# New Challenges when Teaching UX Students to Sketch and Prototype

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## Abstract
In this paper we report on new challenges when teaching UX students how to sketch and prototype their designs. We argue that UX students sketch and prototype differently than other design students, and we discuss how changes in the field necessitate a response in education. We describe sketching and prototyping as a continuum that students successfully traverse when they follow a process of 'double loop learning'. We highlight three new challenges: (1) New computational design materials, (2) new maker tools, and (3) changes within the tech industry. We explore these three challenges through examples from our students, and we outline strategies for sketching and prototyping in this new reality. We conclude that this is a starting point for further work on keeping education up to speed with practice.

*Keywords: sketching, prototyping, UX design, double loop learning*

## Introduction

Teaching interaction design/user experience design (UX) students how to sketch and prototype their ideas has always been a challenge. UX is different than most other design practices because designers give form to *behavior*: the behavior of the products, services and systems. UX designers might create a conversational UI, a mobile app, or an Internet of Things device. While they can use traditional sketching and prototyping methods to address the physical form or the visual elements, envisioning and refining behavior remains challenging. Students learning architecture, communication design, or industrial design typically spend time in their studios sketching with pencil on paper and prototyping with physical materials to better understand what the form of a thing might be. UX students work differently. They spend time making and arranging sticky notes, sketching with narrative to explore possible scenarios of use, and drawing and scripting storyboards that often function as early prototypes.

Over the last several years, advances in the tools professional UX designers use, advances in the technical materials, and changes to the IT industry have all made teaching UX students how to sketch and prototype even more challenging. Advances offered by new maker tools move design students farther from the tacit knowledge gained from working materials by hand. Technical advances in the areas of big data, machine learning, and crowd-power present UX designers with an ever-growing array of possibility, but also with a huge gap in understanding the capabilities of these emerging design materials. The shift within the tech industry away from products and towards services challenges students to envision financial models as a part of their sketching and prototyping. It changes the challenge from making things users want to searching for co-production of value between users, customers, stakeholders, and service providers. Finally, the growing practice of A/B testing means many tech companies now focus on deploying minimally viable systems that get tweaked towards optimal design following deployment, and not during a design process that precedes release.

In wrestling with this growing set of challenges, we have developed several insights that can aid others in teaching their UX students how to sketch and prototype their ideas. These insights frame the continuum between sketching and prototyping as a process of double loop learning. We hope the insights will help UX instructors to better critique student work and that they will result in expert UX students who easily transition into industry practice. Our insights include developing tacit knowledge of new maker tools, collaborating on teams with technology experts, creating conceptual models as prototypes, and teaching students to prototype toward their greatest risk (i.e., that what is most likely to fail) instead of prototyping based on fidelity.

## Background on Sketching and Prototyping

Today, many design instructors hold a traditional and possibly even romantic view of how to teach sketching and prototyping. They often teach students to sketch by roughly drawing many possible forms by hand as a way of exploring the solution space. Students next produce higher fidelity renderings on their way to producing high-fidelity 3D models of their idea, such as a clay model for a new car. Throughout this process, students engage in both individual and social classroom critiques where their ideas are challenged and sometimes celebrated. The design actions and the discussion collectively carry students from sketching to prototyping to arriving at their final design.

Many design researchers have discussed sketching and prototyping. We do not attempt to provide a detailed review, as this would exceed the bounds of a conference paper. Instead, we touch on a few key insights and advances on sketching and prototyping as they relate to and distinguish UX design.

Much of the design research discussing sketching and prototyping focuses on architecture and industrial design. Most of it draws on Schön's discussion of design as a reflective practice involving reflection *in action* and *on action* (Schön, 1984). When involved in the act of sketching, designers *reflect in action*. They react to each mark they make, revealing what their idea is to themselves as they proceed. Once they have produced a sketch or several sketches, designers *reflect on action*; they assess what the idea is and decide to build on it or to explore in a new direction. Schön later described this as the designer having a conversation with material, where the way the material talks back to the designer plays an important role in how the conversation unfolds (Schön and Bennett, 1996). UX researchers have noted that sketching with software is challenging as it is an immaterial material, and it makes this conversation difficult (Ozenc et al., 2010).

Design research has helped advance understanding of sketching and prototyping by more closely focusing on the final product or outcome (Buchanan, 1992). Buchanan's work categorized design as producing four types of output: symbolic and visual communication, material objects, activities and organized services, and complex systems or environments. He describes these as areas of invention, not as design practices. Design practices work across these areas. For example, a UX design that helps shoppers check themselves out of a store would involve communicative artifacts to orient the user to their choices, material form of the device(s) used, and the activity of shopping. The design would both situate the activity within the current context of a store while also attempting to transform this environment by removing cash registers and checkout stations. Buchanan's work illustrates that sketching and prototyping go well beyond the physical form of an artifact.

Since the development and rapid adoption of digital design tools, such as CAD systems, design researchers have more openly questioned the need for sketching in the form of freehand drawing on paper. These types of sketches are performed to help designers develop and reflect on their ideas. One study showed that expert architects could produce high quality designs regardless of whether or not they engaged in an explicit sketching process (Bilda et al., 2006). Instead of sketching, participants developed designs thinking out loud, while blindfolded. However, the architects were not happy with this process. Research looking across several design practices showed that the conversations designers engaged in seemed to have more impact on advancing design ideas than freehanded visualizations (Jonson, 2005). What remains less clear his how sketching leads to artifacts that support these critical conversations. While there is more nuance to these studies than we have space to explain, they point to the possibility that the primacy of sketching as drawing needs to be re-evaluated. Interestingly, design education has remained deeply committed to drawing alone as core to how we teach students to sketch.

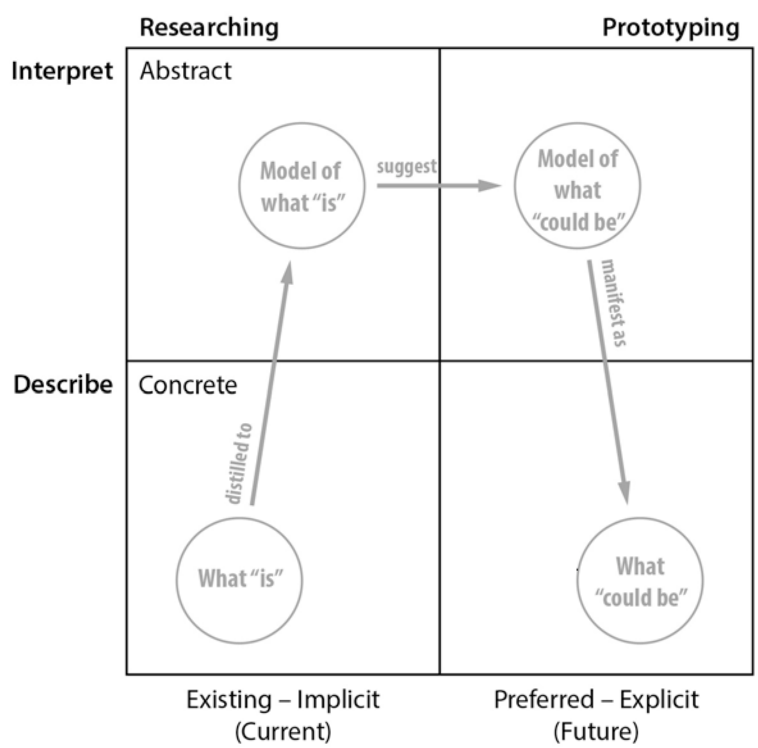
Buxton's work has been seminal in helping to advance the understanding of sketching and prototyping done in UX (Buxton, 2010). Prior to this work, both design practitioners and instructors often used these terms somewhat interchangeably. For example, they would describe things like a scenario, storyboard, or a wireframe as a sketch or as a prototype. Buxton described sketching and prototyping more as a continuum. Designers were sketching when they worked on getting the "right design" and they were prototyping when they worked to make the "design right." As designs became prototypes, the act of sketching worked on ever more granular elements. For example, designers sketch to discover they should be making a food-sharing app. Then, when wireframing the app, designers sketch to develop ideas of how to navigate through the app. Buxton noted that in UX, designers had many tools that supported digital prototyping, but they had almost no tools for sketching.

Participatory design emerged as a practice to develop IT systems for the workplace. In order to address the disruptive change of placing computers in work environments, researchers in Scandinavia created teams with workers who had domain expertise in the work and with developers who had expertise on what computers could do (Muller and Kuhn, 1993). Collectively, the team prototyped future ways for people to work together in order to reveal where computing could add value (Ehn and Kyng. 1991). They prototyped the social to discover the thing.

As computing became less about work and more about other aspects of people's lives, designers created new sketching methods like bodystorming that draw on the designer's understanding of their own body as a way to engage with embodiment, perceptual motor skills, and the social performance of interacting with things (Buchenau and Suri, 2000). As part of this effort, designers also created experience prototyping and prototyping for social action, with a focus on investigating the felt-life experience of a potential product or service before it gets developed (Buchenau and Suri, 2000; Kurvinen et al, 2008).

Other approaches explored abstraction in the form of models to advance sketching and prototyping. For example, the analysis-synthesis bridge pushed sketching and prototyping in a different direction — away from felt life experience and towards abstraction (Dubberly et al., 2008). This model divides the UX design process into four quadrants: what "is", the model of what "is", the model of what "could be", and what "could be" (Figure 1). UX designers transition from researching to making by sketching and assessing models of the future they want to bring into being. Once they have agreed upon the future they want, designers ideate and iteratively refine new product or service offerings. The reflection they engage in is on both the thing and the future it intends to bring into the world.

Figure 1: The synthesis analysis bridge model (adapted from Dubberly et al., 2008).




Collectively, this research shows that UX designers sketch to discover the future they want and to discover products or services that can help them achieve this desired future. This might be done in isolation, following a user-centered design process, or it might be done as co-design/participatory design; in collaboration with users and other stakeholders.

Designers investigate communication, product forms, activities and behaviors, and the larger systems these things reside within. As the work proceeds from sketching to prototyping, the focus shifts to more assessment of whether the design achieves the desired future as opposed to the search for a desired future. Conceptual models can also be used to represent the future, scenarios of use, system behaviors, environments, and stakeholders affected by the design process. As the work proceeds to prototyping, UX designers develop storyboards, wireframes, interaction flows, more detailed conceptual models, high fidelity visuals, and semi-functioning systems. These things remain difficult to sketch and prototype because of a lack of tools particularly for sketching UX and because software, one of the main materials used in interaction design, remains difficult for designers to have a conversation with.

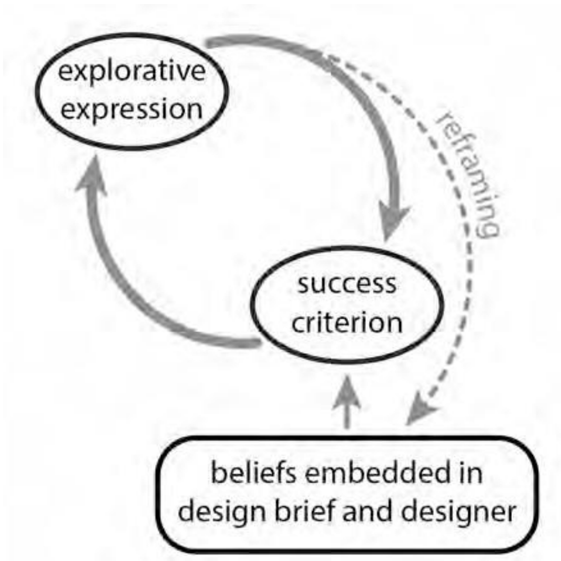



Figure 2: double loop learning in sketching

One of the defining characteristics of sketching is how its process reveals both potential solutions and potential pitfalls. Sketching is a non-linear process where the solution space is explored along with the assumptions and convictions embedded in the design brief and in the designer (Dorst and Cross, 2001). This process of framing and reframing, driven by the ambiguity (or indeterminacy) of the sketch (Fish and Scrivener, 1990), is characterized well in the concept of 'double loop learning' (Argyris, 1976). With double loop learning, both the underlying rules as well as the consequences of a decision matter (Argyris and Schon, 1974). As designers sketch and then prototype, the advances they make change their underlying values and assumptions as these relate to both the *thing* and the impact the designer intends the thing to make on the world (Figure 2). We see this notion of double loop learning as much more at the center of design than the idea of sketches as drawings made by hand.

## New Challenges for UX Sketching and Prototyping

When teaching how to sketch and prototype across the UX design space, instructors typically ask design students to brainstorm, bodystorm, and create many scenarios of use that investigate different users, situations, contexts, and user needs. Much ideation happens using narrative, as this is a design material that lends itself to giving form to the behavior of systems in dialogue with the potential actions users might take. Students are often inspired by conducting some type of research prior to sketching, working from a design brief, or working from a set of personas. Increasingly, UX design programs also have students investigate the possibilities of digital technologies using platforms like the Arduino microcontroller or visually-focused software like Processing. Students “play” with these digital materials in the same way traditional design students play with cardboard in the studio to gain a tacit understanding for the capabilities of digital materials. Currently, these materials lend themselves much more to prototyping, making the thing a designer has in mind, than to sketching, trying to discover the thing to make.

Students transition from sketching to prototyping their ideas by working with a variety of tools. Many generate storyboards by hand before creating wireframes and interaction flows. Students also often make videos showing simulations of what a system might be like, especially when it is meant to communicate ideas design students cannot easily create themselves, such as systems embedded in environments, Internet of Things designs, interactions with robots, or conversational interfaces. In some cases, design students create more fully realized prototypes using web development tools, sensors and microcontrollers, or even mobile development tools. Sketching and prototyping works best when UX students develop a deep, tacit understanding of the capabilities of the technologies they hope to employ in their designs.

Over the last several years, advances in tools, design materials, and in the IT industry have only increased the challenge of teaching UX students to sketch and prototype. Through a process of discussion with alumni working in industry, discussions amongst ourselves, collaborative writing, and reflection on our own teaching, we identified several changes and advances to UX that complicate teaching students to sketch and prototype:

1. New computational design materials: big data, machine learning, and crowds
2. New maker tools: laser cutters, 3D printers, CNC machines
3. Changes to the tech industry: transition from products to services, lean startups, and the rise of A/B testing

## Computational Design Materials

New computational design materials, specifically big data, machine learning, and the many technologies that leverage crowds as a resource complicate UX sketching and prototyping. When trying to innovate existing services, UX designers often find themselves confronting huge datasets of user behavior, and they are increasingly expected to help discover creative new ways to construct value with the data while protecting privacy and working in an ethical way. Banks have mountains of transactional data; healthcare systems have stores of patient and care data; government and social agencies have increasing access to historic sensor data such as weather and user data.

Visualization and data mining are typical ways engineers learn to investigate datasets. However, design students typically do no work with these tools and these tools have not been developed to support the ways designers search for possibilities.

One increasing way technologists have been constructing value from data is through the use of machine learning, which can detect frequent patterns, find more optimal paths and strategies, or discover insights and relationships. This material can be challenging for UX designers because it employs statistical intelligence, which is far from human intelligence and generally lacks common sense. Machine learning systems often require ongoing collection of labels so they can continue to learn, creating new interaction requirements. These systems also make inference errors that can be difficult to predict before completely building a system and testing its performance.

The recent emergence of crowd computing offers UX designers a very different kind of intelligence they can apply to their designs. The development of large-scale social computing systems has created both free and paid labor forces that do things previously unavailable through computation. For example, Youtube users collectively discover and extract key content from video and social mechanisms. Counting views allows crowds to collectively curate the quality of digital video clips. Services like Amazon's Mechanical Turk allow developers to rapidly engage people in completing micro tasks. One of our favorite examples is the VizWiz system, which allows blind users to take a picture and get near real-time textual descriptions. VizWiz users have asked the crowd to read thermostats, to read cooking instructions from food packages, and even to describe attractiveness of the people they are with (Brady et al., 2013).

When sketching, UX design students often fail to consider the capabilities of these new materials. As they transition from user research to sketching, students search for opportunities for technology to add value, but this search is always limited by their understanding of what can be done. On the occasions that students do begin to consider big data, machine learning, and crowds, they often think of these materials as if they are magic that can do anything. Their lack of a tacit knowledge of these materials makes it difficult for them to envision new futures. As they move their ideas forward, and transition from sketching to prototyping, they almost always lack the technical expertise or access to resources such as a paid crowd or a large dataset that they might leverage to investigate more fully what might and might not be possible and what might and might not be a preferred future.

## Maker Tools

The emergence of tangible interaction (Hornecker and Buur, 2006) — the use of material artifacts to control and interact with digital systems — as well as the increasing technology focus on the Internet of Things (Hounshell, 2017) has helped to promote the importance of designing material artifacts as a core part of UX design. While UX design educators have grown more interested in teaching students to investigate the material forms of products along with their behaviors and their sensing services, the 3D form giving aspect has become complicated due the emergence of maker tools, e.g., 3D printers, laser cutters, and CNC machines. These new tools typically take input from a digital file and then add or remove material in the process of making a physical thing.

Industrial design students often learn to work with materials by hand before moving to digital tools. They typically carry out several design projects where they cut cardboard or other materials by hand in order to learn its capabilities as they repeatedly cut, fold, bend, and glue. Students then move to more dangerous tools like table saws and band saws. They learn the capabilities of wood and plastic by cutting and feeling the resistance, by sanding and fitting pieces together, and by finishing with paint and stains.

Maker tools place a computer as a mediator between the designer and the target material. They remove the ability to gain a felt understanding and tacit knowledge as the tool does all the adding or removal (Frens and Hengeveld, 2013). This is particularly problematic when looking at this practice from the perspective of double loop learning. The ambiguity that fuels the conversation with the material is simply not present. Maker tools produce 'perfect' results that hamper the process of reflection on the assumptions and beliefs embedded in the design brief and brought to the table by the designer. In this process of creation, all sensory feedback is removed, creating a gulf between the design student and the material, and preventing an effective conversation with the material from starting. They create a separation between planning (making the digital file) and acting. The process of making that affords unforeseen routes to unimagined solutions is not accessible.

## Changes in Tech Industry

Over the last decade the tech industry has almost entirely transitioned to a financial model oriented around multi-stakeholder services rather than one product designed for one person. In the past, UX designers made things people wanted to purchase. Now, increasingly, UX designers find themselves working on projects where the users and customers are two different groups (for example, Google search users and advertisers) or where systems bring disparate groups of people together (for example, Ride sharing drivers and riders). In both cases, the purpose of the design activity is to envision an ecology where value flows across several interrelated stakeholders. While UX designers know how to prototype interaction flows and screen designs, it is less clear how to teach students to sketch and prototype an effective ecology of exchange. When working in these spaces, teams often spend as much time prototyping financial models as they do interaction designs.

Another change in the industry has been a move by many startups to a "lean" model of development — the idea of making a minimally viable product as a first item to deploy. This mindset can conflict with the focus on UX on discovering and expanding upon what users want and desire. When working in this climate, UX designers must work to discover the minimal that can be delivered in order to drive an initial round of product/service adoption.

When systems get deployed, tech companies increasingly use A/B testing as a way of modifying and redesigning their systems. When doing this, companies make several versions of the same thing and assess which one produces the user behavior they most desire. This is different than a traditional model of design, where the designer is in charge of creating and evaluating renditions of a product. In fact, one designer famously quit their job at Google due to the dominant culture of testing every design decision (Walker, 2009).

A/B testing challenges the social critique model that has been long held in design, turning it from a discussion into a search for empirical evidence that one idea is "better" than another.

A/B testing, similarly to lean UX, breaks a design down into many small pieces that can be individually tested and measured, and it often misses changes things holistically, as there is little opportunity to do so. A/B testing changes the power dynamic in the decisions around what to make and when a designer's judgment should be trusted. Traditional studio courses, with their dependency on the critique do not prepare students for this new reality they will increasingly face.

## Insights on Teaching the Future UX Designer

To address these challenges, we spoke to our many alum working in industry about their practices. In addition, we reflected on our work with constructive design research (Zimmerman and Forlizzi, 2014) where we design new artifacts as part of academic research. Our research includes tangible computing, Internet of Things, digital service design, human-robot interaction designs, interaction with intelligent systems, smart environments, and interaction with social/mobile systems. We subsequently distilled a small set of insights that begin to address the challenges we outlined above. These insights serve as a first offering in space that requires considerable more design research.

### New Technical Design Materials

We have two recommendations that help sensitize UX design students to working with unfamiliar technical materials. Both help students understand the capabilities of the material so they can better recognize the opportunities to play with it in a way that increases the likelihood of envisioning things that can be built. First, we recommend that students conduct a competitive analysis of current systems. For example, if students are to better understand the possibilities presented by conversational user interfaces, ask them to perform a competitive analysis of current systems. As part of this work, students should generate design patterns to reveal the different ways other UX designers have integrated this technology into their designs. Patterns should reveal matches between the user's intention, the context, and the abilities of the technology. Based on the resulting set of design patterns, students should abstract a set of technical capabilities. This may require them to examine some of the research literature on the underlying technology, as the capabilities should address both the abilities and the current limitations of the design material.

Second, we recommend placing students on interdisciplinary teams. When working on big data or machine learning, try to add someone with expertise in data science. When working on crowd-powered systems, try to add an expert in social computing. Ideally, the interdisciplinary team will work together in both the early, middle, and late stages of the design process. Adding an expert helps to place a person as a proxy for the new material. As student teams work to identify opportunities, ideate possibilities, and refine their ideas, the more design-focused students can engage team members with technology domain expertise into a Schön-like conversation with the technical material (Schön and Bennett, 1996).

These two activities singly or in combination will not result in a UX design student who is an expert on the new design material. However, it will result in a student who is sensitized to the challenges of working with this material and who is better able to discover opportunities to apply it.

## New Maker Tools

In addressing this challenge, we have had to work on *our old-timer designer* bias that doing early design work by hand is better than doing this work on the computer. The best evidence we found that challenges this bias is in our own students who have somehow gained a strong felt-understanding for maker tools, and can produce highly inventive designs even though they start in the digital space.

One example that was particularly insightful comes from a first year master's student who is skilled and experienced with new maker tools and blended this skill and experience fashion aesthetics. The student worked on a service design for an exclusive car brand, positioning his work in the near future where ownership of cars might be more exclusive than it is now. He speculated that his target users would want to show off their ownership of an expensive car by showing the key fob, such as casually laying them on the bar while drinking espresso. He envisioned a parametrically customized and fitted bracelet that would act as key fob and bragging apparel. Here we focus on his design process rather than on the service itself.

The student tried to answer the question of how a computer algorithm for generating forms could be tuned to embody the form language of an exclusive car brand. After a few, very literal tries with 3D printing exact representations of brand elements, his exploration moved to Processing, where he used elements of the car to seed a generative algorithm. Tuning and tweaking algorithms, he found that the abstraction of Processing did not give him enough 'control' over the expression of the brand language. Next he took off the shelf, scriptable animation software (cinema 4D) and 'misused' it to run generative scripts that would give him algorithmically driven progression of form expression over time. This gave him the iterative tool that he needed to tune his algorithms and he engaged in a process of 3D printing families of bracelets that matched the brand language (Figure 3).

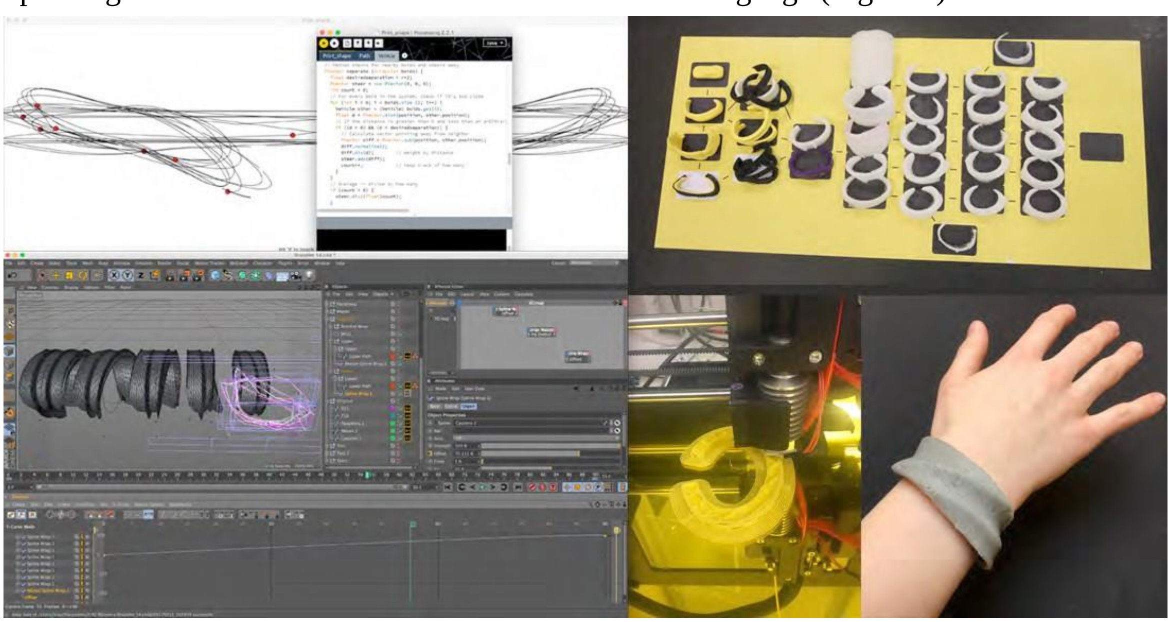


Figure 3: Generating form in Processing (top-left), Generating form in Cinema 4D (bottom-left), printed bracelets (right). images courtesy of Troy Nachtigall

The student created his own tools in order to explore his design challenge in a way that it opened the conversation with the digital material (Stienstra et al, 2015). He could do this because of his extensive experience and deep understanding of both algorithmic form generation and 3D printing.

Students who can design effectively using maker tools spend a tremendous amount of time working with one or two individual machines. In the same way many of us learned about materials by playing with them in the studio, these students have gained a tacit understanding of what the tool can do by spending lots of time working with different materials. We notice they often have a systematic approach of trying many small changes in both settings and in the details of their digital files. They employ a rapid process of iterative exploration, tweaking things until they discover a combination that works. Gaining a tacit knowledge of the tool helps these students to both sketch with the tool and to iteratively refine their designs.

## New Technology Development Practices

To help students better understand how to sketch and prototype for services, instructors should first provide grounding on the differences between products and services and background on key service concepts such as co-production of value (Prahalad and Ramaswamy, 2004), customer competence (Prahalad and Ramaswamy, 2000), and service concepts (Goldstein, 2002). When ideating, students should focus on discovering opportunities for value co-production — situations where all of the stakeholders will benefit. Students should also take advantage of customer competence by asking not just what the service provider can do for users, but also what users can do that benefits the service provider. Often the best exchanges of value are not about money. For example, designs that use gamification operationalize this idea, often trading the entertainment of a game to get users to do work for free. Finally, students need to understand that the outcome of a service design project is a strategy that describes how both customers and the service provider get what they want. Once a service concept has been developed, then many independent design projects can happen somewhat independently, as they all follow the same underlying strategy.

When prototyping services, students should learn to explore and investigate ideas by sketching conceptual models of possible future states. They need to reveal the underlying system of value flow between stakeholders before they attempt to design other artifacts within a service system. As designs advance, we recommend prototyping by simulating the service encounters (Frens et al., 2012). These can be quickly created and assessed using UX design methods like experience prototyping (Buchenau and Suri, 2000).

To prepare students for working in a world of lean startups and minimally viable products, we recommend changing the focus of prototyping. Instead of focusing on advancing through levels of ever-higher fidelity, students should focus on risk. They should examine their design idea and determine the most likely reason it might fail. They should then focus their prototype on assessing if this specific challenge can be overcome. If not, then they should pivot to a new idea, again evoking double loop learning. This focus on risk prevents teams from working on an idea that will never work. In one example from our teaching, we had a UX team that wanted to make an automated translation app for people that travel. The first risk they encountered was the cost of data services when traveling internationally. This killed the idea, but helped the team to pivot and focus on renting Mi- Fi's at airports so international travelers could have cheap access to data services.

To prepare students for a tech industry that may seem hostile to design judgment that is not backed up by empirical evidence, we recommend bringing some of the culture of A/B testing into studio sketching and prototyping activities. Instead of relying solely on the critique as an evaluation of ideas, instructors can encourage students to leverage the crowd as a design resource. For example, when students generate a set of possible ideas, they could post these as a set of choices to relevant communities using services like Reddit. For a more rigorous approach, students can quickly create online survey services and conduct a pairwise comparison of ideas. Asking participants to share their rationale provides some insights on why their designs are being rated in a certain way.

We do not intend or want to replace the studio critique with crowd opinions. Instead, we have found that collecting this information before a critique can bring a new and valuable dimension to the conversation. We also feel that practicing how to discuss design judgment in conjunction with empirical data helps prepare students to describe their intentions in a way that leverage the data instead of trying to deny it.

## Conclusion

The pace of change with respect to UX tools, technology, and work practices have only increased the challenge of preparing UX students to enter industry. Over the last several years, we have observed that the standard methods for UX sketching and prototyping no longer fit with many of these advances and changes. In this paper, we share a set of insights gathered from discussions with our alum working in industry, informed by our own constructive design research projects, and based on changes we have made to our own UX studio classes. We view these insights as a starting place in a much-needed conversation with both UX practitioners and UX instructors. There is a huge need in our community to try new sketching and prototyping approaches in both education and practice, and to reflect and share what does and does not work. Through the collective actions of researchers, educators, and practitioners, we can continue to prepare students to enter UX practice ready to help and advance the state of UX design.

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## Author Biography

### Joep Frens

Joep Frens was born on September 11th, 1974 in Amersfoort, the Netherlands. After obtaining his master degree in Industrial Design Engineering from Delft University of Technology he went to Switzerland to pursue a career in research at the Swiss Federal Institute of Technology in Zürich. He returned to the Netherlands as a PhD student. In 2006 he received his doctoral diploma from the Eindhoven University of Technology and started as assistant professor at the same university. He held the prestigious, invited position of 2014-2015 Nierenberg Chair of Design at the Carnegie Mellon University School of Design. He teaches courses on all academic levels and advises a number of PhD students. He regularly gives workshops on cardboard modeling and runs a website around the technique.

### Jodi Forlizzi

Jodi Forlizzi is a Professor of Human-Computer Interaction in the School of Computer Science at Carnegie Mellon University and a Co-founder of Pratter.us, a healthcare startup. She designs and researches systems ranging from peripheral displays to social and assistive robots. Her current research interests include designing educational games that are engaging and effective, designing services that adapt to people’s needs, and designing for healthcare. Jodi is a member of the ACM CHI Academy and has been honored by the Walter Reed Army Medical Center for excellence in HRI design research. Jodi has consulted with Disney and General Motors to create innovative product-service systems.

### John Zimmerman

John Zimmerman is a Professor of Human-Computer Interaction in the School of Computer Science at Carnegie Mellon University. He teaches courses on interaction design, service design, HCI, and innovation. His research investigates four areas: (i) interaction with intelligent systems, (ii) service innovation, (iii) crossing the digital-physical divide, and (iv) research through design as a scholarly approach to inquiry.