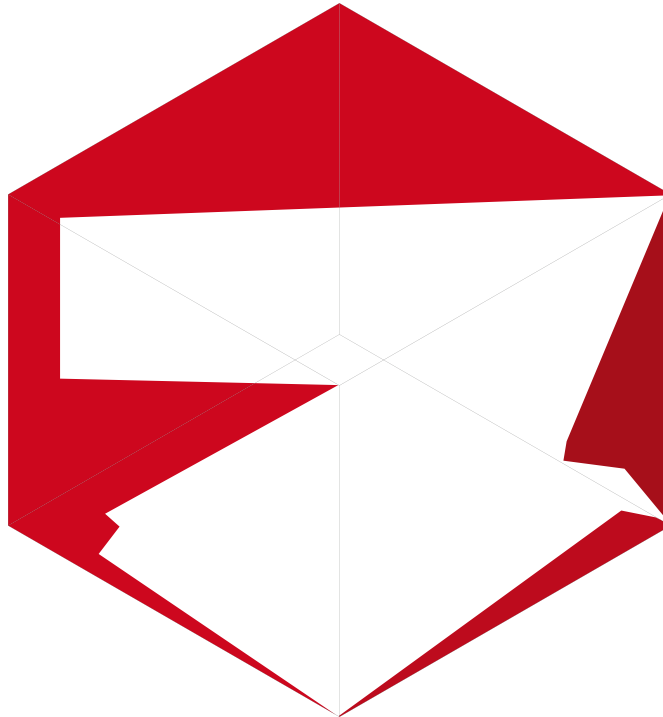


Studies in Material Thinking



Faculty of Design and
Creative Technologies
Auckland University of Technology
Auckland 1142, New Zealand

Eml info@materialthinking.org
Web www.materialthinking.org

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Form to Product: Making as Pedagogy

Mitzi Vernon & Martha Sullivan

Abstract: This paper responds to a need for scholarly discussion about form within industrial design curriculum. We propose to revive form-giving through an iterative and analytical process of making. In this visual essay we feature selections from ten projects and forty students in the second year studio of the Industrial Design Program at Virginia Tech. We use a term, “form-matrix,” as a way to talk about the various divisions of form and how they overlap and inform each other. The project case studies articulate not only the student work but also a primitive form vocabulary through their use of craft, materials, two- and three-dimensional iteration, and graphic analysis. The work emerges from a new triangulation of courses in second year: Design Visualization (analog and digital), Computer-Aided Drawing (using the application, Solidworks), and Design Proficiencies in Workshops (hand- and digitally-crafted 3D form studies). These courses scaffold the studio – the central node of education within our program. We have reshaped our curriculum to address the qualitative nature of form-giving, while building on the existing “Bauhausian” workshops within our School. This pedagogical paradigm focuses our studio on “search” rather than “solution” through making. We move from concept-to-form and from form-to-product.

Key Words: Form-giving, industrial design, studio, curriculum, digital fabrication

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Authors

Mitzi Vernon /
Industrial Design /
School of Architecture + Design /
Virginia Tech /
vernon@vt.edu

Martha Sullivan /
Industrial Design /
School of Architecture + Design /
Virginia Tech /
millsulli@vt.edu

How do we embed form—as an *active* constituent—into product design education? The spring 2012 issue of *Innovation*, a journal published by the Industrial Design Society of America, is a collection of perspectives on the role of *form* in industrial design education and practice. While the editor indicates that the issue was composed out of a concern about immateriality, the commentaries do not venture to anatomize the process of form-giving.¹ We propose a path towards form-giving through an iterative and analytical process of *making*. In this visual essay we feature selections from ten projects and more than forty students in the Industrial Design Program at Virginia Tech, an array of work from the second year studio. We use a developing term, *form-matrix*, as a means to talk about the various divisions of form and how they overlap and inform each other.



Figure 1. Linear Flowform. Scott Shumaker: Bent Basswood.

The School

Though it has become a source of debate as a tipping point for design education, the mythic Bauhaus provides an indisputable example of systematic form study. The School of Architecture + Design (S^oA+D) at Virginia Tech is rooted in the Bauhaus model, as many of the program originators were students of Bauhaus faculty, either in Europe or the United States. Charles Burchard who studied under Walter Gropius (founder of the Bauhaus) at Harvard is credited with establishing Virginia Tech's S^oA+D "foundation studio" (often and originally referred to as a laboratory or as "lab") in 1967, which is modeled after the Bauhaus open floor concept.

Accordingly, the studio *method*, as commonly found in both product design and architecture schools today, is an evolved form of the Bauhaus pedagogy.² At its inception the Bauhaus used the term "workshop" as a core element of the first three semesters.



For decades, Virginia Tech's S°A+D has embedded the workshop concept in labs and supplemental courses called *Design-Related Media*, including dedicated workshops in ceramics, printmaking, photography, silkscreening, etc. The pedagogical paradigm established by Burchard in the 1960s positions the focus of labs on "search" rather than "solution" and for moving from "concept to valid form."³



Figure 2. Students and Professors discuss Platter Project models in the studio.

Second Year Industrial Design

With this Bauhaus historical root, the work presented here emerges from the second year studio in industrial design and a triangulation of support courses—Design Visualization, Computer-Aided Industrial Design, and Design Proficiencies in Workshops. The **Second Year Laboratory** is an introduction to the discipline of Industrial Design, as the students in the first year foundation lab are developing a broader understanding of all the design disciplines within the S°A+D and the overarching elements, principles and history that connect them. Emphasis in the second year within industrial design is placed on two- and three-dimensional form generation, including: design theory, problem solving methodologies, conceptualization of ideas, and aesthetic sensibility. Skill development includes awareness of materials and manufacturing processes, model making, storyboarding, written documentation of design process, and verbal presentation. **Design Visualization** positions students to think about lines, planes and solids with pencils and kinesthetically with their whole bodies. As in many ID programs, drawing prepares students to think on paper through hand sketching, marker rendering, and computer enhanced imagery. In our program, we teach sketching as a process for grappling with conceptual problems—a method of thinking and communicating as a cohesive practice—for form development.

Computer-Aided Design (CAD), as a tool, is a bridge between science and design; in our case studies, the **Computer-Aided Industrial Design** course builds a relationship between digital technology and craft. CAD exercises incorporate: (1) a grounding in the dimensions and parametrics true in any given form or geometry and (2) the dissection of a structure into features, parts, and assemblies. Students experience the results of their decision-making process in the CAD environment when physical models are produced in the workshops, especially through rapid prototyping methods (e.g. 4-axis milling and 3D printing). CAD does not replace the "design thinking" involved in the hand sketching process or the physical construction of the object; *the virtual model is only as good as the data that drives it*, but CAD does enable fluent iteration, as well as thorough and meaningful evaluation.



Coinciding with the first semester of the second year studio is the **Design Proficiencies in Workshops** course consisting of a five-week module in the wood shop and a five-week module in the metal shop. Experienced shop technicians lead these courses, which include critical skills for manipulating wood and metal power tools. The course is designed to build upon the skills acquired in the First Year Shop Orientation by providing a more in-depth survey of materials and processes as they relate specifically to product development and prototyping. Topics in the Wood Shop include: wood technology, tool safety, production order (from sketch to final form), wood joinery and product assembly. Topics in the Metal Shop include: measuring tools, cutting and altering sheet metal, welding, and operating a mill and lathe. The workshop format encompasses more than wood and metal within the studio, short demonstrations are common during transitions from one form exercise to another; including introductions to thermoforming in our plastics laboratory, paint finishing, resin casting, book-binding, and clay slab construction.

The key integration of all of these courses is *shared language*; the CAD course, for example, aims to explain software behavior through terms used in the Design Visualization course (including form generation from 2D sketching, cross-sections, and translation of points in space), to achieve similar results. Similarly, the process of building a model in CAD is one mode of form generation, though less comprehensive than the physical modeling processes in the Design Proficiency Workshops. **Additive, subtractive, and deformative** processes for the construction of form relate in the virtual model and the physical manifestation of ideas. We strive to consider and reconsider the terms of our work across all of these classes. *How do we construct a fair curve with a pencil using our whole arm and torso? What is the structure of software that allows the same? What are the machine capabilities that enable the expression of a fair curve...as a line, a plane, and a solid mass?*

**Form Families:
Joseph Ballay**

Our renaissance of systematic form study at Virginia Tech began with a more contemporary concept, *form families*, developed by Joseph Ballay, industrial designer, partner at MAYA Design and educator (Emeritus Professor at Carnegie Mellon University). According to Ballay:

Families of Form is an attempt to develop an industrial designer's primitive form vocabulary. It isn't meant to be exhaustive, but inclusive enough to provide designers—industrial design students in particular—with enough form language to explore beyond the narrow, predigested form clichés that popular culture provides.⁴

Ballay conducted two workshops with the second year studio at Virginia Tech during the fall terms of 2009 and 2010. We have now advanced Ballay's concept, reshaping our foundation curriculum, toward a *form-matrix*, which addresses the qualitative nature of form-giving, by developing a morphology for this spatial language. Ballay describes *levels of form* (line, plane and solid) and *form families* (linear flow, planar flow, solid flow, et al.) together as a set of processes by which students move through hierarchical decisions towards a specified product form (see Figure 1). At Virginia Tech we have reshaped our second year studio to begin with these and similar processes.







	FAMILY Tectoform	Flowform	Rotoform	Plastoform
MODE Line	Linear-Planar Tecto 	Linear Flow 	Linear Roto 	Linear Plasto 
Plane	Linear-Planar Tecto 	Planar Flow 	Planar Roto 	Planar Plasto 
Solid	Solid Tecto 	Solid Flow 	Solid Roto 	Solid Plasto 

Figure 3. Table of Ballay Form Families with 2011-2012 student work embedded.

**Case Studies:
The Studio &
The Form-Matrix**

The cases discussed include versions of Ballay's form exercises: *linear flowform*; *planar flowform*; *solid flowform*; *solid rotoform*; and *solid tectoform*, plus a new exercise in 2012, *linear-planar tectoform*. Our mission with the exercises is to precede each with an etymological discourse on how and why we associate particular terms with properties of materials and behaviors of shapes. For example, in discussing flowforms, we have a cursory discussion of fluid flow—hydrodynamics. We place terms within tangible and *learning* (as Burchard would describe) situations: we understand a fair curve through the critical relationship between the form of an airplane wing and air and the form of a ship's bow and water. Burchard explains the studio as a place that provides situations where students discover their composite skill sets for solving complex *problems*.⁵ As a way of unpacking the inherent complexities of form, we use the concepts of morphology, syntax and semantics—building blocks of language. Points, lines and planes, for example, each have their own inherent hierarchies (morphology); when joined they create other syntactical relationships; and when we iterate on those relationships, we are manipulating the semantics of the ultimate form—how the form communicates and to whom.

We have designed extensions to the exercises, which are *product* projects. Students are asked to take forward lessons learned from the exercises, directly and immediately, into a product with specific utility. The examples featured: *tool cradle* (responding to the linear-planar tectoform); *platter* (responding to the planar flowform); *hand tool* (responding to the solid flowform); and *citrus juicer* (responding to the solid rotoform). For our own assessment we conducted a series of interviews with students about their making process. In a selection



of the case studies below, we have included excerpts that best express pivotal moments in the understanding of form. This work is the genesis of an educational idea; the exercises still experimental. Some of Ballay's conceptions, such as the *plastoform*, have not been fully investigated.

01. Linear-Planar Tectoform

We begin with *line* and the points forming it, not unlike how we traditionally learn geometry. The focus is on using a limited number of thin components to express a composition of tectonic lines (and planes), and in this case we prescribed a focus on *compartmentalization*. At this early stage parameters (limitations) to the project are critical. And this nucleus was a bridge to the first form *product* project—the tool cradle. Key terms: linear-to-planar; intersection; hierarchy; pattern; and inference to compartmentalization.

We represent lines with media on paper or as pixels on a computer screen, and they have width. But these are physical representations of a corresponding mathematical construct; the line is a concept with no tangible presence—width = 0. Therefore, a conversation emerges when we talk about the possible distinction of line versus plane. Where is the *line* between line and plane? How do we differentiate between a linear and planar expression. This project is a beginning to the challenging and rich discourse of the intricacy of form typology. Lina Garada experimented with the argument of line and plane by using one to create the other as seen in Figure 4, Right. She iterated in both wood and metal:

After cutting both planes, I stretched out the lines slowly, to allow the grain of the wood to stretch without snapping. Each line was inserted into the other plane, one by one, like weaving...Fabrication of the idea heightened the importance of material and details. Each material brought new concerns to the table, in addition to more room for iteration within the basic idea.⁶

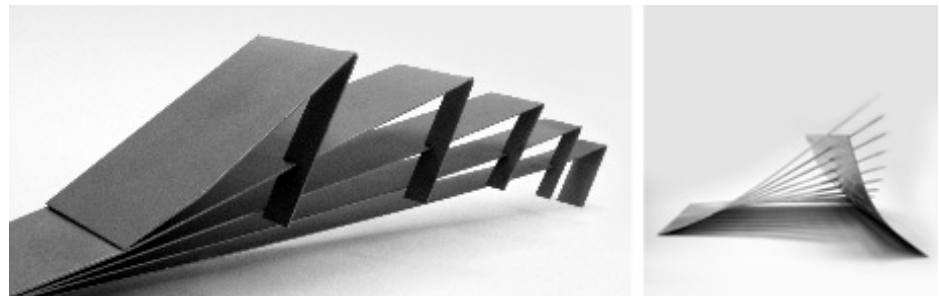


Figure 4. Linear-Planar Tectoform exercise 2012. Left: Campbell Efirid (steel). Right: Lina Garada (aluminum).

02. Tool Cradle

We quickly move into a first *product project* as a way to differentiate the studio experience from first-year foundation, which is largely focused on the abstract. It is crucial to build the relationship between form and utility early in the second year. The **tool cradle** product is for *small* tools. Students choose the tools of: drawing; painting; ceramics; workshop (for lathe, mill, drill, etc.); mechanics; electronics; medical; sewing; or they may suggest one. As a brief introduction to user-centered research, the students must also investigate and characterize a persona through interviews and ethnography of three users. Further, we require secondary research of current trends in the respective product areas. Key terms: linear, planar and/or solid tecto form; linear, planar and/or solid flow form; compartmentalization; hand interaction; target persona and user needs. In the first semester students worked in drawing and form modeling to prepare for fabrication in spring term. In the example in Figure 5, Alex Chiles developed a concept for holding design markers. She worked iteratively in modeling foam and Adobe Illustrator before moving to CAD:

While my form is fairly simple, it does have some complex geometry on top to create



individual marker cradles...In the early design process I wasn't entirely sure how or what I would do with the extrusion, but I knew I wanted the section to do most of the "work"... when I moved on to designing the extrusion, production started to play a larger role. This switch happened mainly because I started to iterate in *SolidWorks*.⁷



Figure 5. Tool Cradle Project 2012. Alex Chiles.
Left: Foam Form Study; Middle: Ergonomic Study; Right: CAD Model

03. Solid Tectoform

While three-dimensional thinking is inherent in all of the projects, the solid tectoform introduces a direct discussion of solid massing. Like the linear-planar tectoform, the solid tectoform exercise focuses on a limited number of components to express tectonic intersections. However, this project involves breaking apart a mass, conceptualizing a cut that yields sub-forms that must be re-assembled, shifted or rotated. Key terms: intersection of planes; shift in planes; and part-to-whole. The simplicity of a 2x4x18 inch blank makes band-saw iterations rapid and fluent, beginning with foam (see Figure 6).



Figure 6. Solid Tectoform 2012. Foam Form & Assembly Study; End: Final Form & Diagram (poplar): Alex Barrette

Emma Weaver designed one of the simplest tectonic expressions, and explains her approach:

Solid tecto was one of the simpler forms to fabricate because it was about adjusting the saws and planer before the cut, and then just pushing through... "I didn't want it to be a very complicated object with multiple vertices; I started to realize I could alter it but keep it simple and go about it in an architectural way."⁸

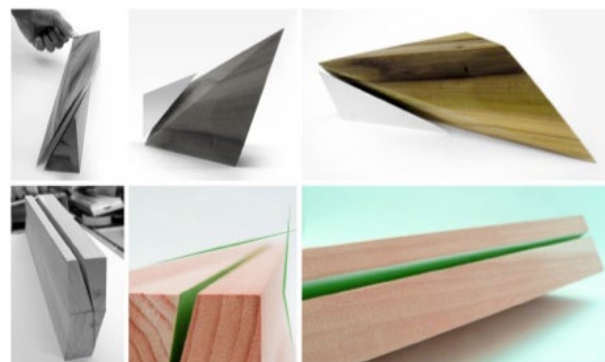


Figure 7. Solid Tectoform 2012. Left: Re-assembly Studies; Top row: Peter Beegle; Bottom row: Emma Weaver



04. Linear Flowform

The focus shifts here from the more straight-forward tectonic form to fluid form, building on the concept of the fair curve. Students are once again allotted a limited number of strip components to express a composition of fair curves, linear flow, and hierarchy. Key terms: linear, fluid flow; uninterrupted fair curve; direction; acceleration; and the suggestion of volume.



Figure 8. Linear Flowform 2011 & 2012. Left Top: Nick Ascosi (steel); Top Center: Kevin Jones (steel); Left Bottom & Center: JT Kelleher (basswood); Right: Linnea Morgan (poplar).

04. Planar Flowform

We move from line to plane, again following the mathematical model. Here, *design* happens after a thermoformed blank is made using sheet plastic, thermoformed over a simple armature. After close observation and sketching on the resulting deformed sheet, students trim away gratuitous plastic to reveal a plane that expresses fluid transitions in and between projections. Key terms: planar flow; fluid transition; contrast; spine; and defining a volume.



Figure 9. Planar Flowform 2011. Diagramming the cuts of thermoformed polystyrene sheet. Top: Adam Frederick; Left Bottom: Michelle Gailhac; Right Bottom: Hannah Minnix.

05. Platter (a flowproduct)

How is a platter constrained by planar flowform? We move students forward to the second form product, the utility of a plane, by taking lessons from the planar flowform— fluid flow, contrast, perceiving a volume—and adding the concept of serving. We also introduce the properties of the hand and how human anatomy extends form behavior. Key terms: plate; platter; platen; sweep; contrast; contain; and offer. Of all lessons learned in the past two years of reshaping our second year curriculum, the platter project stands out as the most comprehensive, revealing and successful. The simplicity of the assignment, the placement of the project in the sequence of form exercises and the variety of material options available to the students were serendipitous.





Figure 10. Platter Project 2011. Edward Coe. Top & Bottom Right: 3D Print; Left: Clay Slab Study & Diagram.

The platter does not demand complex utility, just enough to elicit more responsibility from the students. *Serving, containing* and *offering* didn't intimidate the students. Etymologically we made an easy leap from *plane*, to *platen*, to *platter*. And drawing the platter form was intrinsically convincing as an assignment for fluid sketching. Julia Novak completed her platter using clay slabs over a foam mold covered in cotton fabric. She recalls:

I scraped away around the edge to find the fair curve...It is the first time I experienced the materiality of clay. The project allowed me to explore the capabilities and limitations of clay...The warmth and even color of the clay gave me more warmth for an offering platter⁹



Figure 11. Platter Project 2011. Top Row: Julia Novak; Bottom Row: Hannah Minnix.



**06. Solid
Flowform**

While still leaping from plane to three-dimensional mass, as in the solid tectoform, we now take lessons learned in the planar flow and platter forward to three-dimensional *flowform*. We use a common construct of a pair of curved plane cuts through a material blank (4x4x18 inches). The emphasis is now on intersection and the resulting complex, solid flowform that expresses continuity of line, plane and mass. Key terms: continuous flow; intersection of planes; intersection of extrusions; volumetric; and profile. Alex Barrette describes the overlap of working styles and how it influenced his concept:

Making models, putting it on paper, and then making a full scale model, that was really the big step for me. When I had it on paper it looked completely different than what I imagined it to be, because when you cut this out of a square blank, you don't see the whole shape—you see the outline of one shape. When you open this up (meaning taking away from the outside with cuts running through the solid) you don't know what you are going to get until you actually see it all, it is like opening a present.¹⁰

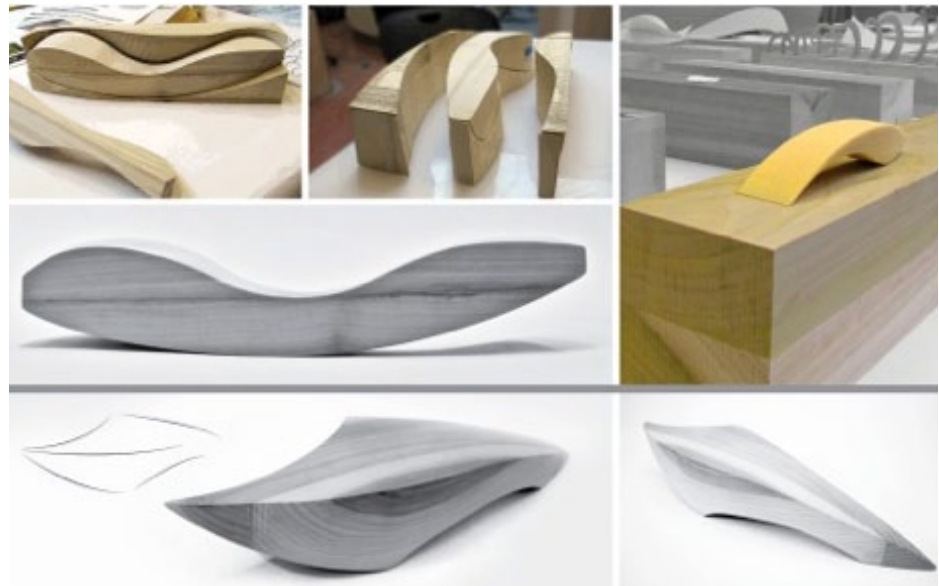


Figure 12. Solidflow Exercise 2011. From foam studies to bandsaw profiles. Top Left & Middle: Alex Barrette; Bottom Row: Max Berney.

**08. Hand Tool
(a flowproduct)**

Blending forms is different than focusing on a single form typology. This is the third form product project where students are asked to combine multiple forms and utility. We move students forward immediately from the solid flowform exercise to the utility of a simple hand tool: continuous flow, and complex, transitional surfaces. We limit the requirements of the tool to scooping, scraping or cutting, in the kitchen. The form should embody the semantics of one of these activities and, once again, the relationship to the human hand. Critical to form thinking, emphasis is on **the form doing the work**. Key terms: transition; contrast; and scale.





Figure 13. Hand Tool 2012. Alex Barrette. Sketch to Foam to Hardwood.

09. Solid Rotoform

Embedded in the solid flow construct are still more complex configurations of form. Cylindrical, spherical, bending, twisting, swiveling, etc. behaviors are common. This exercise focuses on a modest move from the solid flow to **turning** a solid flow. The emphasis now is still on a profile, as first discussed in the solid flow exercise, but now the profile must yield a decision for cutting through, interrupting, the axis of the form. Reassembling the sections must express a change or shift in the axis. Again the resulting form should express a thoughtful intersection and emphasis on the subforms. Key Terms: axis; shift in axis; profile; and intersection-compatibility. Emma Weaver describes her struggle with proportion and how she made decisions critical to the final form:

I started off with a fairly small model made out of foam...but you can't really understand how a form is going to read until you have made it full scale. By making the original smaller form from the blank, I don't think I would have known from looking at a computer screen that it would feel this way to the eyes until I made it in this scale, and then I knew it was just too small. I had to go outside of the original prompt and blank size...It is a nice feeling to start out with a big blank piece of wood that doesn't really say anything...you just start to remove layers and you get something smooth and something completely different inside...¹¹



Figure 14. Solid Rotoform 2012. Emma Weaver. Paper Model to Sketch to Scale Model to turned Hardwood.



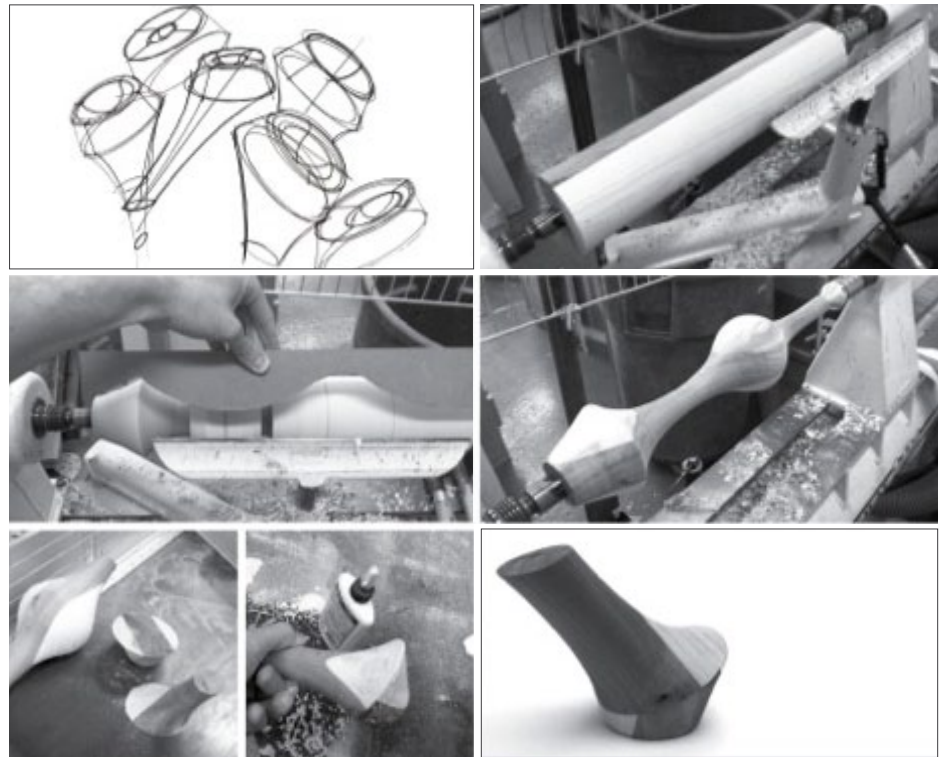


Figure 15. Solid Rotoform 2012. James Connors. Sketch to Blank to Profile; Cut; Reassemble.

**10. Citrus Juicer
(a roto-product)**

In the final form product project students must again combine multiple form constructs and utility. In this case we move students forward immediately from the rotoform exercise to a simple hand tool—but including rotational utility and behavior by designing a tool for reaming citrus, not smaller than a mandarin orange or lime, and not larger than a grapefruit. *How does the new form improve the long-existing wooden, single-axis juicer?* Key terms: axis; shift in axis; profile; and intersection. Shane Zeigler explains his conceptual and fabrication tool path:

The juicer was developed over a series of iterative sketches. The sketches were then translated into Solidworks [CAD] models in order to more fully understand the form. I gained confidence on the lathe while developing my rotoform. This led to a decision to use the lathe for the complex form of the wooden shell of the juicer.¹²



Figure 16. Citrus Juicer 2012. Shane Zeigler. 4-Axis CNC milling (interior reamer) and hand-guided turning (vessel).



Conclusion

When assigned a project that at first glance seems mundane, like a plate, students must abandon what they think they know. The perception of the inexperienced eye is that plates are not remarkable and that no one *designs* them, and yet it is precisely this type of object that embeds itself in daily routine. Students can be victims of style and fashion, with a narrow view of morphology. An immersion in material and process elevates one's sense of composition and structure. That level of engagement forces a *coming-to-terms* with the language of form. Student J.T. Kelleher reflects on the workshop experience:

It is so much better to have it in your hands, as easy as it is to 3D-print or mill something. Doing it yourself and making decisions in real time [allowed for] noticing something in the wood shop and saying 'what if it does this or that?' was one of the best things [about the project]. When you work with something you start to make a map of what can happen, what the tools can do, what the material can do...¹³

The making process commands a set of principles of *acceptability*, which emerges necessarily through grappling with form language. Whether through words or material, form then becomes an *active* constituent in design education. In the studio and simultaneously in the workshop, students can build a set of standards that survive beyond the university.

We ask ourselves if pushing a student to work out their form principles facilitates an ability to make good work...for a long time? We want students to understand form as the most important thing in the world, as consequential in all endeavors of social involvement, not just in the case of making good products. Otherwise, we become subject to entropy and indifference. Studio work is the catalyst for imprinting a student's trained eye for form. However, the education within our triangulation of courses is not path dependent. Whether work is conceptual, analog, or digital there is transfer of information between and beyond these domains of design through the integration and synthesis of form and the problem-solving process of a product designer. Studio is in fact an analog for the higher purpose of education, a moral enterprise. Design occurs there, but design is simply a conduit for students to establish a set of principles of acceptability...for their life. If a student is asked to identify a fair curve (like the bow of a boat), she isn't just learning to see it in objects; she will see it as authenticity, and look for it in other situations.



Endnotes

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- ⁴ Joseph Ballay, *email message to Mitzi Vernon*, December 8, 2009.
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Mitzi Vernon /
Industrial Design /
School of Architecture + Design /
Virginia Tech /
vernon@vt.edu

Mitzi Vernon is a Professor of Industrial Design in the School of Architecture + Design at Virginia Tech, Blacksburg, Virginia, USA. Her career spans 25 years of practice and teaching in industrial design, engineering and architecture. As Principal Investigator of the project, Fields Everywhere, she has been recipient of several patents and grants supporting her research in using design to teach science to children. She was one of the inaugural speakers for VT TEDx, delivering Mapping the Invisible; is co-PI of the NSF project, Studio Collaborative, studying the design studio as an educational model for the design of software-intensive systems; and is an Edward Singleton Diggs Teaching Scholar. She has also been honoured with a 2008 Dell ReGeneration International Design Educator Award and the prestigious William E. Wine Award for Excellence in Teaching.

Martha Sullivan /
Industrial Design /
School of Architecture + Design /
Virginia Tech /
millsulli@vt.edu

Martha Sullivan is a Visiting Professor of Industrial Design in the School of Architecture + Design, at Virginia Tech, Blacksburg, Virginia, USA. Martha instructs courses in Ceramics (hand-building, wheel-throwing, and slip casting), Computer Aided Design (SolidWorks for students in Industrial Design), and Foundations of Design Laboratory (a first year course for students of architecture, landscape architecture, industrial design, and interior design). In 2013, Martha was awarded Virginia Tech's University Certificate for Excellence in Outreach for conducting service learning projects in multiple courses with students, as well her volunteer work with regional art associations. She has previously been honoured with an Excellence in Teaching award from the College of Architecture and Urban Studies, as well as the Gianninoto Graduate Scholarship from the Industrial Designers Society of America for her thesis work in industrial ceramics.

