deep historical roots that leads directly to what we today call computational design. Historically, it accommodated specific types of practice, and it still enables specific types of thinking. Its logic is fundamental to what happens behind the computer screen, and the training provided by this project, while not literally practical, provides an exposure to that logic with long term practical and intellectual benefits. The project willfully and transparently foregoes immediate satisfaction for the sake of the long game—a tough argument to prove, but an important one to make, to first-year students.

Another line of reasoning is that the challenges imposed on contemporary eyes by the drawing sets counteract bad viewing habits that those eyes bring to the computer screen. Following the argument of Alberti, the inability to "picture" the designs in an intuitive and immediate manner is not, in fact, a problem that needs to overcome. Instead, it is condition in which to struggle and learn. Whereas orthographic line drawing and analytical physical modeling were tools that made sense to realize Alberti's understanding of beauty, point-based seeing is a precondition for realizing the emerging understandings of beauty in the early computational design era.

The objective here is not to design mass/void cubes that meet certain aesthetic criteria (either imposed by the instructors or brought by the students), but rather to work through a process that both speaks to the value of constraints on design intention and trains students' eyes to see the digital model in a more analytical manner. The impulse to see the cubes in a more intuitive manner, though understandable, is incompatible with these objectives.

The coda to the project involves, finally, the construction of digital models, and it comes after the construction of point-based drawing sets so that students are able to demonstrate their retention of the lessons of analytical visualization in the previous stages. The foil here is the tendency to "look at" digital models through a camera capable of flying around a model with infinite ease and virtually no constraint, which limits analytical thinking and does a disservice to the logic of computational design. In this pedagogy, students' first use of digital modeling involves smarter ways of looking. A degree of intuitive viewing is acceptable, but only if complemented by modes of analytically controlled viewing rooted in point-based geometries.

In this stage, after students construct models of designs realized in the previous stage, they conduct another process of design development, this time using automated tools comparable to the manual operations conducted previously. The analysis includes both how design operates differently in the modeling environment and how different viewing strategies affect the process. The lessons in projective geometry, for example, help students to create camera positions for analytical perspectival views, which may be saved and revisited throughout the process as a control on the freedom of the camera. As they were in the projective geometry rounds of the previous stages, students are encouraged to discover analytical non-embodied camera positions and even levels of visual distortion that would be deemed unacceptable in a normative rendering—positions and distortion that help

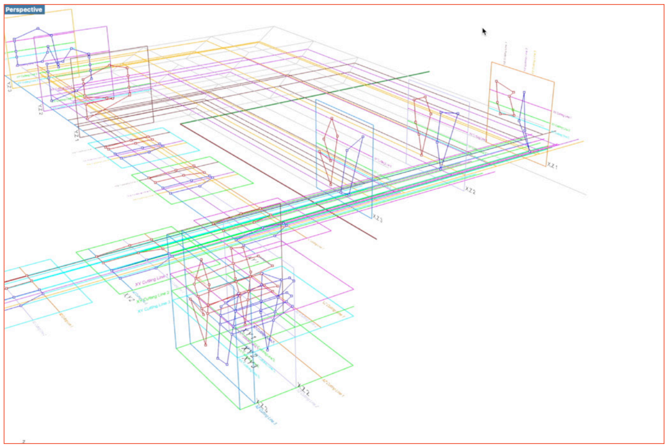

Figure 7. Stage 3, digital modeling, Noushin Radnia (instructor demonstration).

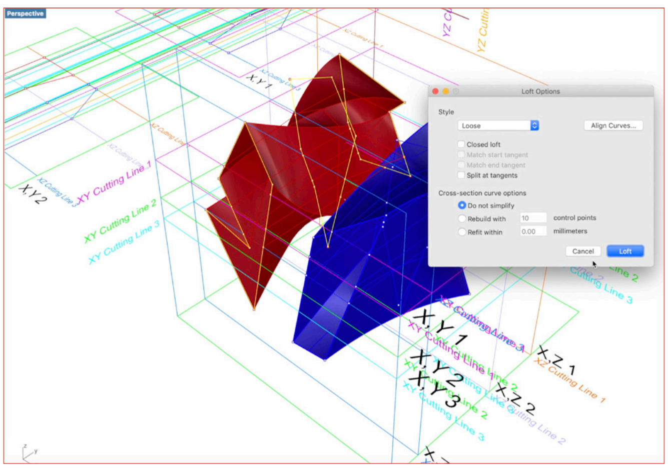

Figure 8. Stage 3, digital modeling, Noushin Radnia (instructor demonstration).

to reveal qualities of the design that escape realistic views.

One of the most compelling realizations of this stage is that automated processes create different results than manual ones, given that the computer crunches more data behind the scenes. To demonstrate that condition, one exercise involves the automation of the initial manual lofting procedures of Stage One. The results are different, and both are correct based on the data used to create them. Given the same starting point, different amounts and types of data create different architectures—a lesson that plants a seed in first-year minds with great potential to be revisited in more advanced processes.

The analytical potential of the digital model both adheres to Alberti's mandate to view architecture through a non-pictorial lens and supports computational innovation. As aesthetics cede to performance in the post-critical era, it may be argued that modes of visualization are less consequential than they were to so-called critical practitioners; however, even in extreme (and extremely rare) cases, in which data entirely steers the development of geometry, visualization matters. Its significance is neither obvious nor unassailable, and foundation design is where the lessons must begin. The task is to steer beginning students away from the hazardous allure of instant visual gratification and to help them to develop design processes that more effectively engage computational principles.

THE QUESTION OF THE ANALOG

An implicit goal of leveraging the analytical potential of the digital model is to project that type of thinking into all modes of architectural representation, both digital and analog. To understand that analytical thinking is not exclusive to a particular method, and that the analog practices of free-hand drawing, sketching, and physical model-making share the same fundamental questions of abstraction, helps students to think critically about the various design processes they face and to identify strategic ways in which to traverse them.

Though not covered in this paper, it is important to note that an analog curriculum rooted in precedents runs parallel to the project described here, taking place in studio and advanced maker labs. While distinct, the digital and analog tracks of the course overlap in significant ways, informing each other in planned and spontaneous ways. They help make sense of each other thematically through an overlap of themes and methodologically through contrasts between different types of craft. Students emerge both with what we call a proto-computational training through project, and with what we consider to be an essential complement to it—actual material engagement.

Notes

1. Leon Battista Alberti, *On the Art of Building in Ten Books*, trans. Joseph Rykwert, Neil Leach, Robert Tavernor (Cambridge, MA: MIT Press, 1988), 33-35.