Smart Cooking Tools
A Study of the Design & Development of Sensor-Based, Internet-Connected Devices for Cooking

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I would also like to thank my classmates Madison Berger, Ceara Byrne, and Stephen Audy. I could not imagine going through this process without them. Our mutual frustration, problem solving and triumph has been a source of strength.

- Jim Schuster, Spring 2013

Abstract

For the past 50 years, appliance design has been chasing efficiency. For more and more consumers, cooking has gone from a chore to a pleasure. Consumers now yearn for kitchen products that enhance the joy and camaraderie of cooking. We are at a point of change in the appliance industry.

Ubiquitous computing—a technology model where computers recede into the background of everyday life by being integrated into everyday objects—has begun to appear in household products like thermostats and bathroom scales.

The culture around a product has also begun to drive innovation in the consumer products industry.

Product design methods are shifting away from siloed approaches—where researchers, designers, and engineers do not collaborate often—towards design methods where many stakeholders work together to define all parts of how a product is designed.

The purpose of this project is to bridge ubiquitous computing, domestic culture, and cross-discipline design methods in order to design, develop, and test concepts for future cooking tools. Using user input to drive concepts generated by a multi-disciplinary team, this study hopes to design better, more useful, usable and desirable cooking tools.
Project Background
A Point of Change

The vintage advertisement to the right touts a feature-packed range that is probably similar to the ranges in most kitchens today. While features have been refined and improved, the functionality remains generally the same.

By contrast, the couple portrayed in the advertisement does not reflect today’s appliance users. While efficiency is a major selling point for many users, the culture of home life has been left largely unaddressed.

Ubiquitous computing has started to reach beyond mobile devices and move into household objects such as thermostats and bathroom scales.

The culture surrounding products has also begun to play a large role in their design.

Design methods are also shifting. Designers are being integrated into multi-disciplinary teams that bridge technology, interaction, and form.

Yours! Automatic, Big-Range Cooking with this Tappan Electric Space-Saver

Yes, with the 36” Wide Tappan Electric, you have all the wonderful time-saving features of the biggest ranges and ease, too. Nobody, too. Everything, from demand is going into the Tappan Electric, including the Tappan Electric’s unique, cross-shaped oven.

Look at that divided top, enough shelf space for you and your “cooking chemist.” Plenty of room for big, a little pans. And plenty of cooling helps on the back panel: automatic wine controls, Harbour Inn, appliance door— all the cook-in-the-future features of a Tappan range.

Not one of the hundreds won’t come through exactly.

Let your style be what you need it to be. With the Tappan Electric, you can have it all: automatic wine controls, Harbour Inn, appliance door— all the cook-in-the-future features of a Tappan range.

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In recent years, internet connectivity has spread throughout the home through the advent of smart devices. Smart devices were dreamt up by the pioneers of ubiquitous computing as a way for physical objects to become connected to a home network (Weiser, 2002). Once connected, everyday objects—kitchen appliances, bathroom scales, etc.—could feed their data back into a larger, whole home system (Misner, 2009).

A starting point for many of these devices is in academic research environments. Numerous concepts focus on augmenting activities in the home to give more feedback and information. For example, the Intelligent Spoon from the MIT Media Lab uses sensors to measure temperature, acidity, salinity, and viscosity to give a very accurate measure of every aspect of what is being prepared (Bonanni & Cheng, 2008).

Similarly, Kranz et al. created a cutting board and knife combination that senses weight, force, and movement to gather more precise data about prepping food (2007).

Research concepts have also explored the possibilities of a system level product to augment cooking activities. One example comes from Smart Kitchen: A User Centric Cooking Support System. This product proposes the use of cameras as a way to track cooking activities across the preparation of a meal. With that data, the app is able to provide exact directions for the next step in recipe (Hashimoto, 2008).

Sensing technology size and cost has reached a point where embedding them in physical objects is easily prototyped and can scale to mass manufacturing. The quantity and variety of cooking tools is a prime base for creating sensor augmented products and experiences.

Within the appliance industry, the influence of ubiquitous computing principles has begun to crop up in products. Some appliance manufacturers such as Samsung have released high-end refrigerators (Figure 1) with embedded tablet computers and a washer-dryer pair that can be controlled remotely from a smart phone (Appliancist, 2011, 2012).

Research concepts have also explored the possibilities of a system level approach, the GE Nucleus Home Energy Manager (Figure 2) serves as a data aggregation tool for the nebulous concept of home energy usage. Paired with GE smart appliances, the Nucleus can give users data about their energy usage and habits (“Brillion Products,” 2012).

Within the appliance industry, the influence of ubiquitous computing principles has begun to crop up in products.

As internet-connected products become more common, they will merge into systems that share of data and information across multiple platforms.

Adjacent home product industries have also felt the influence of ubiquitous computing. The Nest Learning Thermostat (Figure 3) leverages sensing of human behavior to provide better thermostat controls. By sensing activity in the home and combining it with desired temperatures, the thermostat starts to create a schedule designed to save energy and money (Labs, 2012; Patel, 2011).

Fitbit has begun to create a system of products that track personal activity and health. By combining a Fitbit One activity tracker and an Aria scale (Figure 4), user activity, weight, and body fat data are aggregated automatically and presented in a central location (“Fitbit Aria Wi-Fi Smart Scale,” 2012).

As internet-connected products become more common, they will merge into systems that share of data and information across multiple platforms.
Phase 0
Project Background

Understanding the culture surrounding a product is as important to its value as simply augmenting it with sensors or internet connectivity, if not more important. As an example, Fast Company blogger Cliff Kuang sought to show how the Nike+ Fuelband activity tracker beats the Jawbone Up, its closest competitor (2012). Kuang’s findings show that despite the function of each device being the same—using sensors embedded in a wrist band to track activity—the Fuelband sets itself apart by tapping into the culture of running and sport.

While searching for how to best serve this market, Nike found that by tapping into a team mentality, they could encourage users both individually and socially in a way that was familiar to them (Adkins, 2012). This concept of encouragement through athletic metaphor was extended into the interface as well, with data shown as a graph pushing towards green and a points goal to be achieved for the day (Adkins, 2012; “Nike+ Fuelband,” 2012).

In looking at the history of the modern kitchen, this understanding of culture has not been embraced. Part of the reason for this is that many technologies for the home have migrated from the office environment. As they moved over, they brought with them the mantras of efficiency and time savings (Bell & Kaye, 2002).

These mantras were cemented in the culture of appliance design through kitchen of the future concepts. George Keck’s House of Tomorrow was one of the first instances of a future kitchen concept (“House of Tomorrow,” 2012). Its overall design focused on efficiency and spurred the idea of technology attempting to solve problems in domestic life.

Around the same time in Germany, Margarete Schütte-Lihotzky designed what would later be known as the Frankfurt Kitchen (Figure 5). With a design inspired by laboratories and factories, the Frankfurt Kitchen was intended to lessen a woman’s work but its cold and utilitarian appearance and finishes made it very polarizing (“Counter Space: Design + The Modern Kitchen,” 2010).

Post-World War II, the kitchen of the future shifted to become a corporate showcase platform. The Monsanto House of the Future celebrated the larger role that plastics were playing the home. Today we see similar concepts coming from Microsoft, whose Productivity Future Vision video features a home and life centered around touch interfaces. The kitchen experience in particular suggests that digital interfaces and technologies will become the center of the cooking experience (“Showcase: Productivity Future Vision (2011),” 2011).

Figure 5: Frankfurt Kitchen installed in the MoMa Museum, New York.
Photo by Jonathan Saar from Wikipedia
From a test bed for theories of factory efficiency to a utopian technological existence, innovation in the realm of the kitchen has been seen through a skewed lens. Bell and Kaye developed their kitchen manifesto to counteract this lens and give a guide for thinking that is agnostic of design and technology for domestic spaces (2002).

They propose the following:
- Value experience over efficiency
- Understand the use of objects in context
- Consider context to be cultural and dynamic
- Pay attention to people and their experiences
- Find and support rituals of domesticity
Creating a smart device requires collaborative efforts of researchers, designers, and computer scientists (Díaz & Ekman, 2011; Knutsen, Martinussen, Arnall, & Morrison, 2011; Kunaviisky, 2010). The influx of internet-connected devices combined with the desire of product designers and manufacturers to incorporate data and processing technology more deeply into their products has brought about the need to define new strategies for design.

These new design strategies are often referred to as user experience design. Mike Kunaviisky defines user experience as "the totality of end users’ perceptions as they interact with a product or service. These perceptions include effectiveness (how good is the result?), efficiency (how fast or cheap is it?), emotional satisfaction (how good does it feel?), and the quality of the relationship with the entity that created the product or service (what expectations does it create for the subsequent interactions?)" (2010).

These high-level needs help to point to what disciplines will need to be engaged and how they will work together. For example to achieve emotional satisfaction, design researchers gather insights about users’ explicit and implicit needs, and work with industrial and interaction designers to create forms and interactions that surprise and delight the end users. Similarly, Thébault et al. argue that smart devices require a shift from technology-driven research methods to user-driven methods. “This has led designers to step in and to collaborate with engineers to focus on the design of user experiences.” (Thébault, Samier, Bihanic, & Richter, 2008).

The purpose of this project is to bridge ubiquitous computing, domestic culture, and cross-discipline design methods in order to design, develop and test concepts for future cooking tools.

In order to design future cooking tools, a design methodology was developed by the researcher to pull together user ethnography data and a collaborative design team.

The framework starts with a multi-disciplinary team and need finding from appliance users. With the findings from the user interviews, the design team can begin to answer how the product is designed and used.

Insights from the variety of skills and backgrounds on the design team feed into the top track. Findings from user research feed into the bottom track. As the design is refined, the two tracks come together to create one product.
The project was structured in five phases: 1 - Semi-Structured Interviews, 2 - Multidisciplinary Design Workshop, 3 - Concept Generation & Review, 4 - Design & Development, and 5 - Usability Testing.

1 - SEMI-STRUCTURED INTERVIEWS:
Interviews were held with three young professional couples with an interest in cooking.

2 - MULTIDISCIPLINARY DESIGN WORKSHOP
A design workshop was held with students from varied academic and professional backgrounds to generate concepts that address needs found through the interviews.

3 - CONCEPT DEVELOPMENT & REVIEW
Sketch level models were created based on the concepts from the workshop. Concepts were then reviewed with user experience, industrial design, and software development experts.

4 - DESIGN & DEVELOPMENT
Prototypes were generated based on feedback from the expert interviews. Prototypes were then tested using a pilot study.

5 - USABILITY TESTING
Designs were evaluated by young professionals with an interest in cooking. Test results were compared to the interview findings and concepts were compared on the metrics of accuracy, efficiency, attention, time, and satisfaction.
Semi-Structured Interviews
Interview Framework

The goal of the semi-structured interviews was to gain insight about how potential users cook in their homes and what they think about their cooking appliances. The interview structure was developed based on a model by Dev Patnaik (“Interview Structure”).

Patnaik’s interview structure starts with simple introductory questions, then moves into building a rapport with the interviewees. Next, the interviewer asks the interviewees to give him a walk-through of their habits surrounding the interview topic. Lastly, the interviewer asks questions designed to have the interviewee reflect on their experiences and stories.

Final questions and comments are a sometimes overlooked but very important part of the interview. Allowing time after the interview gives interviewees a chance to ask questions or give thoughts that did not directly answer a question in the interview but they felt were important.

Interviews were done with 3 young professional couples in the participants’ kitchens—where the magic happens. Each session was audio recorded and photographed. Sessions lasted no more than one hour.

How often do you cook?
Do you cooking alone or with others?
What got you interested in cooking?
What appliance do you use the most for cooking?
What do you like about your range?
What do you wish your range could do?
Can you walk me through how you go about preparing a meal?
What do you enjoy about cooking?
What is your motivation for cooking?
What holds you back from cooking more?
If there was an application for your range to help you cook, what would it be? What would it do for you?
Do you have any additional thoughts or any questions?

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**Couple #1**

Couple 1 has been dating for 4 years and started renting their home 2 years ago. Since they rent, they did not have the option to upgrade their appliances. They are avid cooks and participate in a Community Supported Agriculture program (CSA)—giving them a large stock of local produce and meat.

The following interview excerpts highlight the couple’s frequent parties and the stories of how they became interested in cooking.

**Do you usually just cook for the two of you?**

**GIRLFRIEND 1**

Usually. Sometimes people come over. But then a lot of our friends are good cooks too, so they bring stuff that they have already made and keep warm in the oven.

**BOYFRIEND 1**

There was a time that we had six crockpots in the kitchen.

**Well, that’s because it was a crockpot-themed party.**

**Everything had to be made in a crockpot.**

**What, individually, got you interested in cooking?**

**GIRLFRIEND 1**

My mom did all of the cooking every day. So when I went to college I knew some basic stuff like making pasta. In college I started to really learn how to cook.

**BOYFRIEND 1**

I just started to do a little bit more and a little bit more and I was like, “Man, I’m good at cooking. This is awesome.”

**Eating? Eating well.**

I was forced to cook when I was little. My mom would make my brother and I cook once a week so we could learn how to cook. She was a good cook so I got used to eating good food so I couldn’t really give up that habit.

She had stacks of recipe books and she would be like, “Find a recipe and I’ll buy the stuff to make it.” Sometimes it worked, sometimes it didn’t. I would try to find the most random recipes I could.

To accommodate the large amounts of food they get through the CSA program, they purchased a freezer the same size as their refrigerator to store soups, sauces and meat.

Their large collection of countertop appliances are stored in a back room next to the kitchen.
**Couple #2**

Couple 2 has been married for 7 years and bought their house shortly after getting married. They have 2 young boys. When they moved into their house, they purchased a refrigerator but kept the other existing appliances.

The following interview excerpts highlight the couple’s attempts to cook together and the stories of how they became interested in cooking.

<table>
<thead>
<tr>
<th>Does one of you usually cook alone or do you tag team it?</th>
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<tbody>
<tr>
<td>WIFE 2: We attempt to tag team once a week and we usually fight.</td>
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<tr>
<td>HUSBAND 2: We have very different cooking styles.</td>
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<tr>
<td>Like I like my onions chopped smaller than he does. Right there off the bat we get into a fight.</td>
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<tr>
<td>And I’ll say, “It’s supposed to be sour cream not yogurt!”</td>
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<table>
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<tr>
<th>What, individually, got you interested in cooking?</th>
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<tbody>
<tr>
<td>WIFE 2: When I was growing up we ate really healthy. So I would go places like Girl Scout camp and there would be Rice Krispy Treats and I tried to figure out how they made them. I was putting together Rice Krispy and honey because I didn’t know, because my mom never made junk food. I taught myself how to bake because I like sweet things. And after that I took over the baking part of all the meals at my family’s house. My mom is a really good cook but she doesn’t really like to bake. Every once and a while she’d make a carrot cake, with lots of carrots in it.</td>
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<tr>
<td>HUSBAND 2: I always watched my mom and my grandmother cook when I was growing up. I’m much more free with my substitutions. I’m like “They’re both dairy, you know, it’s fine.” Also she really likes to follow certain recipes and I’m much more free with my substitutions. I’m like “They’re both dairy, you know, it’s fine.” I taught myself how to bake because I like sweet things. And after that I took over the baking part of all the meals at my family’s house. My mom is a really good cook but she doesn’t really like to bake. Every once and a while she’d make a carrot cake, with lots of carrots in it. And also I interested in weird things like making biscuits in the microwave, which were absolutely gross. I was just fascinated with trying to cook them. I thought it was neat that I could cook them on my own.</td>
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</tbody>
</table>

Despite having a small kitchen, the couple has adapted by crafting clever storage solutions for their myriad of ingredients and gadgets.

A hall closet serves as storage space for countertop appliances.

Frequently used appliances, such as the toaster, stay out on the counter. When cooking, the toaster’s flat top serves as a staging area for cutting boards and plates.
Couple #3

Couple 3 is recently married and purchased a house together about a year ago. Both husband and wife enjoy cooking, but unlike the first two couples, they do not commit nearly as much time or energy to cooking.

The following interview excerpts highlight the couple’s motivation to cook regularly and the stories of how they became interested in cooking.

What motivates you to cook?

WIFE 3
I like it when my husband likes what I make. I’m motivated for him to say, “That’s really good.”

HUSBAND 3
My wife gets cranky if she’s hungry. That’s so true. He’s gotta feed the beast.

WIFE 3
We participate in a CSA, so we don’t have the option of what we buy. We have collards for 6 weeks in a row, so we have to figure out what recipes we’re going to make for collards. That helps me enjoy cooking more because I don’t have to think about making a menu; it’s already in my house and I need to do something with it.

HUSBAND 3
I’ve just always done it since college. I never cooked before that but I just started. To me it’s artistic. I’ll look at a recipe to get an idea of something but then I just go on my own. I just like creating things. The big thing too is health wise. I found out how much bigger I get if I eat out every night. That’s a big part of it.

When they moved in, the couple renovated their kitchen—doubling it in size. Along with the renovation, the couple purchased all new appliances. The couple designed their kitchen to accommodate large gatherings so that friends could join in the cooking.
Task maps of the couples’ kitchens were created to visually represent the cooking experience. The kitchens of couples 1 and 2 had small footprints and limited counter space. By contrast, couple 3’s kitchen had a large and open footprint.

Staging of ingredients was a major issue in the smaller kitchens. Wife 2 found that plates would sit nicely on top of the coffee maker and toaster. Boyfriend 1 would load the dishwasher as he cooked to free up counter space by the sink.

Cooking for couples 1 and 2 often expanded into adjacent rooms. Couple 1 used the room next to their kitchen for storage and an extra freezer. Couple 2 used their dining room (not pictured) and a hall closet for extra storage space for specialty appliances.
Interview SWOT Analysis

Quotes from the interviews were broken out into a Strengths, Weaknesses, Opportunities and Threats (SWOT) matrix for cooking appliances. Taken from the business world, the SWOT matrix is a tool for evaluating a particular product or service based on internal and external factors.

**STRENGTHS**

If there was something that would help you coordinate multiple dishes.

The range could sense if it’s boiling too much or if it’s simmering just right.

Something to help you adjust it, that would be awesome.

We attempt to tag team once a week and we usually fight.

We have very different cooking styles.

I’ve heard horror stories about gas ovens and not having the temperature be right.

A lot of recipes will say simmer and that’s a hard thing to judge.

The front can start to look, like the knobs and handles and the window can start to look bubbly and I didn’t like any of them.

More manly I guess.

**OPPORTUNITIES**

I just started to do a little bit more and a little bit more and I was like,

“Man, I am good at cooking!”

Honestly, if I had more time I would spend more time cooking. I like it that much.

That’s how he wooed me.

If I had more time I would spend more time cooking. I like it that much.

We have very big friend gatherings.

Lots of our friends are good cooks too.

I feel like that would be useful to mount a laptop in the kitchen so that it was usable but out of the way.

To me it’s artistic.

I’ll look at a recipe to get an idea of something but then I just go on my own.

I just like creating things.

**WEAKNESSES**

I would have loved to have a couple more burners.

I feel like it’s really right.

What do you wish your range could do?

Keep a steady temperature.

And the correct temperature.

Oh yeah, our oven sucks!

It would be nice if we could grill inside when the weather is nasty.

I do like grilling.

What features do you like about your range?

Like?

I feel like it would be nice if we had big friend gatherings.

I just find it satisfying creatively. It’s something where I can sort of zone out.

I can listen to the news or think about things and decompress.

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**THRUSTS**

Definitely I’ve gotten to the those days where I’m just like, screw it, we’re just getting McDonald’s from here on out. That’s it!

Frankly I was shocked at how many little options you have now in ranges.

If something takes longer you’re like,

“Oh, that vodka cream pasta I just made from scratch was really not that amazing for having taken three hours to make!”

I get frustrated with the boys because they’re so picky about they eat. It makes me not want to fix anything.

Definitely I’ve gotten to the those days where I’m just like, screw it, we’re just getting McDonald’s from here on out. That’s it!

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Frankly I was shocked at how many little options you have now in ranges.
Users love to cook!

Some users gain satisfaction from knowing their food was made with quality ingredients and prepared just to their liking. Others enjoy the experience of connecting with nature through the foods they prepare. By eating seasonally and locally, they are proud of their food and community.

Relaxation and reflection draws some to cooking. Lastly, creativity plays a large role in fueling the desire to come up with new and tasty dishes.

There is an emotional connection to cooking. While on some nights it can be more about just getting food on the table, the overall experience is something that users value. Cooking is an activity that enhances their quality of life in many ways.

Users actively collect gadgets to supplement what would be considered basic kitchen supplies.

Couples 1 and 2 had full closets devoted to storing their countertop appliances. These devices have become staples in their meal preparation. It allows them to have a wider range of preparation and cooking options as well as to try new techniques. While these devices often are hard to clean—such as food processors and bread machines—the pleasure of making a pie crust from scratch or fresh bread outweighs having to wash extra dishes.

The activity of cooking is deeply rooted in the use of tools. Tools that provide convenience and better results will be valued and used often. Cooking tools provide opportunities to create new experiences.

Users encounter challenges when taking on complex recipes or managing multi-dish meals.

New recipes present a challenge in getting the timing right and to ensure tasty results. Some take on this challenge by trying to perfect dishes—making biscuits every morning for a month until the recipe, timing, and technique are just right. Others try new dishes more infrequently for fear of the results. Timing multiple dishes was an issue across the board for all the couples.

The tools for managing the precision and logistics of cooking are lacking. Current kitchen tools do not provide reference points for comparison. Timers focus too narrowly on individual items as opposed to the meal as a whole.

Users see opportunities for apps to help them cook better, but current solutions do not fit their habits.

Several users use their computers and smartphones to find new recipes and make shopping lists. When they start cooking however, the device becomes a bit of a burden—taking up valuable counter space or needing to be protected from spills and spatter. Some users talked about possibly integrating these types of displays into an appliance, but the same issues arise.

Technology has yet to find its place in the kitchen. Mobile devices integrate better into the cooking environment than laptop computers, but have not yet become connected with the cooking experience.

Insight 1
Users love to cook!

Insight 2
Users actively collect gadgets to supplement what would be considered basic kitchen supplies.

Insight 3
Users encounter challenges when taking on complex recipes or managing multi-dish meals.

Insight 4
Users see opportunities for apps to help them cook better, but current solutions do not fit their habits.
Multidisciplinary Design Workshop
Workshop Framework

The goal of the workshop was to understand user goals when using their cooking appliances, understand the culture and rituals surrounding cooking, and find opportunities for rethinking cooking appliances.

The workshop consisted of four activities—introductory questions, a mind map activity, a collage activity, and final discussion leading to design imperatives.

Participants were 6 students from the Georgia Institute of Technology. They come from various colleges of the institute, including design, computer science, engineering and psychology. The session lasted one hour.

Individual Mind Map Activity

A mind map is a diagram used to visually outline information. A mind map is created around a single word or idea, placed in the center of the page, to which associated ideas, words, and concepts are added.

Collective Collage Activity

Design collages are visual tools for expressing thoughts, feelings, desires, and other aspects of a concept that are difficult to articulate using traditional interview and ethnography techniques. A collage kit typically includes cards or paper sheets, a present collection of images, words, and shapes, and glue sticks.

Design Imperatives
Introductory Questions

To start the workshop, participants were asked to answer four questions about their experiences with cooking. This information was helpful in understanding the participants' interests in cooking as well as providing them with jumping off points for the mind map exercise.

1. How many appliances do you have? Please list them.
2. What is your favorite appliance? Why?
3. What could your cooking appliances do better?
4. What is the future of cooking and cooking appliances?

Mind Map Activity

After the introductory questions, the participants were asked to create a mind map of ideas about ways to improve future cooking appliances.

They were asked to generate keywords that in their opinion meant “smart” and “connected,” or take ideas from their responses to the introductory questions.

From the center point—"internet-connected cooking appliances"—the participants were given four starter branches of the map to fill. They were encouraged to add branches as needed and make connections across the map.

Group Collage Activity

The main component of the workshop was the group collage. The collage was designed to create a level playing field for the designers and non-designers to visually express the ideas they had come up with in their mind maps.

The group was encouraged to search through magazines and photos provided to them. By building the collage together, the participants were able to combine similar ideas as well as extend the ideas of others.

Design Imperatives

To end the workshop, participants discussed and summarized their experiences and thoughts. The discussion was directed by asking them to generate a list of four design goals for an internet-connected cooking appliance, as well as four future steps for cooking appliances in general.
## Participant Introductions

<table>
<thead>
<tr>
<th>ACADEMIC BACKGROUND</th>
<th>FAVORITE APPLIANCE</th>
<th>CURRENT APPLIANCE IMPROVEMENTS</th>
<th>FUTURE THOUGHTS</th>
</tr>
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<tbody>
<tr>
<td><strong>Industrial Design</strong> + Computer Science</td>
<td>![Image]</td>
<td>Be more aware of what is inside them. Most appliances are heavily time-driven and have no real measures to prevent user error in cooking.</td>
<td>Appliances that act like a full system together and are aware of their contents, their context, and the systems around them.</td>
</tr>
<tr>
<td><strong>Chemical Engineering</strong></td>
<td>![Image]</td>
<td>Work a little more quickly for tasks like pre-heating the oven. The freezer should also have more specific settings, for example a setting specifically for ice cream.</td>
<td>Appliances that respond to verbal commands, like the television show The Jetsons!</td>
</tr>
<tr>
<td><strong>Electrical Engineering</strong></td>
<td>![Image]</td>
<td>Be easier to clean, have controls that are simple and direct, and easy to understand.</td>
<td>Appliances designed for enjoyment. A way to socialize and bring people together.</td>
</tr>
<tr>
<td><strong>Psychology + Human Factors</strong></td>
<td>![Image]</td>
<td>Be able to control time and temperature better. For example baking at 400° for 10 minutes and then changing to 350° for 30 minutes without my intervention.</td>
<td>Appliances that text me when food is done and especially if something is burning.</td>
</tr>
<tr>
<td><strong>Mechanical Engineering + Industrial Design</strong></td>
<td>![Image]</td>
<td>Have timers and reminders that are all controlled from one spot. When making a big meal it’s hard to keep track of everything that’s being made.</td>
<td>Appliances that are more automated. Similar to the popcorn button on the microwave, the appliance knows how to cook to perfection.</td>
</tr>
<tr>
<td><strong>Industrial Design + Theatre</strong></td>
<td>![Image]</td>
<td>Adapt better to fit different sizes and configurations of pots and pans. Detect safety issues in the making, before serious problems occur.</td>
<td>Appliances that honor traditional methods and the cooking experience. New technologies will be incorporated, but it should augment what is great about cooking now.</td>
</tr>
</tbody>
</table>

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Photos courtesy of the Whirlpool Corporation
The mind maps took different paths. Some looked at different parts of the cooking process, from finding recipes and learning techniques to reminders and alerts.

Others looked at the system aspects of a connected kitchen, specifically how making the appliances aware of what they are cooking could enhance the experience.

Some even looked at the social and playful aspects of cooking, suggesting how technology could be leveraged to make the cooking experience more social or game-like.
The collage featured different aspects of what a potential future cooking product could be. Some clusters were concepts for feature sets. These included augmented reality displays for an oven, auto on/off controls, applications to adapt recipes to different food preferences and portions, and the need for alerts and feedback when things go wrong. Other clusters include visual inspiration of neat cooking device concepts or fancy cooking gadgets.

The whole chart was centered around technology—computers, phones, and tablets. Interestingly, this section of the collage was dubbed “Technology?”
**Recipes & Techniques Direction**

Augmenting recipe information was a part of almost all the participants’ mind maps and the collage. Participants thought of it as a helping hand with cooking, providing guidance, and tips. Others proposed functions were recipe serving, recalculation tools and ingredient substitutions.

While not the most novel concepts, the sheer quantity of recipe-related items suggests that recipes and techniques have potential as a design direction.

**Social Cooking Direction**

Designing for enhanced socialization while cooking was a surprise finding from the participants’ mind maps. Two participants keyed into cooking being a social activity. One suggested sharing the making of a meal with the help of an application. The second wanted an experience that was more playful and game-like.

Socialization already has a place in the kitchen, as evidenced by guests congregating in the kitchen during dinner parties. Products that leverage this behavior are a logical next step.

**Context Aware Devices Direction**

Context is an important part of product design, especially for smart products. A handful of participants keyed into this idea. One proposed an augmented reality oven that used the door glass as a place to display timers. Others suggested specific tools having advanced features that gave extra information, for example, a cutting board that gives knife technique tips.

Kitchen tools already have a well-defined context of use. Making those tools aware of the context of their use can bring novel and interesting experiences for users.

**Central Control Direction**

User interviews identified managing complex meals as a major stumbling block to cooking better, and workshop participants agreed. Some participants suggested central controls that move food between the phases of a recipe. Others suggested syncing timing of recipes across appliances and tasks.

Central controls may not be a standalone solution, as complexity scales quickly. However, combined with other directions to give focus, central controls begin to make sense.
Concept Development
Addressing User Needs

Concept development began with identification of user needs and translating them into possible design goals. While not all design goals can be satisfied with one concept, pairing different goals together provided a starting point for creating concepts. The following are the possible design goals:

**PRECISION CONTROLS**
Give users cooking tools that give precise information and actionable steps to mitigate mistakes, especially when learning a new recipe or technique.

**SAFETY**
Give users cooking tools that reduce worry about leaving an appliance on, without sending out false alarms.

**TIMING**
Give users cooking tools that off-load managing a multi-dish meal, leveraging current behaviors to reduce complexity.

**SKILL BUILDING**
Give users cooking tools that let them confidently learn new techniques and verify their results.

**SOCIALIZATION**
Give users cooking tools that share the cooking experience with friends and family, near and far.

An understanding of market approach is another important part of the concept phase. By analyzing trends in computing and product development, an estimated product introduction time frame was identified. Concepts were catered to expected technology advances.

As a starting point, consumer-data-driven business models were analyzed. Tim Misner states that current data collection trends from companies like Google and Amazon can enable more consumer-centric, data-driven design for traditional physical products (2009). Specific to this project, the trends of sensors, use-based design, and service design were identified as key factors for designing future cooking tools.

Sensors in physical products play two roles. The sensors provide advanced product functionality and direct access to information about how users interact with a physical product. Use-based design is the process recording the sensor data about how the product is used. The data can then inform the design of future product releases. Service design methods can be applied to products with advanced sensor functionality to address the overall experience of the product.

In the appliance industry, the use of advanced sensors is just beginning. Sensors are used to provide new features but data about user behavior is not tracked. For example, the GE French Door refrigerator’s auto-fill feature uses advanced sensors to fill various sized vessels (“GE Refrigerator Technology & Features,” 2013).

Taking these factors into account, the projected development time frame for these concepts was determined to be 3-5 years. The 3-5 year time frame was based on the expected time to integrate advanced sensors into existing cooking tools and then connect the data from those sensors to a system that can leverage use-based design methods.
Scenarios of Use

Scenarios were developed to outline possible design solutions by combining design goals and the four design directions from the design workshop.

The precision cooking scenario was chosen as the best scenario to drive concept development. It fits best with the project goal of designing future cooking tools. Aspects of each scenario play a role in precision cooking and were included as part of the initial concept.

### Scenarios

<table>
<thead>
<tr>
<th>Desires</th>
<th>Possible Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Host a Dinner Party</strong>&lt;br&gt;A couple wants to have several friends over for dinner and drinks. Both are decent cooks, but normally just cook for the two of them.</td>
<td>• Help managing multiple dishes&lt;br&gt;• Scaling recipes to serve a crowd&lt;br&gt;• Needing to entertain guests&lt;br&gt;• Needing to show off and impress guests</td>
</tr>
<tr>
<td><strong>Precision Cooking</strong>&lt;br&gt;A wife wants to improve her cooking skills. She prefers to cook in a methodical way, but her current kitchen tools do not give her feedback on how her execution compares to the recipe.</td>
<td>• Controlling temperature for low, long cooking dishes&lt;br&gt;• Tools catered to the appliances she owns&lt;br&gt;• Tools that mind dishes when attention is elsewhere</td>
</tr>
<tr>
<td><strong>Cooking as a Social Game</strong>&lt;br&gt;A single young guy likes to cook, but cooking for himself does not allow him a lot of opportunities to try new things. He would like a way to mix up his normal routine.</td>
<td>• Push to mix up a boring routine&lt;br&gt;• Engage with friends outside of dinner party setting&lt;br&gt;• Learn useful new cooking skills&lt;br&gt;• Quantify his cooking abilities compared to friends</td>
</tr>
</tbody>
</table>
Design Criteria

The design criteria were developed to guide concepts for the precision cooking scenario. The criteria were influenced by the findings of the background literature, interviews, and workshop.

Ubiquitous computing would be central to any concept. To best leverage the capabilities of ubiquitous computing, a concept would need to include multiple devices that could share information wirelessly.

The history of the kitchen as a space gives insight into how potential users may perceive a concept. Concepts that aim to reimagine the kitchen space or propose drastic changes to how users currently cook could be initially impactful, but often may be seen as novelties rather than acceptable design solutions (Bell & Kaye, 2002).

The interviews conducted as a part of this study found that kitchen gadgets and specialty tools are an investment that users are willing to make to cook more confidently. By leveraging the willingness to invest in kitchen gadgets and tools, concepts that augment the cooking experience through add-on devices may be more acceptable to potential users, as compared to fully reimagined kitchen concepts.

OVERALL DESIGN CRITERIA
Design a system of add-on and supplementary cooking tools and an interface to allow the tools to share information.

COOKING TOOLS
- Tools designed using ubiquitous computing principles
- Embedded sensors that share data wireless
- Aggregated sensor data that can be used to enhance system capabilities
- Tools designed around current kitchen tools, respecting current context of use
- At least one tool interfaces directly with the range

INTERFACE
- Interface designed for a device that can be used in the kitchen (e.g., tablets, smartphones, laptops)
- Interface designed using appropriate device design guidelines (e.g., Apple’s iOS Human Interface Guidelines)
Phase 3

Concept Review

The goal of the concept review was to have design professionals provide feedback on concepts for precision cooking tools. Concepts were integrated into a document that was sent to the experts. Experts were recruiting using a snowball sampling technique. Two experts from an Atlanta-area design research firm participated in the concept review.

Experts were emailed a document outlining different tools that could be integrated into a system for precision cooking. The tools were a pressure sensing cutting board, a precision burner knob, a temperature sensing spoon, a multi-recipe timer, and a recipe application. The document included sections on each concept page where the experts could write their thoughts about the concepts.

The presentation of the concepts as individual tools was confusing for the experts. They commented that it was unclear how different tools would interact with one another.

Experts felt that the concept of a multi-stage timer was strong and they could envision using it in their own kitchens. The knob and spoon received mixed reviews.

The experts felt that the cost to benefit ratio was too skewed to make the knob and spoon viable solutions. They also questioned if these products could hold up to the heat and moisture in a kitchen. However, the experts found the tangible aspects of the spoon and knob interesting and were interested to know what the tools would be like to use.
Phase 3 Concept Development

**Precision Cooking System Storyboard**

Based on the expert review feedback, the individual kitchen tool concepts were brought together into a storyboard, outlining how the tools work together as a system.

Search for a recipe online and have the cooking timer application import and translate it. From there, timers can be set up for one or multiple dishes, for example steak and a soup.

After prepping all ingredients, it is time to start cooking. Using a smart knob, the tablet knows when the range is turned on and how high the burner is set.

Turning on the knob also starts the timer for the first dish in the sequence.

After the timer begins, the recipe will auto advance to the next step.

Stirring with the temperature sensing spoon checks cooking temperatures against the recipe.

By using the spoon's temperature readings, timers are updated on the fly without the user having to do anything.

The spoon's LED indicator also provides a gentle reminder to stir long cooking dishes at a set interval.

When the meal is almost ready, timers can be dismissed by waving a hand, spoon, pot holder or whatever is handy in front of the timer.
**System Framework**

Using the storyboard as a starting point, a functional framework for the system was defined. The diagram below outlines the process of translating a recipe into measurable data points.

The recipe serves as an entry point into the system. It is read by a simple text-searching application called a parser. The parser searches for pre-defined keywords and phrases. It tags the phrases based on type.

By associating certain words and phrases together, the parser can define steps of the recipe. Each step is defined by start and end actions. These actions are based on times specified in the recipe and physical interactions the user has with the cooking tools.

In between each start and end action, there may be certain feedback mechanisms that provide users with information and status of the recipe step.

By breaking the recipe into discrete steps based on actions, timing is based on user actions and is therefore more precise. When additional recipes are added to the system, adjustments can be made on the fly to keep all the recipes synchronized.

For example in the diagram below, the time to bring the water to a boil is an unknown variable. A traditional timer cannot account for this variability, whereas the action based system described can.

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**Recipe**

- Place beans into pot and cover with cold water.
- Bring water to a boil, then reduce to simmering.
- Simmer for 5 min. and then remove from heat.

**Keyword Tagging**

**Start Action**

**Feedback**

**End Action**

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(From Left) Recipe Card by James Schuster
Dial by P.J. Onori from The Noun Project
Spoon by Katie M. Westbrook from The Noun Project
Concept Wireframes
The storyboard and system framework were translated into detailed wireframes. Wireframing gives a visual representation to the tasks users can perform within a system. The wireframes outline the functionality for a three cooking tools—a timer, a knob, and a spoon—and a recipe application that connects with the cooking tools.

Adding a New Recipe from Online
The first step in the process is to add recipes to the application. To add a recipe, the user enters a search term and selects a recipe from the results. The experience is intended to be very similar to searching using Google, however the user does not have to leave the application to search.

Once the user has chosen a recipe, it can be saved to the application. During saving, the application reads the recipe, searching for keywords and phrases related to the steps of the recipe. Using these keywords, the application creates checkpoints for the self-updating timers.
The second step in the process is to set up the timers. To add a timer, the user selects a recipe from the list of saved recipes. Additional recipes can be added as well—up to four recipes.

If the user wants to add buffer time to the end of a dish, the user can select to stagger the end times. Staggering the end times adds a few minutes to the end of a recipe so that all the dishes do not finish at the same time.
The final step in the process is to cook. To start cooking, the user sends to timers from the application to the timer.

The cooking experience simply asks the user to follow the recipe. As they prepare the meal, the user’s interactions with the burner knob and spoon advance the recipe and update the timers.

The application also features a visual dictionary to help define cooking jargon—simmer, sear, sauté, etc.
The finalized wireframes informed the design of functional prototypes of the tablet application, timer, knob and spoon. Prototypes were then validated with potential users through usability testing.
Testing Framework

The goal of usability testing was to gauge potential users’ efficiency, effectiveness, understanding, and acceptance of a self-updating timer, enabled by sensors embedded into cooking tools—a timer, burner knob, and spoon.

The study consisted of three parts—review of a website for the product, searching for recipes then setting up timers, and executing those recipes using the cooking tools. After each task, participants were asked to complete a questionnaire. When the study was completed, an interview was conducted asking participants to reflect on the study and the overall concept.

Participants were recruited using a snowball sampling technique, beginning with participants from the initial interviews. Participants were Couple 1 from the semi-structured interviews, a single young professional male, and a recently married couple. Each session lasted one hour.

The product website evaluation provided a way to introduce participants to the self-updating timer concept in a medium used by similar high-tech products for the home.

The recipe search and timer setup evaluation was done on a computer using a simulated tablet application. The participants were asked to search for a specific recipe and then save it to the application. From there, they were asked to set up timers for two recipes with different cooking times.

The cooking tools evaluation asked participants to act out preparing the dish. Participants followed the recipe on the application, which guided them through the interactions with the cooking tools.
**Functional Prototyping Sensors**

The self-updating timer takes data from sensors embedded in the cooking tools and compares them to the checkpoints in the recipe. The system provides feedback through the countertop timer and the simulated tablet application. Prototyping this system began with creating a schematic for the sensors to show how they relate to one another.

- **Temperature Sensing**
  
  A digital temperature sensor was used to gauge the temperature of a liquid being cooked. This data was used to adjust for variability in the starting temperature and volume of liquid. For example, a small pot filled with warm water will boil faster than a large stock pot filled with cold water.

- **Position Change Sensing**
  
  A tilt sensor was used to read when the burner knob was turned. This data was used to advance the recipe based on the recipe checkpoints. For example, a recipe requiring bringing a liquid to a full boil before simmering, boiling and simmering would be timing checkpoints.

- **Visual Feedback**
  
  An LED array was used to provide visual feedback for the timers. Each row of LEDs represents a different recipe. Additionally, the LED array plays animations to indicate timers being updated, timers starting, and timers finishing.

- **Control Module**
  
  An Arduino micro-controller was used to manage the input and output of the system. The Arduino is a small computer that reads data from the sensors, sends output to the LED indicators, and sends data to application.

- **Simulated Tablet Application**
  
  A simulated tablet application was the central interaction point of the system. It was prototyped using the Processing—a visual programming language based on the Java platform. The application translates data from the sensors and displays the data in the application.
Functional Prototyping Physical Devices

After building and testing the sensors, controls, and feedback mechanisms, physical devices were created to house them. Computer-aided design (CAD) software was used to create virtual models of the devices. Using CAD gave the opportunity to design in features to house the sensors and allowed for quick refinement of form details. The CAD models were then translated into a series of stacked slices, similar to a sliced loaf of bread. These slices were then cut out of plastic and assembled to form the devices.

Below are the devices with their embedded sensors. From left to right:
- Timer with LED array for two timers
- Knob with tilt sensor for reading turning
- Spoon with temperature sensor
Product Website Review Results

Q1. The website clearly explains the product's purpose.
Q2. The website clearly explains the features of the tablet application.
Q3. The website clearly explains the features of the spoon, burner knob and countertop timer.
Q4. I feel that the products would help me to with timing recipes.
Q5. Based on the website alone, I would be interested in trying the products.
Q6. Based on the website alone, I would consider purchasing the products.

Overall, the product website was well received by all participants. The concept of an self-updating timer was clearly described. Participants were excited about how the system could help them with managing multiple recipes, which all participants identified as an issue they run into when cooking.

Willingness to try out or purchase the product was surprisingly high. However, two participants expressed reservations about purchasing the product.

One participant felt that having more information on the website would help him to make a more informed decision.

The other participant wanted to be able to try the product out in a store. Both these participants said that online reviews of the product would also play a role in their decision making process.

Going forward, the product website needed to include more information about how the system works, video demonstrations of the system, and product reviews from people who had purchased the product. On a larger marketing scale, different sales channels needed to be explored that could allow potential buyers to try out the system.
Recipe Search & Timer Setup Results

Q1. The process of searching for and saving recipes was intuitive.
Q2. I felt confident when using the recipe searching and saving feature.
Q3. The process for setting multiple timers was intuitive.
Q4. I felt confident when using the multiple timers feature.
Q5. I would frequently stagger recipes end times.

Overall, the recipe search and timer setup portions of the application were well received by participants, however the design of the application created stumbling blocks for all the participants.

From observation during the study, it became clear that the participants quickly created a mental model of how to perform a task using the application. The lock-step design of the application often broke the mental models of the participants, resulting in mild confusion and frustration.

Participants were fond of the ability to search for recipes anywhere on the internet, as opposed to having to use a set of recipes that came with the application. They felt that being able to save recipes would be helpful in keeping organized.

Participants felt that the multiple timers feature would be useful when cooking special meals, such as dinner parties or a meal with their parents. Participants felt that the application could help them ensure that everything would be done at the same time while still allowing them to entertain their guests.

When setting up timers, three participants expressed confusion about how the timers would be organized—sorted longest to shortest time, sorted by order added to the queue, etc. This also made the staggered end times function confusing to use because it was unclear how each timer related to the others.

Two participants noted that sometimes they do not follow a recipe, but that they would still like to be able to set multiple timers.

Going forward, the application needed to be designed to accommodate variability in workflows to perform the same task, provide clearer feedback about how recipes are sorted in the timer queue, and provide the ability to add timers outside of the recipe based method.

Recipe Search & Timer Setup Post-Study Questionnaire

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Average Likert Scale Responses

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Cooking Tools Post-Study Questionnaire

Q1. I found the system intuitive to use.
Q2. I imagine most people would learn to use this system quickly.
Q3. It was easy to identify what step I was at in the recipe.
Q4. The information and prompts from the spoon and knob were helpful.
Q5. I felt confident that the system would correctly update the timers I set.

Overall, the cooking tools were usable but lacked clarity in their information feedback. The participants found the features and form of the devices appealing.

From observation during the study, it became clear that the timer feedback was too abstract for most participants to understand. It was unclear how the LED indicators related back to the timers and the recipe.

Two participants were expecting the timer to relate more closely to the steps of the recipe and give prompts accordingly. Others were unclear about which row of indicators corresponded with which recipe.

Two participants suggested adding the timers as a part of the application screen as well. By doing this, they felt that it would be easier to relate the time to the recipes and make the physical timer more intuitive to read.

The temperature feedback of the spoon was not immediately apparent. However, once participants became aware of the spoon readings being displayed on the application, the feedback was understandable and helpful.

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The temperature feedback of the spoon was not immediately apparent. However, once participants became aware of the spoon readings being displayed on the application, the feedback was understandable and helpful.
The usability study results confirmed that potential users found the self-updating timer system to be a novel and useful tool that they would be willing to adopt.

Participants’ feedback was used to refine the design of the application, cooking tools, and overall feedback that the system provides.
Design Refinement
Application & Form Development Process

The goal of application development was to refine the visual design, workflows and interactions of the functional prototype.

The goal of form development was to refine the cooking tools. Recommendations from the usability study were used to refine functional and visual elements.

First, a form language for the cooking tools was defined. A mood board was used to provide visual inspiration for the shapes, materials, textures, and finishes of the cooking tools. Using the form language developed from the mood board, sketches of the cooking tools were created. The mood board was also used to define color usage and iconography for the tablet application. To address the information feedback issues identified in the usability studies, new feedback mechanisms were created. Manufacturing considerations were taken into account through heat and water exposure tests. This information informed the design of the cooking tools, the placement of the internal components, and material choice.
Application Design

The self-updating timer system centers on a tablet application. The application stores recipes, sets timers, and provides recipe directions. The application was designed for the Apple iPad, following Apple’s iOS interface guidelines.

The application has 4 content areas—1. Recipes, 2. Timers, 3. Cooking, and 4. Settings.

The Recipes section is where recipes from the internet can be added to the application for use with the timers.

The Timers section allows users to select recipes from their recipe catalog and then create timing programs.

The Cooking section shows the recipe steps and cooking tools feedback for the recipes being prepared.

The Settings section is where users would connect the cooking tools to the system. The cooking tools connect to the iPad via Bluetooth wireless communication.

The following pages outline the features of the Recipes, Timers, and Cooking content areas, as well as the interactions between the application and the cooking tools.
Application Features: Recipe Catalog

Search
Search for a recipe to add to the recipe catalog.

Select a Recipe
Select a recipe from the search results.

Save the Recipe
Save the recipe.

The application will read the recipe for timer related keywords, then create the recipe steps and the timer checkpoints.
Application Features: Timer Setup

**Add a Recipe**
Select a recipe from the recipe catalog and add it to the timers.

**Reorder Recipes**
Drag recipes to reorder how the timers will be displayed.

**Offset End Time**
Select edit to offset the end time of a recipe.
Application Features: Recipe Layout

Directions

The tabs on the left correspond to the recipes being prepared. The application breaks the recipe into bite-size chunks with the current step highlighted.

When the application processes the recipe, it tags cooking terms—simmer, sear, sauté, etc. Tapping on a term brings up a visual and written definition of the cooking term.

Timers

The time remaining for a recipe is displayed at the upper right of the screen.

Knob Feedback

The feedback from the burner knob is displayed on the center right of the screen. The icon shows the current setting for the knob—low, medium, high, etc. The icon is also used to display prompts for turning the knob up or down.

Spoon Feedback

The feedback from the spoon is displayed on the lower right of the screen. The icon shows the temperature of the food being stirred, as well as the cooking term associated with that temperature. For example, if the temperature is near 195°F, the term displayed would be simmering.

The spoon icon gives alerts when a temperature reading does not match with the recipe.

Navy Bean Soup

**Directions**

Place the beans in a large saucepan and cover with cold water by about 2 inches. Bring to a boil and lower the heat to a simmer. Cook for 5 minutes; remove from the heat, cover, and let sit for thirty minutes.

Drain and reserve. Tie the parsley, thyme, and bay leaf together with kitchen twine.

In a large soup pot or Dutch oven combine the beans, herb bundle, hocks, onions, and garlic with the water. Bring to a boil, cover, and adjust the heat so the soup is simmering.
Application & Device Interactions

Starting a Recipe

Once the timers are all set up, tapping the Start Timers button sends the information to the timer.

On the application, a pop-up notification confirms that the timer has been updated. The indicators on the timer turn on as well.

Moving Between Recipe Steps

When it is time to move to the next step, the next step in the recipe is highlighted. If the screen is not showing the current recipe, an alert badge will appear on the tab of that recipe.

On the timer, the left-most indicator will pulse. If the next step in the recipe requires a change in the burner knob setting, the application will indicate the change required.
Application & Device Interactions

Adjusting for Ideal Cooking Temperature

When stirring with the spoon, the temperature and the associated cooking term are displayed on the application. On the spoon, the light indicator shows how closely the temperature matches to the recipe through varying intensity.

For example, if the recipe says to simmer but the spoon reading is too high, the indicator on the spoon will flash. The application will indicate to turn down the burner knob.

Finishing a Recipe

When a recipe is near finishing, the timer will indicate yellow and red lights at the end time approaches. When time is up, the timer will flash.

On the application, a pop-up notification will appear to indicate that the recipe has finished.

Navy Bean Soup

Place the beans in a large saucepan and cover with cold water by about 2 inches.

Bring to a boil and lower the heat to a simmer. Cook for 5 minutes; remove from the heat, cover, and let sit for thirty minutes.

Drain and reserve. Tie the parsley, thyme, and bay leaf herb bundle, hocks, onions, and garlic with the water.

Bring to a boil, cover, and adjust the heat so the soup simmer slightly. Remove the meat from the hocks, discarding the bones, fat, and skin. Cut the meat into small cubes. Remove the herb bundle and discard.

In a large soup pot or Dutch oven combine the beans, herb bundle, hocks, onions, and garlic with the water. Bring to a boil, cover, and adjust the heat to low.

Add the hake, thyme, onions, and garlic with the water. Bring to a boil, cover, and adjust the heat to low.

Puree about 3 cups of the beans with a some of the broth, brussels sprouts, cream, and garlic with the water. Bring to a boil, cover, and adjust the heat to low.

Your Navy Bean Soup is ready! Season a top of each soup, and serve.
The mood board used images that represent key attributes of the form language for the cooking tools. The attributes were defined by combining current design trends and iconic kitchen implements. The attributes were:

- Organic forms contained within basic shapes
- Bold colors that highlight key elements
- Transparent materials
- Low sheen materials

See references section for photo credits.
Sketching explored different physical forms for the knob, spoon, and timer. Iterations focused on indicators, buttons, and physical touch-points.

The rounded form of the knob helped to inform the shape of the spoon handle and timer body.

Indicators from the knob concepts were translated to the spoon and timer to find a common design.
Manufacturing Considerations

Manufacturing considerations played a large role in refining the cooking tools beyond prototypes. The kitchen is a difficult place to design for; high temperatures, water, steam, and grease spatter have the potential to cause device failures. Additionally, the life expectancy of kitchen tools and appliances is fairly long, especially when compared to consumer electronics. These factors coupled together lead to the need verify that the cooking tools could survive in kitchen environments.

The biggest stresses for the cooking tools are high temperatures and exposure to water. To that end, a test was designed to determine normal surface temperatures of a range and the prototype spoon was subjected to a water exposure and high temperature test.

In order to determine what kinds of temperatures that the knob could be subjected to, the range needed to be heated up to a temperature extreme. The surface temperatures could then be measured to determine if the temperature would be in an acceptable range for the electronics to function correctly. It was determined that running the oven would produce the most heat on the surfaces of the range.

For the heat test, the oven of a standard four-burner gas range was set to 500 degrees Fahrenheit. After preheating, it was left on for 30 minutes, at which point surface temperatures were taken using an infrared thermometer (Figure 6). When compared to the recommended operating temperature of an Arduino micro-controller—negative 40°F to positive 185°F—it was found that surface temperatures of the range would not exceed the recommended operating range of the electronic components.

To test the spoon for water and heat exposure, the spoon prototype was left in a pot of boiling water for 15 minutes. Two-thirds of the spoon was submerged during the test. Afterwards, the spoon was removed from the water and dried. The electronics—a digital temperature sensor—were then tested for correct operation.

It was found that the electronics in the spoon did not suffer any distress from being submerged in boiling water for a significant amount of time.
Timer Design

The timer form was derived from rounded forms of kitchen objects—dishware, glassware, knobs. The sphere is broken by the angled plane of the display area, drawing the eye towards the indicators. The two buttons on the top of the timer form a squared-off ellipse. The visual language of the squared-off ellipse was repeated in the burner knob and spoon.

The display is created using an array of LED’s. Each row represents a timer, with the option to have up to four recipes being prepared at the same time. The buttons stop the end-of-recipe alerts and turn the timer on and off.
**Timer Features**

Recipe times are displayed using progress bars created by 4 LED arrays. The bars are meant to show the general time relationships between the recipes being prepared.

The display is meant to be used at a glance for users to check on their recipes overall. More precise timing is reserved for the tablet application.

- The longest recipe is displayed using the full length of the progress bar. Other recipes are scaled proportionally to the longest recipe.
- As the timers progress, the LEDs will turn off, approaching the yellow and red indicators.
- The power button turns the timer on and off.
- The stop button ends the red LEDs’ blinking when a recipe has finished.
1. Display Faceplate  
   Material: Semi-Transparent Black Polycarbonate

2. LED Reflector  
   Material: Matte White Acrylonitrile Butadiene Styrene

3. LED Board  
   Components: 48 3mm LEDs

4. Main Board  
   Components: Microprocessor, Bluetooth Module, Power Converter

5. Battery Back-plate  
   Material: Matte White Acrylonitrile Butadiene Styrene

6. Upper Housing  
   Material: Gloss Black Acrylonitrile Butadiene Styrene

7. Push buttons  
   Material: Gloss Green Acrylonitrile Butadiene Styrene

8. Lower Housing  
   Material: Gloss Black Acrylonitrile Butadiene Styrene

9. Feet  
   Material: Black Rubber

10. Battery Holder  
    Material: Matte Black Acrylonitrile Butadiene Styrene

11. Batteries  
    Components: 2 AA Batteries

12. Battery Door  
    Material: Gloss Black Acrylonitrile Butadiene Styrene
Burner Knob Design

The burner knob’s cylindrical form was driven by the functional requirements of the components. A softly chamfered channel gives an affordance for grasping the knob. A squared-off ellipse forms the indicator and directional pointier.

The indicator serves three functions—an on/off push button, a status display and a directional pointer. The status display is created using an array of LED’s, indicating if the knob is on or off.

To sense rotation, a black and white patterned circular decal is placed on the face of the range and read by a color sensor. Potentiometers and encoders were not viable solutions for sensing rotation because the burner knob turns the post it is slid onto, therefore a potentiometer or an encoder would not move when the knob was turned.
Burner Knob Features

The burner knob attaches directly to a gas or electric range with existing knobs using an adaptor. Existing range knobs can easily be removed without tools, making installation of the new knob an easy process.

When powered off, the knob can still be used to control the burner. Powering on the knob allows it to connect to the tablet application and be used as a part of the self-updating timer system.

The LED indicator illuminates when the knob is connected to the tablet application. The indicator acts as the power button for the knob.

The knob uses a color sensor and a patterned ring to read changes in rotation. A typical rotation sensor such as a potentiometer or encoder could not be used because when the knob is turned, the post it is attached to turns as well.

The patterned ring is a decal that is attached directly to the face of the range. The color sensor reads the pattern by sensing the change in contrast between the white and black markings.

The decal includes the position indicators for the various knob states—Off, Lite, High, Medium, Low. By including these labels on the decal, the knob can be used with both gas and electric ranges by simply changing the adaptor and applying the appropriate decal.
**Burner Knob Design**

1. **Indicator Faceplate**
   - Material: Semi-Transparent White Polycarbonate

2. **Housing**
   - Material: Chrome Plated Acrylonitrile Butadiene Styrene

3. **LED Reflector**
   - Material: Matte White Acrylonitrile Butadiene Styrene

4. **LED Board**
   - Components: 3 3mm LEDs, Push button

5. **Main Board**
   - Components: Microprocessor, Bluetooth Module, Power Converter, Color Sensor

6. **Battery**
   - Components: 1 Coin Cell Battery

7. **Lower Plate**
   - Material: Matte White Acrylonitrile Butadiene Styrene

8. **Screws**
   - Components: 2 4-40 Thread, 3/8" Stainless Steel Machine Screws
Spoon Design

The spoon’s tapered form was driven by the functional requirements of the components. The major electronics are located in the end of the handle, with the temperature sensor located at the junction of the handle and bowl. The bowl and handle are formed as one part to reduce the likelihood of moisture damage to the electronics. A squared-off ellipse forms the power button and indicator.

The indicator is created using an array of LEDs. The LEDs’ brightness varies in intensity to indicate how close the measured temperature and desired temperature are—the brighter the LEDs, the closer the temperatures. Additionally, the LEDs will pulse as a reminder to stir long-cooking dishes.
Phase 5 Design Refinement

Spoon Features

The spoon’s LED indicator gives visual feedback about the temperature of the liquid being stirred. If the recipe specifies a specific temperature range—simmering, boiling—the LED’s will increase in intensity as reading approaches the desired temperature.

When powered off, the spoon functions like a normal kitchen spoon. Powering on the spoon allows it to connect to the tablet application and be used as a part of the self-updating timer system.

The spoon uses a digital temperature sensor to measure the temperature of liquids, such as sauces and soups. The main electronics on the circuit board were placed near the end of the handle to protect the electronics from heat. The temperature sensor was placed at the junction of the bowl and handle of the spoon to allow for accurate readings.

The LED indicator is dim when the temperature reading is far from the desired temperature.

The LED indicator is bright when the temperature reading is at the desired temperature.
Spoon Design

1. Housing
   Material: Gloss Black Acrylonitrile Butadiene Styrene

2. Main Board
   Components: Microprocessor, Bluetooth Module, Power Converter, Digital Temperature Sensor

3. LED Board & Reflector
   Material: Matte White Acrylonitrile Butadiene Styrene
   Components: 3mm LEDs, Push button

4. Indicator & Push button
   Material: Semi-Transparent White Polycarbonate, Gloss Orange Acrylonitrile Butadiene Styrene

5. Battery Holder
   Material: Matte Black Acrylonitrile Butadiene Styrene

6. Battery
   Components: 1 AA Battery

7. Battery Door
   Material: Gloss Black Acrylonitrile Butadiene Styrene
Conclusion and Future Recommendations

The findings of the study warrant further research into the interactions users have with internet-connected cooking tools. This study indicates that the design of these cooking tools relies heavily on bridging industrial design, interaction design, human factors and engineering. This is evidenced by the future work for this project.

The initial usability study was able to validate the concept of a self-updating timer; however, more in-depth usability testing is needed to refine the interactions and feedback mechanisms of the system. Specifically, studies would need to test a variety of recipe types and the acceptable number of timers to control. Additionally, studies would need to be conducted to inform the physical attributes and ergonomics of the products.

The initial heat and water exposure tests roughly confirmed that the cooking tools could potentially survive in the kitchen. More thorough and controlled stress tests would need to be conducted before moving forward with the development of the cooking tools.

The timer, burner knob, and spoon provided the basic tools to create the self-updating timer. There are many opportunities to expand this system to other kitchen tools.

A multidisciplinary design workshop—similar to the workshop conducted for this study—could be a starting point for identifying potential kitchen tools. As new products are added, the system could become desirable, useful, and helpful for more users.

With the recent influx of ubiquitous computing devices for the home, the appliance industry is poised to create sensor-based products that give users more immersive cooking experiences. The methods and findings of this study serve as reference for creating those new cooking experiences.
References


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The only real stumbling block is fear of failure.
In cooking you've got to have a what-the-hell attitude.

– Julia Child