# Learning by Making

## Embedding Hands-on Experience into Industrial Design Education

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# Preface

In the beginning of your career, if you tell someone what you do for a living they are generally impressed if the answer is specialized and unique. In my twenties when I told someone that I designed large custom superyachts, they would be impressed. It is a small industry which caters to an even smaller demographic. In my thirties when I tell someone what I do, I can stand there and watch the color drain from their face. Most of my friends look dimly on excess and luxury. Unlike when I was in my twenties, I am now surrounded by people in their thirties and forties, and fortunately for me they have asked themselves the same question that I have asked myself. I no longer ask, "*Can I do this job?"* Instead I ask, "*Should I do this job?"* I still love boats of all types, and I still enjoy the job of designing them. I must admit, however, that my reasons for doing so have changed.

Somewhere early on in my practice, I found myself knee deep in journeymen craftsmen. At first these individuals were a real bother. They could see right through my fancy drawings, and knew without a doubt, that I had very little knowledge of their work. Afraid of being exposed as a witless upstart, I came clean and confessed my ignorance. This apparently is not common among my colleagues and the still-in-shock craftsman took pity on me and began to teach me everything they knew about woodwork, joinery and fine furniture making. I never made any furniture myself, but I did spend a lot of time in their woodshops; years in fact. My drawings began to reflect *their* understanding, until eventually what I was drawing was a great challenge for the cabinetmakers to construct, but not at the expense of ignoring their constraints, rather acknowledging their talents.

As the years went by and I found myself working through multiple projects in varying cultures around the globe, a steady curiosity always took center stage. I was always searching for something genuine and real amongst all of this excess . . . the craftsman. For 14 years I have worked alongside men and women who do a job well for its own sake. Regardless of circumstance, they live by a code; a standard, and their pride is housed in their work. They use their hands in a shop space, and they might be part of a group of people that will someday be replaced by machines and robots. It has happened before.

To stop their extinction, some of us need to become craftsman. We need to understand what they know, and how to solve problems the way they do. I believe we do not have to give up our current careers to do this. I wanted to find out what this experience is like, and as an Industrial Designer, I was curious to discover a few things: would I be able to reach the same level of quality as they do? If I have to build one of my designs, will it change my design? Will this change make the design better or worse? After going through this process of hands-on making, will my design thinking change as well? To find out I made this my focus in graduate school. It has been fourteen years since the last time I was required to work in a shop space and build physical models of my designs using manual skills. The setting then was my undergrad work at a university. Now, back in the university, I was asking, "*Should I do this job?"* Instead of "*Can I do this job?"* The wood shop is my laboratory, and the woodwork is my research. I will set out to document and hypothesize outcomes for the sake of preserving the tools and knowledge found exclusively in a shop space. These tools and experiences belong in the hands of Industrial Design Students. Hopefully my work can be embedded into their education.

# Introduction

Industrial Design education must always endeavor to close the gap between academic experience and vocational relevance. To this end, students are trained how to use the latest tools available to the design community, such as 3-D software, computer rendering, rapid prototyping, and computer assisted manufacturing. Proficiency in this area of study reflects current requirements for entrance into the profession. This has been true for quite some time. In fact, enough time has gone by that design thinkers are evaluating the results of this training. It is at this time that a new light is cast upon an old debate; manual skills verses digital skills. This is not a debate regarding class or nostalgia. The bigger question that has come to light is: What gets lost when digital technologies replace physical drawing, model making, and prototyping? While industrial design programs still require some manual skills, some schools are emphasizing design processes, start-to-finish, that are hands-off. Students who focus solely on the mastery of screen work will miss the benefits of engaging the other five senses prevalent in physical work. These senses connect to the brain in a way that informs the students' multi-sensory design intelligence. When digital tools are used without this tactile experience, the head and hand are separated. Simulation can be a poor substitute for tactile experience. What is at stake is a false sense of security. Sophisticated rendering programs allow for powerful presentations, but can be misused if the seductive nature of the presentation arrives before solutions are built into the final design. Design students are better served learning how to discover problems rather than hide them behind communication imagery. CAD and rapid prototyping can suppress manufacturing difficulty. In design school, this may never be exposed. In professional practice, however, this gap is expressed. In the professional world, this false security is expensive, wasteful, and destructive. This is widely known because it occurs in professional practice every day. Why not instead train students to think like craftsmen? Education in any creative field must begin with questioning the absoluteness of the lived world. Students cannot do this by looking at a screen alone. They need empathy for materials and processes that are best learned through repetitive, concrete, hands-on training.

Using well documented experiences with hands-on activities, a series of tests will be conducted which pit the designer's instincts against real-world applications. The drawings and diagrams common to initial conceptualization will be considered the beginning of product development, followed by hands-on conceptualization in the shop space. This activity will demonstrate that when designers consider the shop space as part of the problem-solving studio, the results will be notably different and unique to any other alternative or simulation. Initial results record a great sense of accomplishment preceded by frustration, on-the-fly changes in course, new-found empathy for the materials and rewriting the script or throwing it out completely. In essence, everything the designer does not know at the completion of *hands-off* conceptualization will come out in the experience of hands-on making. Instead of powering around roadblocks and worrying about deadlines, this effort will zoom *in* on the roadblocks in an attempt to understand hypothetical flaws. The outcome will be a fresh new approach to Industrial Design curriculum which emphasizes hands-on making and the importance of building a genuine sense of security in the overall design process.

# Research

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Research suggests that the ideal creative process is multi-sensory. Manual competency as some have stated, connects learning to our brains through our hands. Beithecker concludes, (2010) *"Sound, smell, taste, touch, and movement power memory. An environment rich in sensory experiences helps students retain and retrieve what they learn."* (p. 177). With this in mind, the subject of research will be two pieces of wooden furniture.

**Treble Clef Wall Desk-** A wall-mounted articulating desk. The desk is designed to have a fold-down work surface which provides space for a laptop. When not in use, the work surface folds up into the laminated carcass and protrudes from the wall no more than 12 inches. The desk will be built primarily out of donated hardwood veneer laminations. The process is one of only a few additive processes in woodworking. Most woodwork is subtractive. Along the way, many processes will be implemented and reworks to the original design will take place. What will this say about the competency of the original concept? Does this reworking take place when a designer hands a drawing to a craftsman? These questions will be interesting discussion points.

Hypothesis: Making in a learning environment means sharing space. The nature of veneer is square footage; something that shared-shop spaces have very little of in reserve. Cutting and taping veneer flitches into sheets with the correct grain orientation and pattern takes a lot of space, patience, and accurate planning. Slow work then becomes fast work at glue-up and loading onto the mold require quick reflexes. If a mistake is made in the molding process will the designer have to start over?

Findings: Making this project required understanding the tools; sometimes adapting them by making jigs and carriages to allow enhanced bespoke uses of the tools to meet the needs of the geometry.

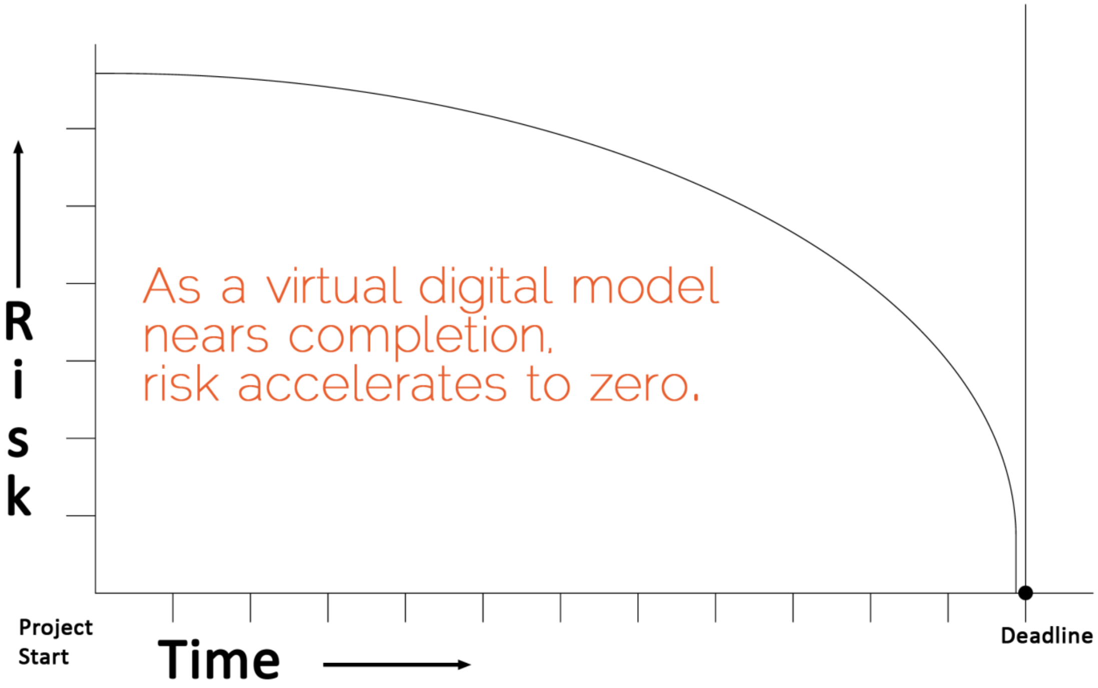
Working in the shop environment means relying upon others to assist and critique. The *drive-by-feedback* is valuable and flows naturally in a shop space.

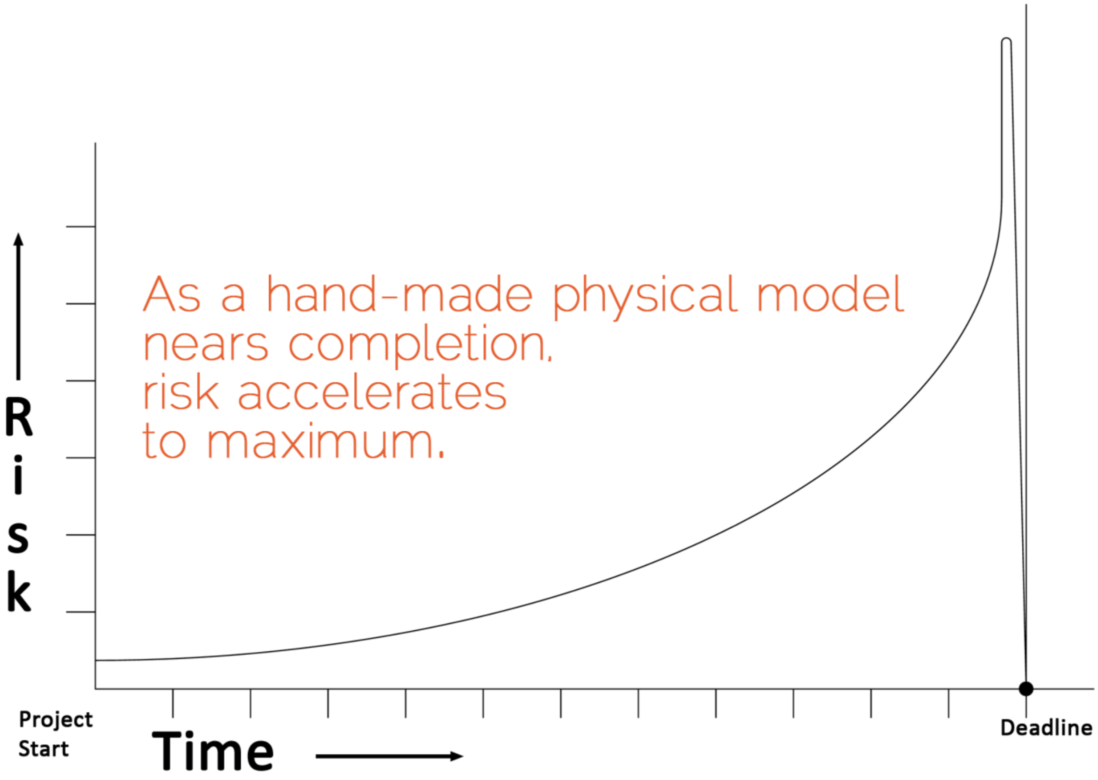
Things break. The shop space does not care how perfect a CAD drawing is. The materials fight back and require a great deal of dialogue between maker and material.

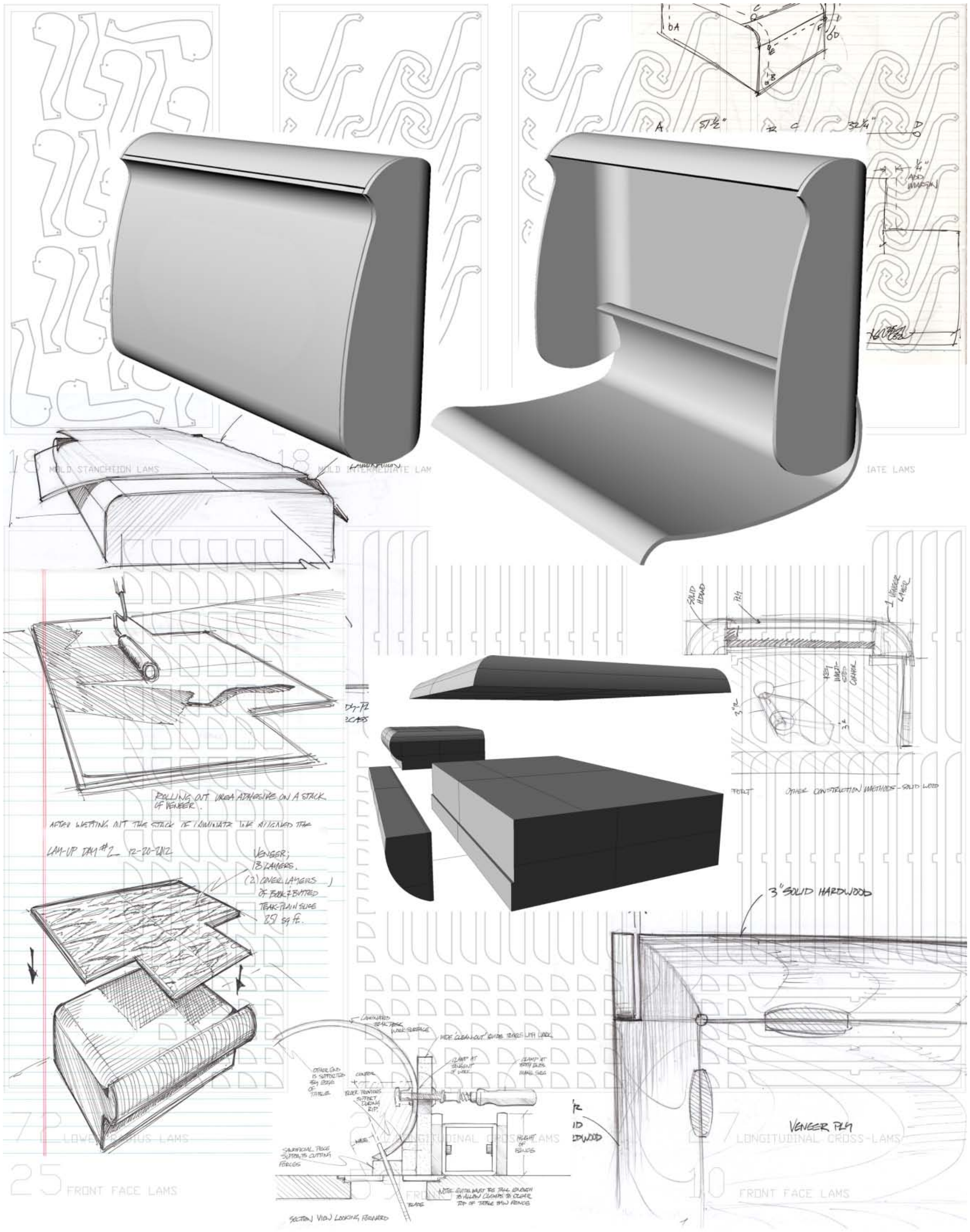
Shifting reference – The object takes form in a shop which in turn makes parts or all of the drawing obsolete as far as a point of reference at full scale. Better to rely upon the built object than the symbol of the built object.

It is always good to continue drawing throughout the building process. Sketches are not just for showing other people ideas. Students need to see their own ideas and figure things out. Pirsig discusses the difficulty with this ability to see, (1975) "We are trained *not* to see it. . . The truth knocks on the door and you say, "Go away, I'm looking for the truth," and so it goes away." (p. 5).

In the shop space Risk-taking is an inverse operation from the virtual digital making process. See diagram.


As a virtual digital model
nears completion,
risk accelerates to zero.
Risk
Project Start
Time
Deadline


As a hand-made physical model
nears completion,
risk accelerates
to maximum.
Risk
Project Start
Time
Deadline



The collage above shows 3D CAD models, CNC cut patterns and support sketches. Toward the middle and end of the project, the designer relies on sketch documentation that is used for thinking on-the-fly. Pirsig explains, (1975) “We navigate by dead reckoning, and deductions from clues we find.” (p. 6). Drawings are not the only clues to what a design should be.

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Using cut-patterns of teak and mahogany veneer with a single-sided mold/vacuum bag process.

**3-Legged Tractor** – An adjustable height stool. Tractor seats are used as retro bar stools, as motorcycle saddles, and even in racing canoes. They were once made of cast iron and contained intricate decorations and logos. You can buy a modern tractor seat office chair. These highly recognizable forms symbolize some of the first attempts at ergonomics. The 3-Legged Tractor will be made of laminated solid hardwood and will involve a large turning operation on the lathe followed by a great deal of hand carving. The form of a tractor seat is the perfect candidate for a 3-axis CNC operation. The computer can easily handle the various contours, valleys and peaks. However, what fun would that be? Hand carving is the pinnacle of intimate slow woodworking. If the objective is to work really fast, then the CNC router can make quick work on the complex form. But the objective is to see how much one can learn from the material, and about the material. Pallasmaa explains, (2009 "You cannot make what you want to make, but what the material permits you to make" (p.55). This will require developing muscle memory, understanding grain direction and tear-out, and learning how to make symmetrical forms.

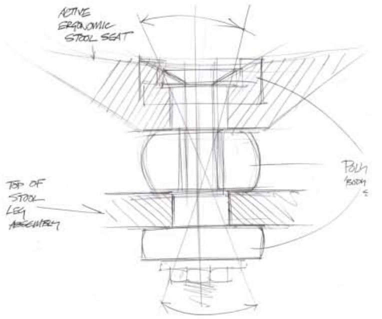
Hypothesis: Stack-laminated solid wood joinery is an exercise in accuracy and material selection. This project will be the opposite of working with veneer. Each step should require careful planning to assure that the choice of joinery is a tight fit. Solid wood expands and contracts and knowing this should affect the type of cuts in relation to the grain. Some say the chair is the hardest design problem to solve. This stool will share this burden. Weight bearing furniture tests the craftsman's understanding of force.

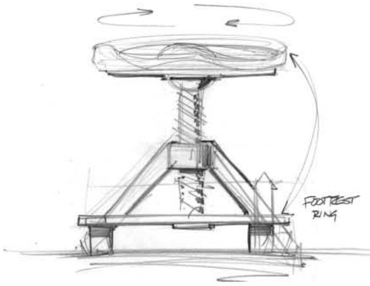
Findings: Incremental steps verses overall process. Building this project teaches the value of knowing more than just the next step. With several identical pieces, the designer learns to use the tools as an assembly line, and make extra parts in case something breaks. Designers are used to creating process books for their projects, but knowing that a stool leg will require 34 separate operations before complete is a more intimate understanding of materials, tools, and the ramifications of a given design.

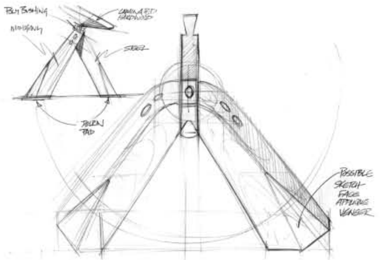
Haptic Feedback - Hand carving a material does not just remove material; it maps the surfaces of the wood to your brain through the sense of touch. Muscle movements adapt to this map subconsciously and enhance the efficiency of the carving motion. Designers must touch their work.

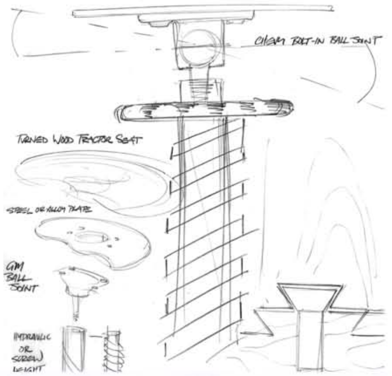
Knowing that *tear-out* is a primary concern when working with solid woods, the *field of perception* needs to increase around such activities. Understanding any material's weakness should prompt the designer in the shop space to the same state of mind. Ken Robinson states, (2001) "We do not see the world as it is but as our particular human senses present it to us." (p. 115).

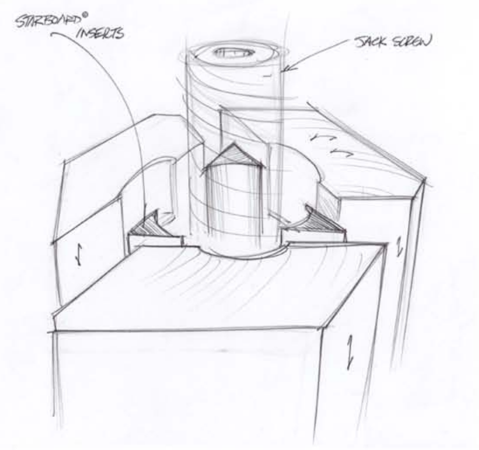
Skewing – Building a wooden stool out of solid boards is a subtractive operation. Once material is removed from a certain region of a part, the chances of reconstituting the part to the original form are slim to none. The right approach to any material or model making activity is *skewing;* the act of tilting the sharp edge of a chisel to release a little bit of material at a time. This lowers friction while increasing leverage without giving up control because the other side of the blade is still clamped beneath wood that has not yet parted. Skewing can be a philosophy that controls the momentum of a process in the shop space no matter what material. In philosophical terms, this mindset is patient and controlled in the face of collapsing deadlines.

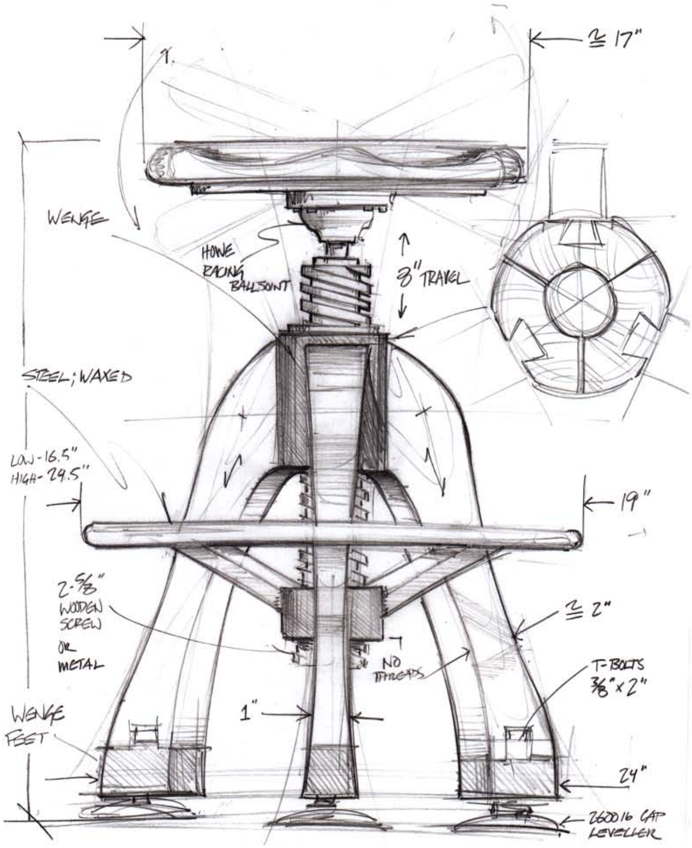

ACTIVE ERGONOMIC STOOL SEAT
TOP OF STOOL LEG ASSEMBLY
POLY BODY

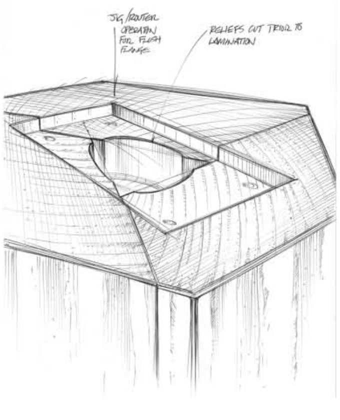

FOOTREST RING

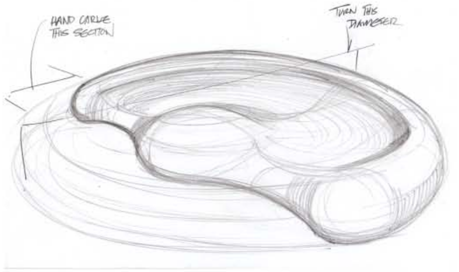

POLY BUSHING
LAMINATED HARDWOOD
MAHOGANY
STEEL
POLEN PAD
POSSIBLE SKETCH FACE APPLIQUE VENEER

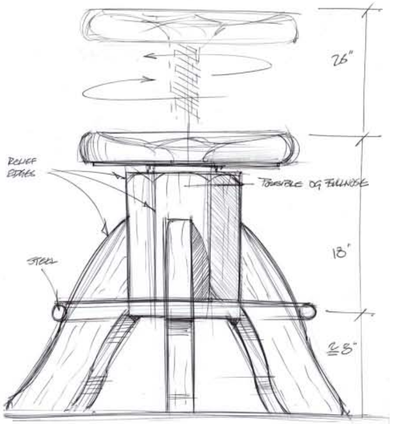

CHEVY BOLT-IN BALL JOINT
TURNED WOOD TRACTOR SEAT
STEEL OR ALLOY PLATE
GM BALL JOINT
HYDRAULIC OR SCREW HEIGHT


STARBOARD® INSERTS
JACK SCREW


1"
≅17"
WENGE
HOWE RACING BALL JOINT
8" TRAVEL
STEEL; WAXED
LOW-16.5"
HIGH-24.5"
19"
2-5/8" WOODEN SCREW OR METAL
NO THREADS
≅2"
T-BOLTS 3/8" x 2"
1"
WENGE FEET
24"
260016 CAP LEVELLER


JIG/ROUTER OPERATION FOR FLUSH FLANGE
RELIEFS CUT PRIOR TO LAMINATION


HAND CARVE THIS SECTION
TURN THIS DIAMETER


26"
RELIEF EDGES
POSSIBLE OG BULLNOSE
STEEL
18"
≅8"

Building an assembly line of Sepele and Wenge hardwood parts; cut, carved and turned.

# Application

Students who use a shop space as part of the overall studio space will benefit from working through Industrial Design problems. This is primarily because the making environment, which utilizes hands-on manual skills, offers knowledge and a form of learning that no technology can mimic or substitute. The exclusive knowledge and learning experiences found within are well aligned with the values of the Industrial Design profession.  The hands-on making culture of Industrial Design education is not important because it is an old culture, but because it is a *core* culture. Students have the advantage of being part of an opportunity in school which affords them the right to immerse themselves in all aspects of, and all ramifications of hands-on making. This is a small window of time along the course of their careers. The hands-on making culture rarely finds its way into professional practice. This is to say that students will most likely work for a studio or corporation that contains little to no shop space. However, the experiences in ID students' education help them cross a major threshold in *thinking* and give them possession of ideas and paths to knowledge that they can apply to every project in their professional career.

With that in mind, the next question is: What is the best way to integrate hands-on making into existing curriculum especially where hands-on making of physical models is phasing out? Looking for the right answers begins with identifying three hierarchal tiers that make up the ID educational system.

1.) Section Level- Working with students and professors to shape individual course work syllabus outlines to include shop space experiences.

2.) Program Level- Working with ID faculty and staff to prepare students for the workload of hands-on making and the skills required.

3.) Department Level- Where does the Industrial Design Program belong? How to balance the burden of learning how to become a designer who works with *industry* not just other designers.

## Section Level

This is the biggest section, because at this level the most can be done in isolation of any hierarchal politics in place at higher system levels. The reference to *drawing* covers any form of communication where Industrial Designers communicate their ideas.

As students begin to hone their skills with drawing techniques, and beginning design theory such as *Line-Weight, Balance, Eye-Movement, Positive-and-Negative Space, Proportions, and Scale* they need to be introduced immediately to the application of theory and the realization of their drawings in tandem. The third dimension is not the successor of the first two dimensions. The third dimension proves the validity of the other two. A hands-on, making-fortified curriculum is a proving ground for 3-dimensional objects from the very beginning.

This approach avoids several pitfalls of beginning Industrial Design students:

1.) Separating image creation from object making. Thus missing the symbolic nature of design imagery.
2.) Delaying the values and benefits of engaging the *other four senses* in the process of decision making with regards to a given design concept.
3.) Isolating the classroom/lecture space from the shop/manufacture space.
4.) Committing to an unproven design without materiality experience.
5.) Justifying a shape or form without considering the tools required for creating the form.

## Part 1 – The Pitfall of Separating Image Creation from Object Making

Professional Industrial Designers will spend most of their careers creating imagery as the main form of their deliverable product output. Their success at this is tethered to always keeping their eyes on the real prize; the actual made object that the drawing represents. The career of the Industrial Design student is different. Sketching, illustrating, modeling and rendering skills occupy a large portion of ID curriculum. Students need this time to master new skills. One may argue that these skills are the most important to master. Portfolio reviews often focus on the designer's ability to communicate via sketches, drawings and renderings. Employers consider this skillset to be the primary bellwether to a candidate's potential, talent, and expertise. Because of this, great emphasis is placed upon mastering drawing technique in the university setting, and rightfully so.

The primary downfall to this emphasis on drawing skills is in the case where design students place the drawings *as* the objects and spend too little time with concern regarding the object that the drawings represent. Reverse engineering from a future portfolio review, a design student may place a large portion of time considering what may lie on a few crisp white pages, or within a PDF portfolio. Sophisticated rendering programs allow for powerful presentations, but can be misused if the seductive nature of the presentation arrives before solutions are built into the final design. Design students are better served learning how to discover problems rather than hide them behind communication imagery. CAD and rapid prototyping can suppress manufacturing difficulty. In design school, this may never be exposed. The truths is, much of the valuable, transferrable skills to be obtained during a student's design project are abstract, visually plain and appear with very little pomp and flash. Even if the student engages in a comprehensive integrated making methodology, the portfolio may never show the grit and hard truth reality of the making process. Editing a portfolio to appear like so many on websites like www.coroflot.com does little to show what Industrial Designers wrestle with each day. Another reason this is poorly depicted is because it is difficult to explain. Educators need to address this difficulty and train their students to not only document the real problem solving portion of the story, but also rearrange their programs to place higher value upon the finished product which will be produced in the real world. To deny the students this is to subversively train them that the object of focus is the drawing. How do educators train their students to grasp this emphasis on drawing as a symbol of the object? A number of activities can reinforce this from the earliest stage:

a.) *Simple Form Process Unplugged.*
In a foundation course, the ID student would sketch in perspective, draft by hand at full scale, and construct a white model without any electrical devise. The size, shape, and complexity would not be specified. Design students would be challenged to make do with available tools, and would be graded upon their ability to execute their ideas from paper to a physical model. This activity reveals the relationship between an idea and seeing this idea realized in the real world. The ramifications of the design enter the consciousness at the conceptual stage. On the making side of this endeavor, students begin to connect with the concept of materiality.

b.) *Designer-Craftsmen work things out during the concept stage using all three dimensions in hand.*
From concept to completion, most ID studio course projects are separated into two distinct operations and environments. The first operation is the studio/classroom setting, where lectures, research, concept sketching, drawing development, 3D computer model making take place. (Sometimes the project may rely upon a form study in the shop as part of the first section.) After sign off from a professor, the second operation is the execution of this refined, developed virtual model in the shop space or the rapid prototyping/CNC lab space.

The problem with this is that students believe that they have completed the design, and are simply going through the busy work of making a model *of* their design. They are also led to believe that if they deviate from their refined, fully detailed virtual model, then they have failed to see through the ‘crystal ball’ correctly and will not wish to proceed with confidence. Remember, the students have placed a lot of value on their 3D computer renderings, and may have already earmarked a page in their portfolio for such imagery. If the final physical model looks nothing like their virtual model, have they failed? Can they show images of both in their portfolio? Furthermore, after realizing that their physical model must change, the students feel confused and unsure about the next step. The pressure of a total rework at this stage is high. The fact that they have learned that their virtual model is not right is hardly greeted as a gift. But in fact it is. To know that something is not right is the most valuable discovery in this entire process. What seems out of balance is to discover it this late in the project. With deadlines approaching, the gift is usually unappreciated. Why not give the students this gift at the unset of the project?

Enter the physical model concept. Students can know things about their work immediately after placing their first concepts to paper. Armed with hand drawn sketches, and a simple manually drafted 2D layout drawing, a student can go into a shop space and begin to try out their ideas. The gift of drawing their first idea is well accepted here. The reason why is because the design student has not spent weeks laboring over revisions and refinements with screen work. In the right place on the project timeline, physical model making begins *before* development is completed. This means that the student is armed with a battery of sketch models which inform scale, weight, strength, proportions, and complicated mechanical relationships. Failure to execute their early-stage models spares them the heartache of discovering shortcomings after much more time, labor, and expenses have been invested. Walking back toward the studio, conceptualization continues. New sketches are drawn, proportions are adjusted, week points are reinforced, and the student begins to realize the value of getting away from paper and screen-work sooner than later. The students next round of ideas include the development that could have only taken place in a shop environment; working with real materials and tools. This is called a higher plane of knowledge. Now intermediate steps can take place and drafting can begin. Each level of *Design Refinement* should be accompanied by a round of shop-space proving and discovery. The final model will become aptly named, as there will be many models preceding the last one. In this shop-space integrated process, studio work takes place in a shop, shop work then informs the classroom learning. The line between studio/classroom and shop/lab will be erased. Other advantages to this process are increased shop experience, shop knowledge, familiarity with tools, and the beginnings of problem solving with others.

The figure below depicts the relationship between concrete and abstract with regard to a given design. Once the physical model takes form, the drawings shift from being concrete to abstract. Thus the object becomes the frame of reference.

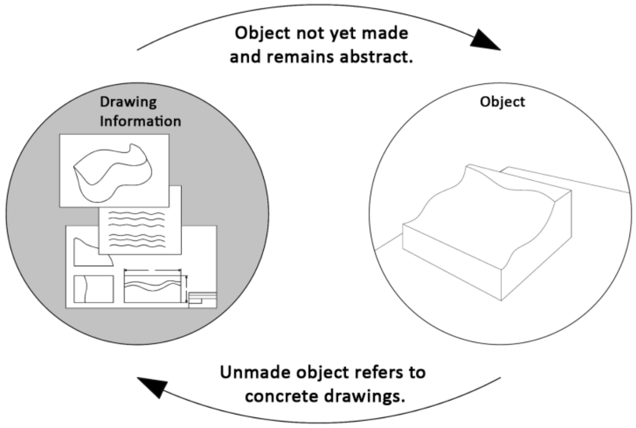


**Fig 1. Initial Phase Drawing information is produced.**

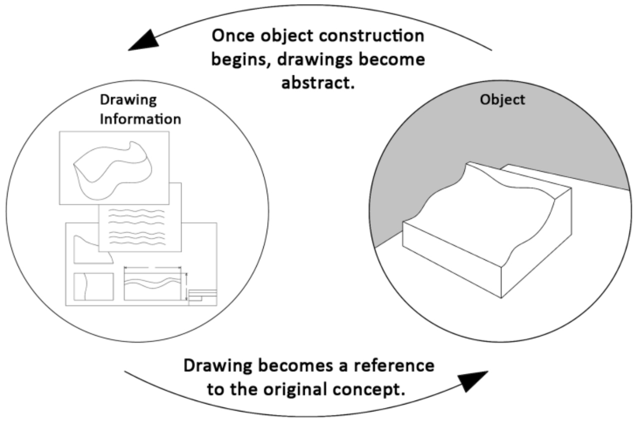
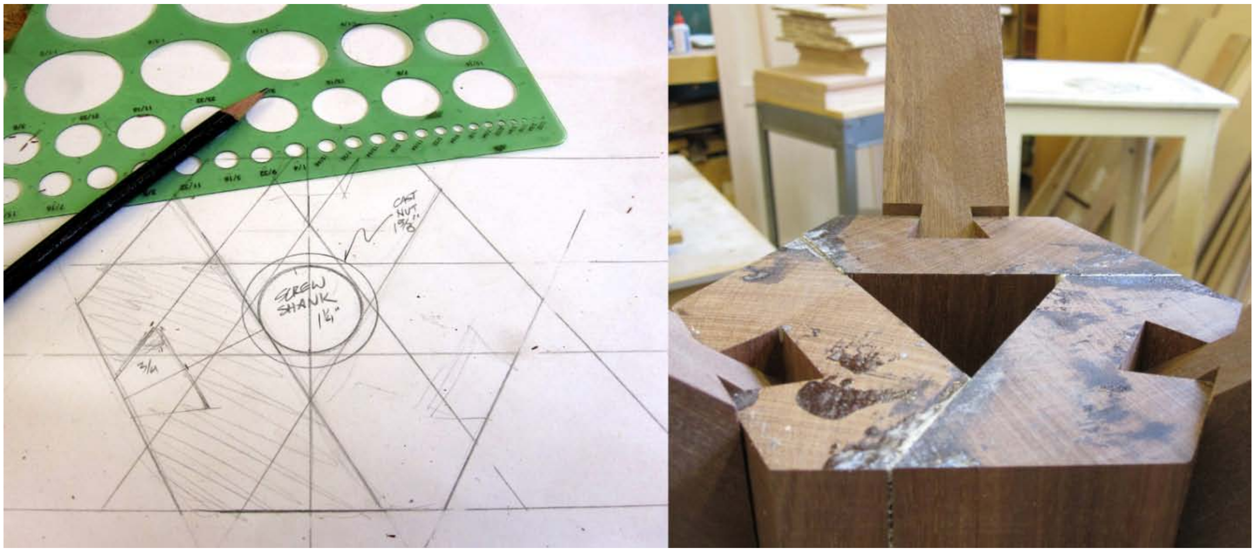


**Fig 2. Final Phase Object is produced.**

Shown Below: Final details are worked out from the pieces of wood and traced out at full scale.

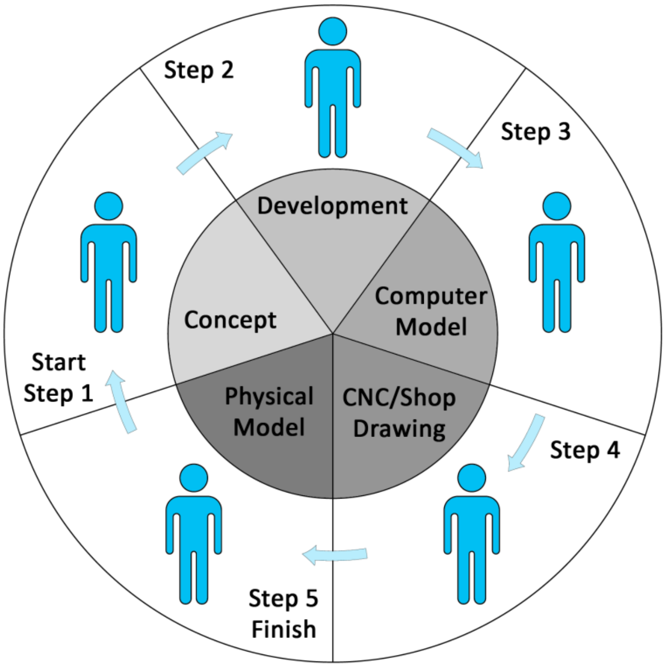


### c.) *Multiperspectival Design for a Singular Object*

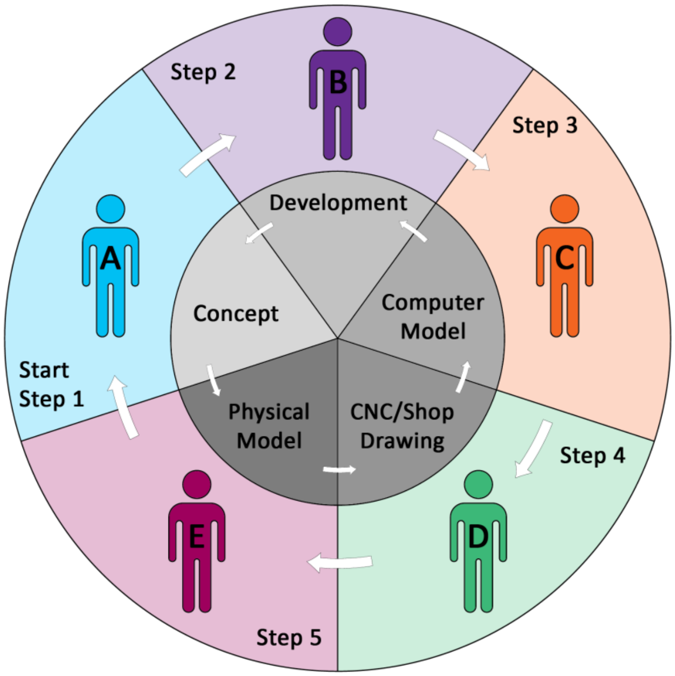
What if the process was set in stone, but the students had to pass portions of the development, and prototyping on to fellow ID students like a relay team for a single project? This is not to be confused with a team project where students work together for each stage. Instead this would mean that the student's initial concepts would be handed to another student to take into the shop and work on the first form studies. Then the second student would pass on the sketch models, hand layout and initial sketches to a third person who would then develop the project in CAD further refining the design. Then a final model or prototype would be constructed by a fourth and fifth person. Each student would shift one step and move over one project to deliver the ensuing step for a different person until each student completed every step in the entire process but for five different projects. The first student who drew concept sketches would pass on their work, and receive from another student their sketches and so on.

This activity would require special focus on each component of the design process. The ownership of the entire project would be distributed among five students, with each of them owning an entire step exclusively. Communication would become a crucial element. Furthermore, the drawing as a symbol would become all too real. The sketches are now objects of description and prescription passed onto another individual who possesses an obligation to find solutions from the drawings. Using multiple design students for each separate phase of process would teach students the value of accepting criticism, respecting others' ideas, and co-ownership of a complete project. The only element the team would have in common would be the object itself.

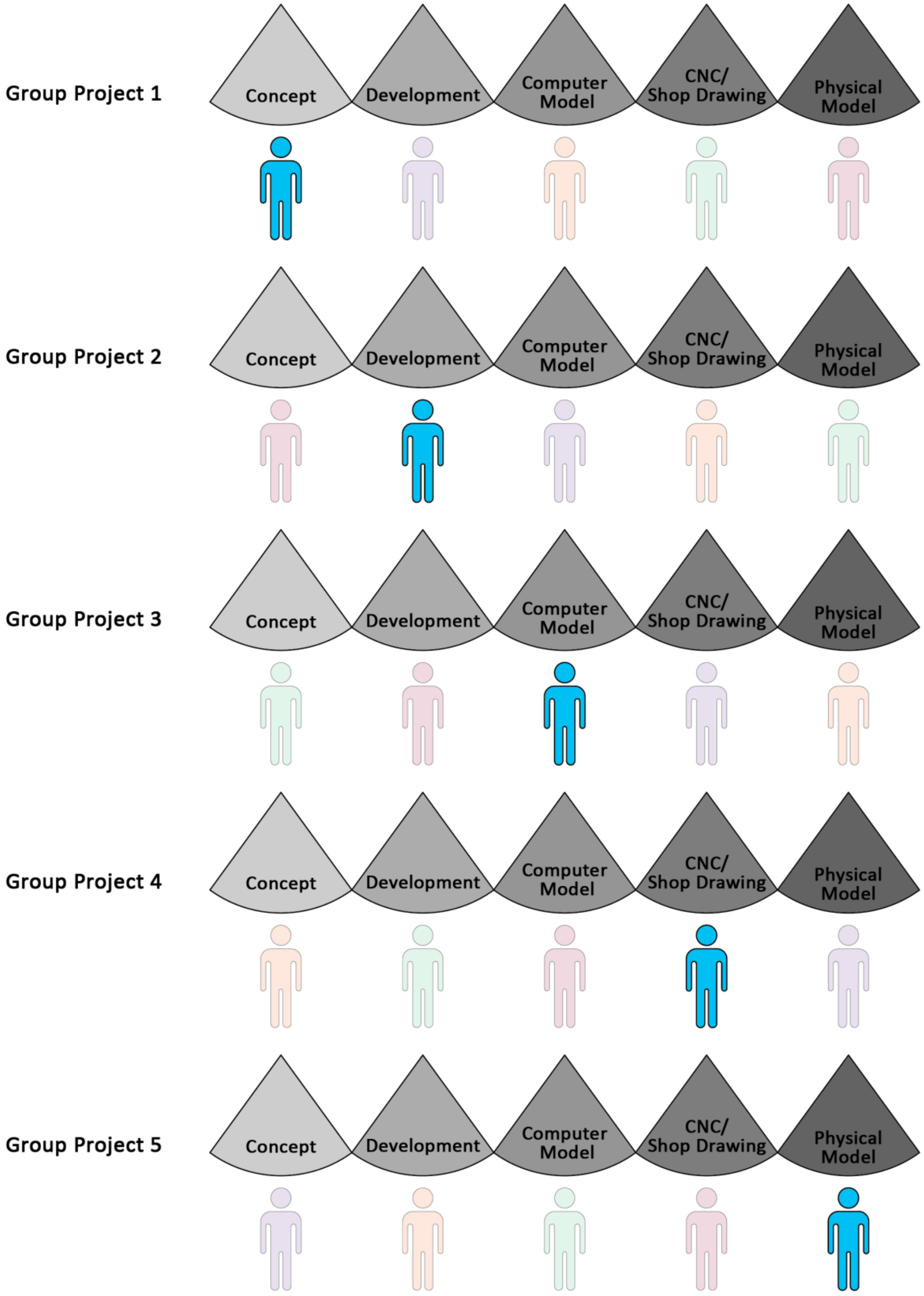
As shown in the diagram below, when a design project is assigned to a single student, the designer works through the various stages until the design is complete.



Leaving a single object or design at the center, what if each of the 5 steps was completed by a different design student as shown below?



On the following page, the diagram depicts an entire class' projects and follows the work path of the blue student "A". Notice how the student moves onto step 2, but does so by migrating down to project 2 and so forth. Each student will complete all five steps on five different projects. The design that student "A" conceptualizes will be completed by 4 other students.


Group Project 1
Concept
Development
Computer Model
CNC/ Shop Drawing
Physical Model
Group Project 2
Concept
Development
Computer Model
CNC/ Shop Drawing
Physical Model
Group Project 3
Concept
Development
Computer Model
CNC/ Shop Drawing
Physical Model
Group Project 4
Concept
Development
Computer Model
CNC/ Shop Drawing
Physical Model
Group Project 5
Concept
Development
Computer Model
CNC/ Shop Drawing
Physical Model

## Part 2 – The Pitfall of Delaying the values and benefits of engaging the *other four senses* in the process of decision making with regard to a given design concept.

The five senses:

| | |
|---|---|
| Sight or vision - | Dominates the other 4 senses within ID curriculum. This is due to the heavy reliance on computer screens and visual data. |
| Hearing or audition - | Primary use of this sense is for reception of the spoken word, lectures and the strong social component of the Industrial Design problem space. |
| Taste or, gustation - | Unfortunately, this is probably not the healthiest sense to rely upon for working in a shop space. However, this sense can be the most valuable for detecting when something is not right. Consider that this sense, along with olfaction is “chemical” sense which can detect airborne substances in the gas form. This can protect a student from dangerous or poisonous substances. |
| Smell or olfaction - | In a properly ventilated shop space where a respirator is not needed all the time, the sense of smell can tell you a lot about how a material is reacting to friction. The burning smell of woods, plastics, and metals is distinct and usually confirms a taste along with a sound that tells the designer that something is absorbing a large amount of heat. In the case of certain metals, this sense can safely react prior to the intervention of Thermoception; thus keeping the design student safe from burns. Furthermore, detecting the burning odor may aid in the protection of the work as well. The smell of burning wood may inform the student that they are incorrectly cutting wood, or that the blade is dull. |
| Touch or somatosensory, also called tactition or mechanoreception- | The sense of touch is the fulcrum for engagement as being either hands-on or hands-off. Such an extraordinary sense is touch, especially with the hands. Pallasmaa (2009) states that, “Our hands are reliable and diligent servants” (p. 27). One old skill that is not under fire is our ability as designers to sketch. The sense of touch seemingly takes over the brain when it comes to sketching. The reactions are so fast that it seems as if the hand is informing the brain of what it has drawn, instead of the other way around. This sense helps us map the surfaces of our projects to our brains. |

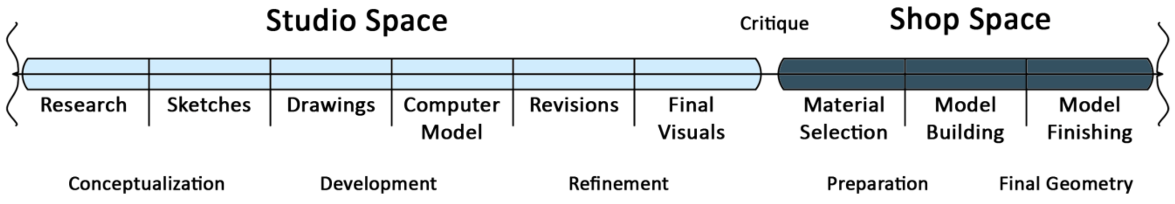
Other senses:

Balance, equilibrioception, or vestibular sense
Thermoception is the sense of heat and the absence of heat
Proprioception, the kinesthetic sense

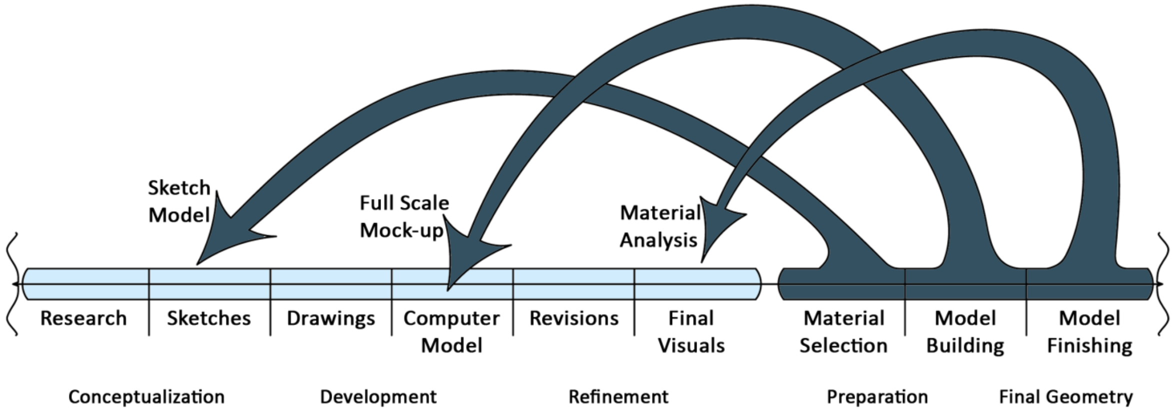
Students' time outside the shop environment is time spent primarily engaged with their design projects using the sense of sight, (A small amount of touch occurs with hand drawings, but their work is mostly sight-based). When the student begins to use the computer as a tool, the screen work is a single sense interaction. Design students fair quite well with the sense of sight. Educators agree with experts that the designer's eye is a crucial sense to develop in Industrial Design curriculum. When a hands-on approach is integrated, the other four senses awaken and contribute to knowledge and learning. The design student's sense of smell can detect and report to the brain information that helps a designer understand what material is being used, and how that material is reacting to machining, cutting, forming and finishing. Many design making processes involve heat. In some cases, the olfactory perception may be the only sense that is capable of reporting the amount of friction being applied to a part while machining takes place. For example, when a piece of hardwood is being fed into a table saw, the smell of the dust can dictate feed rate into the blade. Combine this with the sense of hearing and the smell of burning maple will coincide with a change in rpm as the saw motor bogs down under the load. Chances are that the next sense to inform the brain will be tactition. The sense of touch will feel the resistance of the maple board. All of these senses can tell the brain something specific and intimate about the process in hand faster and more directly than sight. Looking at the board does very little to inform the operator what is happening where the blade meets the wood. Engaging the senses, however, does not just aid in the *use* of the shop space, but helps produce the results from making altogether. A form may look a certain way on paper, but once a physical model has been made, the human hand can inform the designer with information that may not be visually apparent. This is to say that simply holding a form study or white model in hand while being blindfolded will reveal subtleties and nuances with form and surfaces. Research has shown that student's ability to recall and remember certain things grows stronger when this memory is imprinted to the brain by more than one sense; the olfactory sense being the strongest.

**Part 3 – The Pitfall of isolating the classroom/lecture space from the shop/manufacture space**

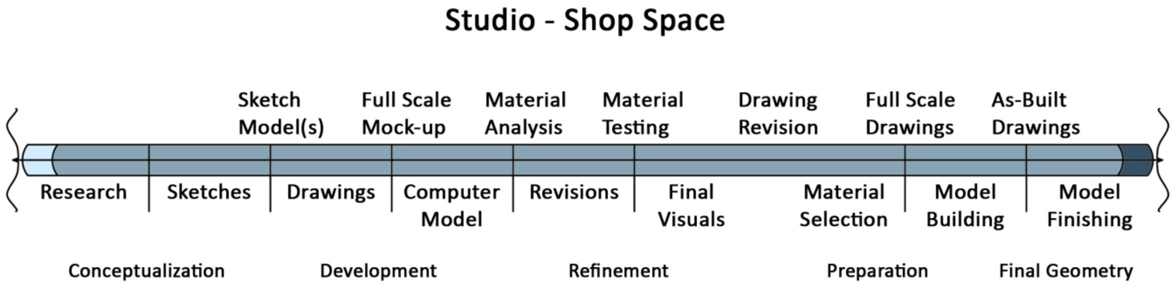
## Typical Design Process



## Combining Shop with Studio



## Hands-on Embedded Design Process



ID students need two distinct spaces. First, a classroom/lecture environment that is clean and orderly which caters to visiting professionals and can be refined enough to double as an exhibit space displaying the students' projects. Second, a shop space, naturally more chaotic and loud, and serves a number of different roles throughout the day. Inside the shop each area belongs to every student, and work flows around the tools and benches. This is in contrast to the classroom where spaces belong to a grid pattern with individual desks for students. A classroom has a natural justification. The front of the room is established. Most of the time, the students' work station face a single direction. The shop has no front, back, or sides; just locations of operations.

After examining research, the case for a making-emphasized program benefits from considering both spaces as learning environments instead of learn in the studio/classroom, then application of knowledge in the shop. Without any infrastructure, a professor can stop the isolation of these two environments and combine them into one. Lectures, critiques and mentoring can and should take place inside the shop space. This may seem radical to professors who rarely visit students in the shop environment. This interaction can sometimes take place during the studio section's timeslot. Bring the students into the shop and demonstrate technique, skill, and intent. Using the shop space during normal classroom time will help set the students' minds toward the notion that the shop is a great learning environment. Furthermore, this helps some students out of their shells.

The classroom can become a comfortable place. This is because the ramifications of failures within a specific design are not exposed in the same manner as within the shop. In the classroom, the drawings, sketches, and computer models all appear as solutions to problems; whereas in the shop, those same drawings pose as a series of problems to be solved during construction. Subconsciously students see the classroom as a refuge from this exposure and delay discovery in the shop. There are two primary reasons for this: 1.) the students have not been trained to accept the value of failure in the experimentation phase of their design project, and 2.) the students are not familiar with the shop environment, and are simply unprepared to work in a shop with confidence. It is the professor's job to instill confidence in the shop space in order to avoid the 'foxhole' approach to the classroom. This confronts the stagnation issues with shop confidence and helps properly align the definitions of both spaces.

The shop mentality can be part of the classroom as well. Students are much more likely to comment on construction methods and progress in the shop. The common use of tools and shared burden of completing a physical model happens in overlapping spheres in the shop space. This is less likely in today's Industrial Design studio. Students can hunker down behind their computers, or focus on their sketching in a quiet static way. Simply isolating these activities to the desk and chair in the classroom lowers the observational conversations that naturally take place in the shop. Flow of students is all but nonexistent. Rearranging the furniture can help with this to a degree. But the real mindset desired can be practiced during class time where the professor can set the tone for circulation and open discussion. Furthermore, students' work should be displayed vertically for all to see. The classroom can function like a nerve center for the project, and encourages the thinking that supports further steps in manufacturing by realizing that the real world work happens just down the hall in the shop.

Another way to bring the shop mentality into the classroom studio is the notion of clean artifacts. If a student has planned to design something which will be made of alloy, the student should bring a sample in and set it next to their drawings. Or if a certain hinge or hardware is to be used, have this at the ready. What takes place is remarkably useful.

> Nicolas Grimshaw commenting on Grimshaw and Partners' office, (1993) "I have always seen the office as part workshop and part studio. My ideal is for each team to have a working model beside them so that they can be continuously aware of the scale and size of the spaces in which they are working. Pieces are added and removed so that in the end the model has the feeling of a battered tapestry. One can also see pieces of buildings, castings and fixings lying around people's desks. This illustrates our constant dialogue with all the various manufacturers and suppliers." (p. 146).

In the case where the school's department has in place a shop technician, he or she can be invited to the classroom during the initial kick-off of a new design project. The technician will benefit from knowing explicitly what the project entails, and the students will be able to raise concerns regarding the project to both the professor and technician. The technician can better serve the ID department by planning for upcoming use of the shop, and knowing what tools will be needed to complete the project. The professor now has a partner in both technique and design theory who is willing to stand beside the students from start to finish. This further enforces the notion of the shop as a learning space by inviting the shop technician into the classroom.

## Part 4 - Committing to an Unproven Design without Materiality Experience.

At some point during foundational ID training, the connection between the characteristics of materials and desired forms and uses for design must begin. As students are learning the basics for form giving, they need to learn the basics for the materials for choice in tandem. What a particular design is meant to be made out of, greatly impacts the range of forms possible. Even if the ID student is charged with making a white model, or mock-up version of the real thing, where silver paint may represent stainless steel on the prototype, the student is best served if they are challenged to design their forms to fit within the constraints of the material choice. This notion of constraints is what sets us apart as Industrial Designers. Understanding this takes time. Therefore the training of material knowledge should not be considered an upper-level idea, but treated like a foreign language that begins with the basic structure, and advances with vocabulary and nuance over time. Waiting until *after* form-giving foundational work has been established does little more than delay the inevitable collision with the real world. Even in the virtual sense, creating geometry in CAD programs my need to be completely revised when real world hardware or materials are specified in CAD drawing form. Some software choices attempt to simulate this. One example of this from outside of the ID studio is the Autodesk© program *Inventor* which has the ability to call out when a piece of stainless steel sheet metal is shown drawn at a radius that is not possible for the material to be formed to. Accepting that materials have their own language is a big step early stage of an ID student's curriculum.

> Pallasmaa on materiality, (2009" "The work of the craftsman implies collaboration with his material. Instead of imposing a preconceived idea or shape, he needs to listen to his material . . . Each material has its own life, and one cannot without punishment destroy a living material to make a dumb senseless thing. That is, we must not try to make materials speak our language, we must go with them to the point where others will understand their language." (p.55)

Designing projects that reflect a growing fluency in materiality brings the ID student closer to basic requirements of professional practice. How can activities within the ID project scope help designers understand materials and their properties using a hands-on approach?  Professors can create ID projects that feature particular materials and process to familiarize their students with the behavior and properties of materials. When a final model must be constructed with *real* materials, the student is even more compelled to try things in preparation for the end result. Such as attempting to bend or cut sheet metal to a specific size and shape *before* having to fit to a nearly complete model. These experiments link back to trying things in the shop space at the conceptual phase. They also help designers find where constraints really come from. Patrick Dunn (2005) refers to this as a component of the designer's *problem space* and mentions a number of contributors. Dunn's term *problem space* reminds designers that their projects are never just about the designer and their ideas:

> "All design activities occur with boundaries set by constraints. Time, budget, user preferences, organisational culture, available technology and the personal whims of clients are all design constraints that define the "problem space" in which the designer works. Constraints are the things that need to be taken into account when solving a design problem. A good understanding of a project's constraints – and the ability to make informed trade-offs between them – increases the probability that the designed solution will meet the needs of users and clients." (p. 2)

When design students consider this problem space, the materiality boundaries are best defined in the shop space. Ultimately the best knowledge about a certain material comes from having to form it, or machine it. Growing fluent in a given material's language, a design student will avoid the pitfall of discovering that the design they have conceived cannot be formed using the materials they have specified.

## Part 5 - Justifying a Shape or Form without Considering the Tools Required for Creating the Form.

When ID students opt to have a CNC part cut from a computer file, there is still the question of how the geometry should be fixtured to make the cuts and create the form. Further analysis is required to choose the proper end mills and cutting heads, and finally the all-important G-Code. Once everything is programmed into the mill or lathe, the part may still be designed with geometry that cannot be reached with certain types of machines. Either way, the machine will obey the code and follow the path of the cutter head exactly. The material's condition may be completely destroyed in the process. This will not slow down the CNC mill; for it does not care about the surface condition, nor does it understand material preservation at all. If the fixtured blank is a solid block of gold or low density urethane foam, the mill does not react with more or less anxiety. (The depth of cut and spindle speed will be set to efficiently cut based upon the material, but it will not change its course of action if the programmed speed and depth cause a crash or tear out.) CNC machines will never *feel* the material react to forces from tools in the same way that a human can. More importantly, the CNC method will take this opportunity away from the ID student. Only the sense of sight can be used to watch a CNC machine hem stitching a cad file into reality through a safety glass panel. This is reminiscent of a proud father from the 1950's smoking a cigar in the hall looking through a window trying to guess which newborn is theirs. In this case as well, the father has the easy task of the day.

Using CNC processes as a means to an end is an important experience for ID students. They need to know what this is like, and they need to be able to harness the strengths of these tools in order to be successful in the field. The only way they will be able to do this is if they first understand what makes a 3, 5, or 7-axis router the right tool for a given affect. How will they do this if the exclusive go-to tool is always a CNC device? When ID students understand *all* of the tools available to them, they will begin to deduce where the CNC fits into this comprehensive package of available solutions. This is in stark contrast to using the CNC devices as the default form cutting methodology for all materials. Doing so rejects the large array of alternative methods, rejects the primary function of CNC strengths, and most importantly disconnects the Industrial Design students from the materials of choice and their engagement with the material with all senses within the human condition. This sounds bad, but it is the status quo at many schools today. ID students gain skill with 3D computer software, avoid the intimidating scenario of working in the foreign environment of the shop space, and rely heavily or exclusively upon CNC tools to realize their models. In this scenario, little to no effort has been applied to sketch models, sorting out materials' characteristics, or studying proportions or scale in the form of physical models. Their physical models emerge from behind the safety glass of the CNC mill to be handled for the first time. The material of choice is most likely what they can get their hands on; urethane foam. From this point, everything the ID student has not learned will be worked out under the pressure of an impending deadline. The ID student has placed his or her confidence in what he or she sees on a screen. The sense of sight has been the sole guide to this stage. What if the part cannot be cut without crashing the bit? What if the part can no longer support itself because it is too thin in one area? What if the simple act of sanding the final layer of foam to prep for painting causes the part to break? Away from the concrete, what if the design in physical form does not look right? What if the part is perfectly cut, but the scale is off? What if some unforeseen proportion has remained hidden through all of the modeling and rendering in the computer? What will the designer do when faced with the more abstract problems that have arrived after the model is finally realized?

With little time left, and many new questions brought to the fore, most inexperienced ID students soldier on and finish what they have conceived; therefore justifying the shapes and forms of their project. The goal of finishing the project becomes the highest priority. Most of this scenario is driven by a classroom-heavy initial project schedule, with very little real world proving experience. The shop remains a mystery, and the project suffers.

Professors have an ethical obligation to train their Industrial Design students to consider the tools required for creating their forms. This in no way means turning off the CNC mill. On the contrary, this guarantees that the CNC devices will be used properly; where the machines can maximize their automated multi axis nature. This also guarantees that the hand planer will remain sharp and slip confidently into the capable, experienced hands of ID students who need to remove a fraction of an inch of wood from the edge of a surface. Reaching for the correct tools in order to yield the best results is not just an exercise that benefits the integrity of the project, but also enhances the hands-on making experience. Each step of process becomes a small experiment that is bolstered by educational guesses, past successes, sound advice from shop technicians and professors, and the healthy interaction of fellow students charged with the same task. Prior to reaching for any tools, manual skill efforts should have been implemented throughout the early stages of the project. After hands-on making has been implemented, design-craftsman starts to see the project from a bird's eye view. As the project design unfolds, the ID student-craftsman can see integrated steps and their associated dependent tools. The shop space 'crystal ball' becomes clear, and the ID student can build their model based on the best material for their design, and the most relevant tools for each perceived step. How the students handle these discoveries is a testament to their growing confidence. These are skills developed by deepening ability through practice. Doing so successfully means negotiating another institutional hurdle. Sennet (2006) discusses this relationship:

> The more one understands how to do something well, the more one cares about it. Institutions based on short-term transactions and constantly shifting tasks, however, do not breed that depth. Indeed the organization can fear it; the management code here is *ingrown.* Someone who digs deep into an activity just to get it right can seem to others ingrown in the sense of fixated on that one thing- and obsession is indeed necessary for the craftsman . . . deepening one's skills in any pursuit takes time. . . Deepening ability through practice sits at cross-purposes with institutions that want people to do many different things in short order." (p. 105)

Universities face tremendous pressure to assure that the students in each major receive an education that meets regulations, and meets requirements from industry as well. This takes place in a fast-paced setting that must keep students progressing toward graduation in a track format. Some schools expect a lot of the support knowledge to be 'self-taught' because there is not enough time or space in a program to offer the required knowledge to be formally taught. A lot of shop spaces operate this way, where students wonder into the shop and try to figure out how to use tools and materials with little instruction. In this case, the students learn from each other and upper classmen. This problem can be solved at the program level.

## Program/Major Level

Designing the major to cultivate hands-on making from foundations to capstone requires an approach that values experimentation, mentorship, cross-discipline collaboration, *less* rigor and more time. Sennett (2006) speaks against speeding through a process for the sake of completion, "Purely operational thinking requires mental superficiality" (p. 120).

**Experimentation -** Projects need to serve a number of objectives. It is not sufficient to shape each project to mimic the exact situation a professional designer will face when handed a new brief. At early stages of design foundations, the Industrial Design student should be praised for trying new things, and testing concepts. The quality of the work will be judged incrementally, but some credit should be granted to the design student who considers the constraints and pushes back. Experimental efforts are still efforts. In these cases, the merit is judged by how well the student considered the possibilities of an unfamiliar material or a new forming process. Most importantly is the notion of generating a test method for the validity of ideas. Pirsig posits, (1975) "An experiment is never a failure solely because it fails to achieve predicted results. An experiment is a failure only when it also fails adequately to test the hypothesis in question," (p. 95) The results may fail to live up to what the student expected, but the experimenting is the point. Students need to feel engaged with the making shop-space as a test lab, not just a manufacturing plant. Testing theories should be engrained into ID students to such a degree, that they realize that product design and product development are two different ideas. As idea people, ID students need to learn the main point behind a scientific approach in the midst of a creative, artistic profession. Pirsig goes on to state that, (1975) "The real purpose of scientific method is to make sure Nature hasn't misled you into thinking you know something you don't actually know" (p. 94).

**Mentorship-** Reaching toward other valuable project objectives requires individual care and mentorship. The idea that students will all receive ample one-on-one time from a single professor is far-fetched. When students need advice, they get it from their classmates as well. But what if they could receive advice from upper classmates? Why do ID students only work on projects within their own graduating class? Age and year-of-graduation does not dictate competency. Drafting a project that required teaming up with under classman would be a great challenge for both classes of students.

**Cross-Discipline Collaboration -** The profession of Industrial Design shares a unique role with other professions. Engineering, Marketing, management, and manufacturers all connect directly to industrial designers. As the cofounder of IDEO Bill Moggridge often said, “Designers rely on all the other disciplines, in that everything else has to work before design has a chance.”

When the ID major is part of a large university, can they work on projects across majors and create designs that cultivate cross-disciplinary solutions, thinking, and relationships. This should be a no-brainer. Consider the added benefit of designing solutions for a project that will be built by a team of students from varying majors. Structural, electrical, mechanical engineers could work with designer to built working prototypes just like in the real world. Industrial Designers would have to expand their vocabulary and learn how to deal with trade-offs that affect other disciplines. Engineers would discover the value of design thinking and process and better understand Industrial Design. Both majors could become familiar with each other major’s facilities, and faculty. This could foster future independent study partnerships and corporate relationships that further enhance the ‘real-world’ experience that undergrad students so desperately need.

**Less rigor, More Time -** When the major does not officially begin until the beginning of junior year, ID students carry a special burden of trying to get better at their making skills for the sake of solving their current studio project problems. Why not create an alternate track for sophomores who are leaning toward Industrial Design so that they may fulfill design foundations credits while having more hands-on making opportunities? This may not require the facilitation of three new making-intensive courses, but could be written into the syllabi of existing coursework. As one university put it, “ID support courses are offered during the sophomore year to prepare students for ID studio projects.” Students need to see the incentive for gaining proficiency with tools that they can in turn use for their projects. If the ID facilities have available certain tools, the professors need to see the advantage of assigning project specifics which require the *use* of that certain tool, therefore motivating the students to master it. By the end of the sophomore year, those students who qualify for entrance into the major will be more confident in the shop space and enjoy their newly acquired aptitudes as juniors. It is a sad state where a student only realizes their design potential in lieu of newly acquired hands-on making skills just as it is time to graduate. Professors can plan the major coursework to safeguard against this scenario.

The issues discussed at the program level require teamwork within the major. Hands-on making objectives can be met regardless of department/school politics. Professors and technicians just need to work together to implement objectives while satisfying the needs of the department.

## Department Level

The Industrial Design Major is found primarily in Engineering, Architecture/Built Environments, and Art schools. Each school or department requires different support coursework as well as the main track of ID studio work. In addition to this, each type of school emphasizes a different aspect of Industrial Design core values which coincidently align well with the other majors found in the same department. Example: Art schools with multiple design majors may consider the collaboration with other design disciplines as crucial. Likewise engineering departments consider math and physics a natural fit. Are we really at home in an art department? If so, should it be mandatory to take fine arts courses? Do we really need higher level mathematics in order to converse with engineers? The answers to these questions will be debated for many years to come. In fact these questions are part of a broken conversation. Rife with controversy and entrenched interests, this conversation is over before it begins.

From an idealist perspective, what is it about engineering facilities and funding that is attractive to an ID program? What about the thinking and exploring that takes place in an art school is crucial to the ID educational experience? Does industry respond better to certain schools?

When considering which environment values hands-on making more than another, the real advantages come into focus. Industrial Design students belong in a program that places hands-on making as one of its top priorities. The first indicator of this is the physical facilities, or direct access to facilities, that cater to hands-on making. Ideally, students would have four major concentrations within the making spaces: Metal, wood, plastics, and composites. The automated CNC/Rapid Prototyping equipment would be located in each respective area depending on what materials the devices are meant to machine. Metal facilities would include CNC mills, lathes for metal, etc. In addition to the 4 main areas of shop space, an ID-only model making shop would be part of the studio space and allow for light work and finishing. This space would be open later hours and fill the need of all three years of ID students as an extension of their ‘classroom’ space.

Another indicator that a department values the hands-on Industrial Design student is their dedication to connecting with industry and professionals. Professors who focus on local and regional relationships give their students a chance to show off the quality of the program. These companies need not be future places of employment for current students. Recruitment is only one benefit of networking. Some industry relationships may not have design teams or future design positions to offer. In this case, the company can partner with the school for a project that needs to explore the possibilities of design’s impact on an invention, or something that to this point, has been nothing more than an engineering solution.

Department level advocacy is important to the health of any major. Industrial Design owes it to itself to implement changes at the section and program level. These in turn, improve the standing of the overall department. In a perfect world, these efforts are rewarded with opportunities for better facilities, stronger teaching with the right staff of professors and technicians, and improved relationships with the department’s professional network.

## Conclusion

Campaigning for more making in any institution can be approached from myriad ways. Hundreds, if not thousands of different arguments are in place to make such a stand. Each argument contains a different objective connected to the same means. This hands-on making is essentially human. By engaging in hands-on making, a person connects their entire battery of senses to the task. No wonder so many people are part of the bigger discussion. Sennett (2008) claims that, “all skills begin as bodily practices.” (p. 65). If the power went out tomorrow, and no more devices or equipment could be switched on, the human race would rely primarily upon what they could do with their hands. Pallasmaa (2009) writes, “Practices of the human hand around the world form the true survival skills of humankind.” (p. 52).

From there we zoom into work, vocation, and what we find value and worth in a day’s labor. Mathew Crawford discusses the dichotomy of mental verses manual work, and argues that the degradation of blue collar work has not just hurt our economy, but has affected our self worth, and understanding of all things surrounding us. He sees today’s contented as the cabinet maker, the mechanic, and the plumber.

Within vocation there is a special breed of professional who benefits from the latest technology and the oldest hands-on technique at once: the Industrial Designer. Most of the professional work produced by an industrial designer will take place on a desk and inside the screen of a computer. Their clients live far away, and the things they design are most likely built in countries outside their own. This work is studio work. This work is office work. Those who hold these positions were once Industrial Design students housed within a major that is now in danger of losing some of its core values. Technology has provided a way for Industrial Design students to complete school with very little to no hands-on making experience. The shop space has adapted to house rapid prototyping and CNC devices that disconnect students from a form of learning that is unique to the hands-on making shop space. Just like embracing sketching and hand drawing as a core value, we need to consider this shop-space experience a core value, which should be fostered and nurtured alongside all of the advancements of automated making.

Industrial Designers are used to the studio environment in which they act as Don Schön (1985) described, “reflective practitioners” (p.98). Similar to engineering test labs, the design studio relies on a common space where making takes place, and is accessible for informal discussion and criticism. A shared shop space for making is a core ingredient in a creative community. Without reorganizing priorities in Industrial Design curriculum, the space where this takes place, along with its tools and knowledge, may become virtually unknown.

## Bibliography:

Backett, Paul. *Rethinking Design Education.* Ziba Perspectives: Vol 3, 2011. Print.

Baird, Davis. *Thing Knowledge: A Philosophy of Scientific Instruments.* Berkeley, Calif: University of California Press, 2004. Print.

Ball, L (2002) Preparing graduates in art and design to meet the challenges of working in the creative industries: a new model for work Art, Design, & Communication in Higher Education Vol 1 No 1 pp 10-24

Buchanan, R (2000) The problem of character in design education: liberal education and professional specialization in International Design Education Conference Reinventing design education in the university, retrieved January 22, 2003 from the World Wide Web: http://www.humanities.curtin.edu.au/html/des/DesEd2000/preconference01.html

Crawford, Matthew B. Shop Class As Soulcraft: An Inquiry into the Value of Work. New York: Penguin Press, 2009. Print.

Doorley, Scott, Scott Witthoft, and Hasso P. I. D. S. University. Make Space: How to Set the Stage for Creative Collaboration. Hoboken: John Wiley & Sons, 2012. Internet resource.

Evans, Mark, David Wallace, and David Chesire. "An Evaluation of Haptic Feedback Modelling During Industrial Design Practice." Design Studies. 26.5 (2005): 487-508. Print.

Kumar, K L (2003) Industrial design scenario in Southern Africa in International Conference of Industrial Design Engineering pp 21e45 retrieved December 26, 2003 from the World Wide Web: http://www.io.tudelft.nl/research/dfs/ide-conference/papers/4_Kumar.pdf

Lemons, G, A Carberry, C Swan, L Jarvin, and C Rogers. "The Benefits of Model Building in Teaching Engineering Design." Design Studies. 31.3 (2010): 288-309. Print.

Lloyd, Alan C, and Russell J. Hosler. Personal Typing: An Intensive Training Course for Writers, Collegebound Students, and All Others Who Wish to Learn Quickly How to Typewrite Their Own Work. New York: Gregg Division, McGraw-Hill, 1969. Print.

Mau, Bruce, and Jennifer Leonard. Massive Change. London: Phaidon, 2004. Print.

Moore, Rowan. Structure, Space, and Skin: The Work of Nicholas Grimshaw & Partners. London: Phaidon, 1995. Print.

Nair, Prakash, and Randall Fielding. The Language of School Design: Design Patterns for 21st Century Schools. Minneapolis, Minn.: DesignShare, 2007. Print.

Pirsig, Robert M. 1974. Zen and the art of motorcycle maintenance: an inquiry into values. New York: Morrow.

Robinson, Ken. Out of Our Minds: Learning to Be Creative. Oxford: Capstone, 2001. Print.

Robinson, Ken. The Arts in Schools: Principles, Practice and Provision. London: Calouste Gulbenkian Foundation, 1989. Print.

Robinson, Ken, and Lou Aronica. The Element: How Finding Your Passion Changes Everything. New York: Viking, 2009. Print.

Schön, Donald A. The Design Studio: An Exploration of Its Traditions and Potentials. London: RIBA Publications for RIBA Building Industry Trust, 1985. Print.

Seitamaa-Hakkarainen, Pirita, Marjut Viilo, and Kai Hakkarainen. "Learning by Collaborative Designing: Technology-Enhanced Knowledge Practices." *International Journal of Technology and Design Education.* 20.2 (2010): 109-136. Print.

Selander, Staffan. "Designs for Learning and Ludic Engagement." Digital Creativity. 19.3 (2008). Print.

Sennett, Richard. 2006. The culture of the new capitalism. New Haven: Yale University Press.

Sennett, Richard. 2008. The craftsman. New Haven: Yale University Press.

Yang, Ming-Ying, Manlai You, and Fei-Chuan Chen. "Competencies and Qualifications for Industrial Design Jobs: Implications for Design Practice, Education, and Student Career Guidance." Design Studies. 26.2 (2005): 155-89. Print.

Yeh, W D (2003) The demand and the evaluation of the industrial design profession from the industries The 6th Asian Design Conference(CD ROM)

The Third Teacher: 79 Ways You Can Use Design to Transform Teaching & Learning. New York: Abrams, 2010. Print.

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