Making Make-throughs: Documentation as stories of design process

Tiffany Tseng

B.S. Mechanical Engineering, Massachusetts Institute of Technology (2009)
S.M. Mechanical Engineering, Stanford University (2011)

Submitted to the Program in Media Arts and Sciences, School of Architecture and Planning, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Media Arts and Sciences at the Massachusetts Institute of Technology

June 2016

©Massachusetts Institute of Technology 2016. All right reserved.

Signature redacted

Author

Tiffany Tseng
Program in Media Arts and Sciences
May 11, 2016

Signature redacted

Certified by

Mitchel Resnick
LEGO Papert Professor of Learning Research
Program in Media Arts and Sciences
Thesis Supervisor

Signature redacted

Accepted by

Pattie Maes
Academic Head
Program in Media Arts and Sciences
Making Make-throughs: Documentation as stories of design process

Tiffany Tseng

Submitted to the Program in Media Arts and Sciences
on May 11, 2016, in partial fulfillment of the requirements for
the degree of Doctor of Philosophy in Media Arts and Sciences

Abstract

Much of what we design today is mediated by digital processes, from digital tools and software used to create tangible and virtual artifacts, to online resources and communities that enable people to exchange design knowledge. Encapsulating information about how we design into shared digital formats introduces opportunities for democratized education, where people contribute to and use shared digital resources to support their learning.

In this dissertation, I introduce a style of design documentation called make-throughs in which people construct personal narratives of their design process, enabling new opportunities for capturing effort, connecting with other like-minded creators, and reflecting on process. I analyze make-through documentation in the context of two platforms I created: Build in Progress and Spin. Build in Progress is a web-based platform for visualizing how design projects are developed, while Spin is a photography turntable system for creating animations of design projects over time.

Through these platforms, I investigate the following questions regarding capturing and sharing design process: (1) How can tools be designed to motivate and support the creation of process-oriented documentation?, and (2) What role can make-through documentation play in enabling reflective practice?

Through an analysis of shared documentation created using both platforms, interviews with select users, and observations of spaces utilizing the tools, I reveal opportunities for integrating documentation into design practice and re-thinking documenting as an expressive and creative activity. I show how make-throughs support a range of motivations for sharing process, and based on these insights, I provide a set of design principles for learning environments, physical and virtual, championing documentation as a tool for learners to communicate their growth as makers.

Thesis Supervisor: Mitchel Resnick
Title: LEGO Papert Professor of Learning Research
Program in Media Arts and Sciences
Making Make-throughs: Documentation as stories of design process

Tiffany Tseng

The following people served as readers for this thesis:

Signature redacted

Thesis Reader

Mathematics

Maria Yang
Professor of Mechanical Engineering
Massachusetts Institute of Technology

Signature redacted

Thesis Reader

AnnMarie Thomas
Professor of Engineering
University of St. Thomas
Acknowledgments

Thank you to the Media Lab for existing and providing the freedom for me to pursue my interests, build projects, and collaborate with such talented colleagues.

First, thank you to my committee for their encouragement and guidance. Thank you to my advisor, Mitchel Resnick, for cultivating the supportive environment that is Lifelong Kindergarten and for your thoughtful feedback during my time at the lab. Thanks to Maria Yang for all of your advice over the years, from my undergraduate thesis to my doctoral dissertation. Thanks to Ann-Marie Thomas for your energy, enthusiasm, and sharp insight.

Thanks to the extended Lifelong Kindergarten family for all of our thought-provoking conversations. A special thanks to Chris Garrity for her patience and invaluable mentorship; without you, Build in Progress and Spin surely would not exist. Thanks to Amon Millner for life advice and introducing me to the Sketching community; David Mellis for helping me debug Spin hardware; Juliana Nazaré, Alisha Panjwani, and Shrishti Sethi for facilitating the use of Build in Progress during the Media Lab India initiative workshops; Amos Blanton for all of your crazy ideas; Philipp Schmidt for co-hosting; and Jay Silver for sharing your Digikey login information and enabling me to get free two-day shipping for the past five years.

Thank you to fellow PhD students Sayamindu Dasgupta, Jie Qi and Ricarose Roque for the constructive peer pressure. Thank you to Geoff Tsai for being a great friend and collaborator over the years (and for building Spin -1.0).

I'm indebted to my Build in Progress collaborators: Alex Ruthmann from NYU, Erica Halverson and Beau Johnson from Wisconsin, and Danielle Martin (formerly of the Computer Clubhouse). You opened my eyes to new ways of using the tool.

Thank you to all of the amazing educators who have used and built Spin. A special thanks to everyone at the Tinkering Studio at the Exploratorium, Jaymes Dec, Andrew Carle, Erik Nauman, and Sara Bolduc.

This work would not have been possible without all of the hard work from the fantastic UROPs I've worked with over the years; thank you to Thao Tran, Nhu Quyen Huynh, Edwin Zhang, Jan Rodriguez, Stephen Rodan, Alyssa Waln, Stephanie Su, Sarah Liu, Eunice Lin, Teresa Tai, Brandon Lam, Amber Meghan, Ryan Prinster, Kimberly Yu, Victoria Jones, Ryan Mather, Ema Kaminskaya, and Rahul Singh for all of your contributions.

Thanks to Abisola Okuk and Stephanie Gayle for making Lifelong Kindergarten work; Tom Lutz and John DiFrancesco for their prototyping advice; and Keira Horowitz and Linda Peterson for helping me navigate the system.

Finally, thanks to Barron and my family for their unwavering support and love.
Contents

1. Introduction 17
   Make-throughs 18
   Chapter Outline 22

2. Background 25
   The maker movement 25
   Design logbooks: Engineering design perspectives 28
   Documentation for learning: Education perspectives 30
   DIY tutorials and portfolios: Hobbyist perspectives 34
   Documenting for storytelling: Gaming and cooking perspectives 36
   Summary 39

3. Instructables Analysis 41
   Instructables 42
   Methodology 43
   Findings 45
   Discussion 53
   Next Steps 54

4. Build in Progress 55
   Design principles 56
   Design 56
   Methodology 63
   Findings 67
   Summary & Future Work 96
5. Spin 99
   Design principles 100
   Prior work 101
   Design 102
   Methodology 109
   Findings 113

6. Discussion 129
   Design differences and outcomes of BiP and Spin 129
   Design parameters 133
   Design principles for supporting make-throughs 134

7. Conclusion 139
   Summary 139
   Future work 141
   Epilogue: Documentation as ‘part of me’ 143

Appendix A: Instructables Survey 147
List of Figures

1  Build in Progress (left) and Spin (right)  18
2  Branching visualization on Build in Progress from "The Big Chill" Heat Transfer Project by tolney01 http://buildinprogress.media.mit.edu/projects/2370/steps  19
3  Spin app with accompanying frames from a single 360-degree animation  20
4  Documentation framework: An individual learner's make-through documentation trajectory (left) and communities in which making is situated (right)  21
8  Thingiverse Customizer feature for adjusting 3D models  35
9  Twitch live stream of Minecraft game  37
10 Image of differences in pancake browning as a result of varying the amount of baking soda in batter from Serious Eats [López-Alt, 2015]  38
12 Make-through and tutorial comparison  40
13 Sample Instructables project page http://www.instructables.com/id/Rubiks-Cube-Lantern/  42
14 Instructables Survey  45
15 Images from interviewed authors' projects  46
16 Documentation strategy of writing after making  47
17 Documentation strategy of writing after replicate  47
18 Documentation strategy of writing before and while making  48
19 Age of participants responding to survey  50
Responses to the question “Please rank, in order of importance, the reason why you look at Instructable” 51

Build in Progress project page layout 57
Edit step form 58
Project page gallery mode (left) and blog mode (right) 59
Highlighting steps that fall beneath a label in the Blog Mode 59
Iterations of the project page 60
Project questions featured on homepage 61
Build in Progress mobile interface 62
Build in Progress architecture 63
Build in Progress entity relationship diagram 64
Process map (left) and select images from Elucidator’s Kirito’s Blade
project (right) [http://buildinprogress.media.mit.edu/projects/207] 69
Branch for alternative battery options 69
Process map (left) and select images from Tower Defense Arcade Game
and Box (right) [http://buildinprogress.media.mit.edu/projects/1577/steps] 71
Branches for sharing iterations of the arcade game 72
Select images from Arduino BLE Breathalyzer 74
Process map (left) and select images from Internet Monitored Sprinkler System (right) [http://buildinprogress.media.mit.edu/projects/1721/steps] 76
Bluetooth connection branches in Internet Monitored Sprinkler System 77
Process map and selected images from Remix: Soft Circuits 85
BiP on display in workshop space 86
Steps added to projects over time for Arduino BLE challenge 89
media.mit.edu/projects/3242] 92
Types of processes in an integrated hardware and software project
Individual contributions to a collaborative project [http://buildinprogress.
media.mit.edu/projects/1949] 94
Types of design processes and versions shown in branches [http://
builtinprogress.media.mit.edu/projects/3066] 95
Annotated sketch of process for Infinite Mirror [http://buildinprogress.
media.mit.edu/projects/118] 97
media.mit.edu/projects/113/steps] 98
Spin turntable and iOS app 99
Initial Spin notebook sketch 100
13

48 DIY Turntable created by Geoff Tsai (http://fab.cba.mit.edu/classes/863.13/people/geoff/index.html) 101
49 Catch-Up 360 Turntable (http://mi-lab.org/files/2014/12/GallerySetup.png) 102
50 Spin system diagram 103
51 15 frames of spin animation 103
52 Interior of Spin turntable 103
53 Spin build instructions at http://spin.media.mit.edu/build 104
54 Modified turntable with feet 104
55 Interaction flow for Spin mobile app 105
56 Adjusting the distance between the mobile phone and Spin turntable 105
57 Add spin to an existing set 106
58 User profile page on Spin website 107
59 Set viewer on website for project http://spin.media.mit.edu/sets/402 108
60 Filmstrip view mode for project http://spin.media.mit.edu/projects/402/filmstrip 109
61 Entity relationship diagram for Spin database 109
62 Architecture of Spin system 110
63 Map of locations that built or borrowed Spin turntables (Red circles indicate out-of-school makerspaces; yellow schools indicate schools using Spin) http://spin.media.mit.edu/locations 113
64 Stills from propeller-powered car set, viewable at http://spin.media.mit.edu/sets/378 (A-CS) 114
65 Google+ posts from A-CS 115
66 Artbot activity at museum G-CS, with feed of animations on left and Spin turntable set up on right 116
67 Child creating artwork with her artbot 117
68 Still of an artbot spin (G-CS) 117
69 Profile feed from museum workshop 118
70 Children arranging 3D printed designs on turntable before creating a spin 119
71 Child holding up iPad when creating audio recording 119
72 Still images from multi-spin nightlight project (N-S) 120
73 Display of spin animations in N-S makerspace 121
74 Child creating a spin of her 3D printed project at N-S 122
75 LEGO number activities shared by Pre-K students in K-S 122
76 Spins set up in makerspaces next to craft materials, 3D printers, and other fabrication machines 123
77 Custom Spin backdrops (E-CS, P-C, B-S, R-AS) 124
78 Girls constructing backdrop for Spin at E-AS 124
79 Spin selfies (K-S, H-CS, O-S) 125
80 Custom Spin stands (M-S, N-S, K-S) 125
81 Spin created without turntable (P-CS) 126
Zoetrope spin (Q-S) http://spin.media.mit.edu/projects/1419
Stop animation created using Spin (J-CS)
Visible displays of digital documentation using BiP (left) and Spin (right)
Shark box Spin http://spin.media.mit.edu/projects/420
List of Tables

1 Research questions for four dimensions of creating make-throughs 21
2 Documentation motivations and styles of documentation 40
3 Summary of Arduino BLE challenge participants 66
4 Summary of schools using BiP 67
5 Summary of Spin makerspaces (S: school; AS: after-school; CS: community space. + indicates the turntable is still active at the site as of 3/31/16) 112
6 Differences in design and use of BiP and Spin across dimensions of the documentation framework 130
1. Introduction

In this chapter, I describe how new fabrication technologies combined with communities of practice are democratizing design. I argue that transparent, process-oriented documentation (make-throughs) can empower new audiences to participate and describe how I study this potential through the design of novel documentation tools.

Today, we have an unprecedented ability to make things. This ability stems both from new fabrication technologies that bring manufacturing from the factories to our desktops and new communities of practice, both in-person and on the web, that are democratizing who designs and what gets designed through shared resources for learning how to make.

Contemporary Do-It-Yourself (DIY) culture is empowering an increasingly diverse audience to make. It has roots in counter-culture phenomena of the past half-century, from the Whole Earth Catalog periodical [Brand, 1968b], first published in 1968, that covered topics ranging from gardening to welding to alternative education, to punk zines of the 1970s, where musicians rejected large music labels and, instead, found ways to promote their art through self-published magazines. Both proliferated with advances in publication technology; zines utilized inexpensive and accessible photocopying technology, while the Whole Earth Catalog applied new typesetting technology, described by its founder Stewart Brand as follows:

So far as I can tell, the 1968 Whole Earth Catalog was the first example of desktop publishing. The breakthrough tool was the IBM Selectric Composer, a fancy electric typewriter with a replaceable "golf ball" instead of individual keys striking the paper...Typesetting was instant and cheap. [Brand, 1968a].

With modern DIY culture (the maker movement), two technologies are shaping how things are made and how ideas are spread: (1)
personal fabrication technologies, and (2) the Internet. *Makers* are engaging with DIY practices to create artifacts of personal value, from utilitarian alternatives to mass-produced products, such as a 3D printed phone case, to designed objects for play, such as a crafted stuffed animal companion whose eyes light up when hugged. These technologies work synergistically: Fabrication machines take digital instructions, whose digital format enables them to be directly shared on the web. Others can then download and modify shared design files to support their own making.

Yet, digital files are just one piece of the entire design process. They are void of the social contexts in which they are made, including the inspiration for making and the iterations that went into their creation. Additionally, much of what we make involves automated workflows combined with manual processes – in the case of the interactive companion, digital files may govern the outline of fabric cut on a machine, but assembly may still require the manual process of sewing pieces of fabric together. Capturing non-digital processes and the social contexts that motivate their practice provides new ways for people to learn about and reflect on how we make.

*Make-throughs*

This dissertation reveals opportunities that arise when designers share not just *what* they design but *how and why* they design. In other
words, what happens when people share their process of creating, rather than focusing solely on the products they produce? I introduce a style of DIY documentation that I call a make-through, defined as follows:

**make-through**: A type of design documentation where designers, (1) capture their process as they develop a project and, (2) showcase the iterations they work through as they create a project.

The spirit of make-throughs is embedded in the design and public use of two platforms I created to support people sharing design process: Build in Progress and Spin (Figure 1).

Build in Progress (BiP) is a web-based platform for visualizing iterations in a design process. Using BiP, designers share how their projects evolve over time, organizing steps of a project into branches (Figure 2). Social features on BiP enable users to get feedback on work in progress by posing questions to the larger community and receiving responses via commenting. Since launching in May 2013, BiP [buildinprogress.media.mit.edu] has supported over 1,500 users sharing projects.
Spin is a photography turntable system for creating playful animated documentation. With Spin, I consider ways that the act of documenting might be more seamlessly integrated into the design process. Spin is a physical turntable that is used in conjunction with a mobile application to create 360-degree animations of an object (Figure 3). Users can capture how a design evolves over time by adding multiple animations to a single project, and the animations can then be shared directly to social media or downloaded as a video or GIF. Like BiP, Spin is open to public use: Instructions for building your own Spin turntable are shared on the Spin website [spin.media.mit.edu], and the companion iOS application can be freely downloaded from the Apple App Store.

Over the past four years, I have iteratively developed both platforms and studied how they are used by a broad audience of makers "in the wild," specifically analyzing two overarching questions:

- How can tools be designed to motivate and support the creation of process-oriented documentation?

- What role can make-through documentation play in enabling reflective practice?

I analyze these questions within a framework representing four dimensions of documenting: capturing, sharing, reflecting, and situating (Figure 4). In this dissertation, I describe how individual designers...
capture, share, and reflect throughout the process of documenting, all situated in the context of the communities in which they create their work (Table 1). Communities include virtual spaces (Build in Progress and the social networks where Spin animations are shared) as well as physical spaces (such as after-school centers and schools where both tools are employed).

<table>
<thead>
<tr>
<th>Capturing</th>
<th>Sharing</th>
<th>Reflecting</th>
<th>Situating</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can tools...</td>
<td>facilitate the process of capturing physical design workflows?</td>
<td>enable users to connect with others?</td>
<td>communicate the value of sharing process?</td>
</tr>
<tr>
<td>How do makers...</td>
<td>incorporate documentation into their design practice?</td>
<td>leverage networked tools to share their documentation?</td>
<td>situate and motivate sharing process?</td>
</tr>
<tr>
<td></td>
<td>reflect on their design process when creating make-throughs?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The contributions of this dissertation are as follows:

1. A study of contemporary documentation practices of authors and readers of the established DIY online community Instructables

2. The conceptualization, design, and implementation of Build in Progress and Spin, alternative platforms for sharing make-throughs

Table 1: Research questions for four dimensions of creating make-throughs

3. An analysis of the styles and practices of creating make-throughs,
illustrated through case studies of makers using both platforms

4. Design principles for learning environments, physical and virtual, for supporting process-oriented documentation

Ultimately, these results inform the design of meaningful and relevant documentation experiences for a broadening range of designers, from hobbyist hackers to children designing for the first time. I explore how open and transparent forms of documentation provide a new lens for understanding the process of learning to design and how process-oriented documentation can be supported by educators, tool designers, and researchers.

Chapter Outline

I organize this document into seven chapters:

Chapter 2, **Background**, describes the historical precedence of design documentation for a range of audiences, including professional engineers, hobbyist, amateur cooks, and video game enthusiasts. I trace the lineage of non-digital forms of documentation, such as logbooks and journals, to new digital formats including wikis, online portfolios, and video tutorials. I then describe online DIY communities and current practices for sharing what people make, identifying opportunities for alternative styles of documentation.

Chapter 3, **Instructables Analysis**, shares an analysis of one of the oldest and most popular online DIY communities, Instructables [http://www.instructables.com/]. The analysis covers both how authors create documentation they share on Instructables, as well as how readers utilize the documentation they find on the site to support their own design practice. Interviews and surveys with users of Instructables ground the creation of the make-through style of documentation, which emphasizes the process of creating over documenting finished, polished products.

Chapter 4, **Build in Progress**, describes the motivations for creating the online community Build in Progress, followed by documentation of the design of the platform, with a particular focus on developing a visualization tool for representing iteration and creating social features for users to connect with one another to ask questions, seek feedback, and share their work. Using content analysis of shared
documentation and interviews with project authors, I describe how the platform supported students, educators and independent hobbyists documenting across the four dimensions of the documentation framework, ultimately highlighting how the social context supported authentic reflection and brought to light different strategies for when and how to document, a motivator for considering how to aid the process of capturing documentation.

Chapter 5, Spin, begins by framing an alternative, non-text-based style of documentation designed specifically to make capturing and representing process more engaging for new audiences. I provide a technical description of Spin, a platform for sharing playful animations of design projects. I show how the dimensions of the documentation framework are represented in examples of Spin from K-12 classrooms and after-school centers around the world, revealing how documentation can become a creative making endeavor.

Chapter 6, Discussion, highlights the different parameters explored through the design of BiP and Spin and provides design principles for virtual and physical spaces promoting documentation practice as a way to support learning.

Chapter 7, Conclusion, returns to the original research questions proposed in the Introduction, describing how Build in Progress and Spin address these questions and what new questions emerge. I point to several potential future directions for designing and supporting documentation systems.
2. Background

In this chapter, I outline related work on design documentation from a variety of perspectives, including engineering design, education, DIY communities, and hobbyist video game and cooking communities. For context, I provide a brief overview of the maker movement and its growing presence in formal and informal learning environments. I show how shared design documentation has already shaped maker practices and outline how new forms of design documentation are positioned to transform the ways we learn about ourselves and learn from one another.

While networked forms of design documentation are relatively new, design documentation more broadly has long been valued as a tool for communication and self-reflection in professional and educational contexts. This chapter provides an overview of design documentation from several vantage points and combines these perspectives to ground the design of tools for makers.

To begin, I briefly describe the maker movement and how documentation has played a fundamental role in supporting it. I then step back and trace the historical roots of design documentation, from design logbooks and portfolios to teacher-scaffolded documentation and reflection. I follow with a description of existing online communities for DIY tutorial authorship and compare them with related hobbyist practices, drawing specifically from video game and cooking communities. Finally, I discuss how the convergence of design documentation, online communities, and reflective practice can support a growing audiences of makers sharing creative work.

The maker movement

The contemporary phenomenon known as the “maker movement” is characterized by a do-it-yourself attitude in which people design,
build, and share projects they create for fun, to learn new skills, or even to start new business. The maker movement developed through the practices of hobbyist engineers and artists and evolved from community hackerspaces in Europe in the 90s, where hackerspaces served as a space for programmers to collect and work on projects. Inspired by the c-base hackerspace in Germany, several American hackerspaces emerged in the late 2000s, including NYC Resistor in 2007 and Noisebridge, a San Francisco-based hackerspace that opened in 2008. Simultaneously, innovations in fabrication technologies led to cheaper, more accessible means of production outside of traditional mass markets, and these technologies were adopted by hackerspaces to support electronic manufacturing and physical prototyping through tools such as desktop mills, 3D printers, and laser cutters.

Popularization of “making” (as opposed to “hacking”) is attributed to the birth of Make Media, a company that introduced the term “makerspaces” in their magazine Make in 2005. As described by Make founder Dale Dougherty, “make” was chosen as a term more inclusive of practices outside of “hacking” (often associated with programming); it also does not carry the political and countercultural conventions of hacking [Cavalcanti, 2013]. Through Maker Faire events, where makers come together to showcase their projects (Figure 5), the reach of Make has expanded into spaces for making (called makerspaces) in institutions such as universities and K-12 schools. The act of making has come to be used interchangeably with DIY and craft, where people re-engage with creating and modifying “objects with their own hands,” often for leisure or hobby [Kuznetsov and Paulos, 2010, Tanenbaum et al., 2013, Wang and Kaye, 2011], though making is now beginning to describe professional endeavors as well [Gibb and Abadie, 2014, Lindtner et al., 2014].

While there is debate about exactly what encompasses making, people generally characterize making as an activity that supports the design and production of material artifacts, using a combination of physical and/or digital processes, for creativity and engagement with do-it-yourself practice [Blikstein, 2013, Halverson and Sheridan, 2014, Kuznetsov and Paulos, 2010, Martin, 2015]. Referred to as “the new industrial revolution” [Anderson, 2012], making is an umbrella term for a diverse array of practices, drawing from traditional crafts, mechanical fabrication, and programming and electronics, with the latter serving as a means to provide interactivity to physical objects.

A distinctive quality of the maker movement is its open culture in
which designs are commonly shared freely online to support remixing. Two prime examples of open source hardware are the Arduino microcontroller ¹ and Rep-Rap 3D printers ². Both are models of open source in which the schematics for building the product are free for anyone to use, modify, and sell [Gibb and Abadie, 2014, Thompson, 2011], enabling others to learn from how they are made and use them as a basis of their own (also open) products. Hardware companies such as Sparkfun ³ and Adafruit ⁴ open source a majority of the products they sell. This general spirit of sharing is prevalent in maker culture, with makers sharing their creations with one another online through digital design files and written tutorials on sites such as Instructables and Thingiverse (which I describe in detail in DIY tutorials). Being open builds a collective community’s knowledge, with designers collaborating on building better products for everyone, while also helping individual designers establish themselves as experts [Thompson, 2011].

In K-12 education, researchers often draw from Constructionist learning theories developed in the 1980s by Seymour Papert, which promote learning through creating personally meaningful artifacts that can be shared and discussed [Blikstein, 2013, Papert, 1980]. The uptake of making in education is evidenced in a growing number of

Figure 5: Maker Faire Paris http://static.makery.info/wp-content/uploads/2014/06/maker_faire_paris_2014_makery_stand_badge_SD.jpg

¹ https://www.arduino.cc/
² http://reprap.org/
³ https://www.sparkfun.com/
⁴ https://www.adafruit.com/
makerspaces, both by organizations with a history of supporting hands-on learning such as science and children’s museums, as well as new spaces for production such as libraries. There has been a large effort to create new spaces for making in schools as well, with the U.S. Department of Education announcing a Makeover Challenge in early 2016 to support high school teachers building new makerspaces in their schools [DoED", 2016].

While there has been much enthusiasm for making in schools, research studying the learning outcomes of making are only beginning to emerge [Halverson and Sheridan, 2014, Martin, 2015, Wardrip and Brahms, 2015]. In a framework for learning practices around making, Wardrip and Brahams draw from a content analysis of Make Magazine as well as observed behaviors of young makers at the Children’s Museum of Pittsburg and include practices such as inquiring, expressing intention, and developing fluency [Wardrip and Brahms, 2015]. A description of maker mind-sets is described by Martin, which captures the playful, asset- and growth-oriented, failure-positive, and positive nature of making [Martin, 2015].

Design logbooks: Engineering design perspectives

A designer’s sketches, calculations, and meeting notes are commonly compiled in physical design journals or logbooks, which serve as legal evidence of intellectual property and are thus critical for record keeping [McAlpine et al., 2006]. Beyond record keeping, logbooks help capture a designers’ personal decision-making process, from benchmarking research to analysis of design iterations, and serve as a reminder of work in progress. The types of documentation captured can be classified based on their resolution and intended purpose. For example, Ferguson proposed the following categorization for sketches [Ferguson, 1994]:

- **Thinking sketches** - Used for self-reflection for the designer.

- **Talking sketches** - Used to support collaboration within a design team.

- **Prescriptive sketches** - Used to communicate a design to stakeholders outside of the design team.
By consolidating these types of information in one place, logbooks become objects for reflection in which a designer can review their decision-making process [Oehlberg et al., 2009]. Reflection is considered a critical element of a designer’s practice and is commonly integrated into design curriculum [Adams et al., 2003, Agouridas and Race, 2007, Amon et al., 1996]. Reflective practice is often associated with iteration as well because iterating on a design involves evaluating and assessing its outcomes through reflection. Adams et al. describe this practice as “problem setting,” in which designers make sense of ambiguous design tasks by prioritizing relevant information [Adams et al., 2003].

While logbooks often take the form of physical notebooks, electronic instantiations have been proposed to foster communication and information management across teams and corporations. Information management for engineering teams can foster improved performance and product quality [Tichkiewitch and Brissaud, 2004]. Researchers have analyzed the use of physical logbooks with shared virtual file share systems, arguing for hybrid journaling as a means to facilitate shared documentation [Oehlberg et al., 2009]; wikis as centralized repositories for design teams [Walthall et al., 2011, Yang, 2009]; and electronic notebooks for designers [Hong et al., 1995]. Such systems leverage the benefits or features of traditional pencil-and-paper documentation while allowing distributed design teams to share digital design work such as CAD files. Yet, research on knowledge capture and representation is ongoing, with special attention to new interfaces for recording information and open cultures for “mass collaborative product development” [Chandrasegaran et al., 2013].

Much of the work on design journals comes from the engineering design research community and thus studies student teams or professional engineers. These audiences have their own unique documentation goals, such as considerations over intellectual property, and their goals can be distinct from learners or hobbyist designers that characterize the maker movement. For example, from the very nature of developing open hardware projects, many hobbyists wish to create documentation that is accessible to other people to recreate or remix, while this may not be a primary concern to professional engineers. The value of design iteration, though, is supported through both formal and informal design contexts [Adams and Atman, 2000, Mosborg et al., 2005, Norman, 1993, Resnick, 2002].
As documentation is used as a source for tracing thought process, it is unsurprising that documentation is highly valued by educators. The act of documenting involves reflecting through evaluating and communicating one’s knowledge. In How We Think, Dewey defined the act of reflecting as follows [Dewey, 1997]:

Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and further conclusions to which it leads...it includes a conscious and voluntary effort to establish belief upon a firm basis of evidence and rationality.

Reflection is a deliberate process by which a person considers their beliefs or understanding based on evidence at hand, helping people learn new skills, build theories, and evaluate and make decisions [Moon, 2013]. Reflection is a pillar of experiential learning, in which a learner plays an active role in shaping her own knowledge through first-hand experience observing, reflecting, abstracting, and experimenting (Figure 6 [Kolb, 1984]).

The types of reflections that learners may have can be categorized based on the depth of reflection [Hatton and Smith, 1995]:

- **Descriptive** - A description of events
- **Dialogic** - Stepping back from an event and exploring the reasons for the event
Critical - Exploring reasons from a broader social, ethical, moral, or historical standpoint

Similarly, the act of engaging in a reflective practice has been described as progressing from a description of the experience to concluding and planning what to do based on the experience, as shown in Gibbs' reflective cycle (Figure 7 [Gibbs, 1988]).

![Gibb's Reflective Cycle](https://c2.staticflickr.com/8/7010/6641412847_4c55bae318.jpg)

Reflection can occur immediately after an event (reviewing) or after returning to an event (recollection) [Boud et al., 2013]. The time in which reflection happens was further theorized by Donald Schön to involve two types: reflection-in-action and reflection-on-action [Schön, 1983]. Reflection-on-action involves reflecting on a past experience by examining factors leading to an outcome. In contrast, reflection-in-action is a continual process that happens simultaneously with engaging in an activity; reflection-in-action happens in response to an unexpected outcome and informs the next action. Schön's notion of reflection-in-action portrays a fluid and potentially unconscious activity, challenging the proposition that reflection is a deliberate process that requires stepping back to analyze a situation.

Literature on reflection is represented across a broad spectrum of disciplines, from education, medical practice, and design, for novices and professionals. Across these domains, conditions for fostering reflection include allocating time and scaffolding the process of learning to reflect through structured guidance [Moon, 2013].
There are many learning philosophies in which documentation is a pathway for engaging in reflective practice. A prominent one is the Reggio Emilia philosophy, which emphasizes self-guided learning in early childhood education and places a strong emphasis on documentation for creating "visible learning" that teachers can use to understand and support children's growth [Katz and Chard, 1996, Rinaldi, 2006, Wien, 2011]. Through compiling photographs and student-created artifacts (such as sketches and written documents) and putting them on public display, teachers create documentation that sparks discussion between themselves and the children and between themselves and other members of a community. Essential to this process is capturing throughout rather than after a learning experience is complete in order to construct a narrative of "who children are" [Turner and Wilson, 2009]. Tiziana Filippini, coordinator of the Documentation and Educational Research Center of Reggio Emilia, describes the goals of documentation as follows:

"Documentation is not about the reorganization and arranging of material with the aim of assembling a descriptive linear story. Rather, documentation is a narrative pathway with arguments that seek to make sense of events and processes."

Developing documentation habits and strategies has been supported through research with educators, emphasizing understanding basics principles of visual perception to aid interpretation and becoming comfortable with publicly displaying artifacts of learning [Wien, 2011]. Important to this process is valuing documentation not just as a tool but as a means to develop new understandings and relationships to children and their learning.

The philosophy behind documenting work-in-progress has been integral to strategies in arts education, such as the Process-Folio project from Project Zero in which learners capture their design process in portfolios that are discussed and shared [Gardner, 2011]. Portfolios more generally can be used to enhance learning, identity development, and communicative and reflective practices [Barrett, 2010, Brown, 2002]. Existing research has studied both physical, paper-based portfolios and e-portfolios and distinguish between portfolios as workspaces and portfolio as showcase [Barrett, 2010, Bierut, 2013]. Portfolios as workspaces highlight design process, while those used as showcases communicating achievement.
There is a rich history of research on the role of technology in supporting documentation and learning. In the 1980s, Collins and Brown proposed that computers pose new ways to study both created objects as well as the process carried out to achieve them, describing how computers naturally track actions performed by a user [Collins and Brown, 1988]. Lin promoted reflective practice in which learners monitor, evaluate, and modify their thinking while comparing themselves to peers or experts [Lin et al., 1999]. They outlined four design features of technologies that support reflective thinking:

- **Process displays**: Displays a learner’s problem solving process through playback
- **Process prompts**: Prompts a learner to explain and evaluate what they do before, during, or after problem solving
- **Process models**: Models expert thinking in a way that enables learners to compare their own processes
- **Reflective social discourse**: Provides a community-based context for comparing perspectives and gaining feedback

How do methods of capturing actions performed on a computer translate to physical making? While there is a rich history of interactive tools for children that combine physical making with digital narration such as [Jacoby and Buechley, 2013, Raffle et al., 2007], few have documented the process by which children create physical artifacts. Systems that integrate documentation often do so for the purposes of data collection and research, rather than to present the documentation in ways that serve the learner directly (for example [Kharrufa et al., 2010, Lamberty and Kolodner, 2005]). I previously explored this space through the creation of physical toolkits that can automate the process of capturing how they are assembled. For example, I co-designed Mechanix, a camera-based system for capturing children’s creations with a tangible toolkit that projects children’s creations directly on the play surface, enabling children to construct and test each other’s designs [Tseng et al., 2011, Tseng and Bryant, 2013]. I also invented Replay, a construction kit that records how it is assembled and generates a 3D model and recording that can be shared [Tseng et al., 2012]. Yet, with both examples, the documentation is confined to the specific construction kit, limiting opportunities to share with others outside of the system.

In education, documentation is often co-constructed by teachers
and learners, where educators play a major role in capturing and organizing artifacts created by children and the process by which they create them. However, technology can help facilitate the process of collecting and representing documentation. As making becomes more prevalent in schools, how do we help learners develop agency as they capture, share, and reflect on their own development? A growing number of online communities in the DIY space point to several possibilities.

**DIY tutorials and portfolios: Hobbyist perspectives**

Documentation within the DIY community has become particularly salient as the maker movement has grown to support a distributed network of designers of varying backgrounds and skills. Prior work has studied the development of tutorials on sites such as Instructables, Ravelry, and personal webpages and describe hardware developers, IKEA hackers, and crafters [Dalton et al., 2014, Kuznetsov and Paulos, 2010, Phillips et al., 2013, Rosner and Bean, 2009, Torrey et al., 2007, Wakkary et al., 2015]. This work reveals how members of the DIY community engage in project sharing online to express themselves creatively, connect with others, and craft an online identity [Kuznetsov and Paulos, 2010, Rosner and Bean, 2009, Torrey et al., 2007].

Documenting physical artifacts and processes carries a unique set of obstacles, including restricted ability to manipulate physical documentation interfaces due to the preoccupation of one's hands and challenges with capturing and representing three-dimensional creations. These issues have led researchers to study ways to support users capturing and navigating documentation, including video authoring tools for physical demonstrations [Chi et al., 2013] and analyses of how users search through content relating to physical craft processes [Torrey et al., 2009].

The maker community has begun to explore tools for enabling others to remix physical creations. This include the Customizer feature in Thingiverse, an online community for sharing 3D-printable digital designs. With Customizer, users can tweaked a digital design using a set of parametric sliders (Figure 8). However, research analyzing remix patterns on Thingiverse found that few users utilize Customizer to contribute new designs [Oehlberg et al., 2015]. The authors of this paper suggest that tools could be improved by providing...
reference models for consumer products that are popularly adapted as well as highlighting non-physical tools and techniques that are applied to remixing.

While elements of documentation, such as images, may be captured throughout the process, much of the writing process for documenting happens after the project is complete [Torrey et al., 2007]. Kuznestov et al. suggest that a reframing of DIY communities as “studios” rather than venues for “showcasing functional and completed work” may provide new opportunities for users to receive feedback on work in progress. This sentiment for sharing unfinished and evolving work is echoed in the DiYSE manifesto [De Roeck et al., 2012].

A recent analysis of DIY tutorials forefronted several critical parameters for creating documentation others can carry out themselves; these parameters include acknowledging the competencies required to complete a project, using consistent formatting, and ensuring accurate information and sequencing of steps [Wakkary et al., 2015]. This research determines the worth of instructions based on how well others are able to follow it to replicate projects.

The work described in this dissertation, instead, focuses on supporting users capturing their personal experience of creating a project, rather than instructions for others to replicate it. Similar to the online studios proposed by [Kuznetsov and Paulos, 2010], I consider how sharing work-in-progress might support designers throughout their design process. In the following chapter, I will describe how my analysis of the Instructables community substantiates the need for alternative forms of sharing.

Figure 8: Thingiverse Customizer feature for adjusting 3D models
The previous work largely applies to adult makers, but there are a growing number of efforts to support young people making. The Open Portfolio initiative led by Maker Education has begun to examine how portfolio practices can be fostered for young makers as a way to capture and communicate learning [Keune et al., 2015]. Challenges with helping young makers build portfolios involve developing tools that are flexible enough to integrate into existing spaces and workflows and are able to capture both digital and physical making.

Finally, online communities are only part of the maker ecosystem. Facilitation and space design are also of critical importance for supporting designers, particularly young makers, engaging in a design process for the first time. For example, Petrich and Wilkinson describe the craft of designing spaces in order to encourage collaboration and creativity [Petrich et al., 2013]. This dissertation examines the role of both virtual and physical spaces in encouraging process-oriented documentation practices.

**Documenting for storytelling: Gaming and cooking perspectives**

Documentation takes on many different forms across a multiplicity of domains, from cooking and recipe-sharing, video game streaming, programming communities, and action-sports video parts. Here, I focus specifically on documentation for storytelling and play within two domains: video games and cooking.

The term *make-throughs* stems from the concept of *play-throughs* in the video game community. Much like instructions can be contrasted with stories, there are two distinct forms of documentation for gamers: walk-throughs and play-throughs. A walk-through is a guide written with the intention of helping others accomplish a particular goal within a game. They are to-the-point, edited to only include the necessary steps needed to complete a task and can be found on sites such as GameFAQs\(^5\).

In contrast, an emerging format of documentation is play-throughs, which are live-streamed or pre-recorded footage of a user playing a game. Largely unedited, play-throughs capture a specific player’s experience playing a game, often combined with humorous commentary. Examples of play-throughs can be found on the popular platform Twitch\(^6\), in which users share a live-stream of a game alongside a chat window and video feed that may show the player’s facial

\(^5\) [http://www.gamefaqs.com/]

\(^6\) [http://twitch.tv/]
expressions as they play the game (Figure 9) [Hamilton et al., 2014].

Instructional DIY documentation are like walk-throughs: they are guides for completing a particular project. In contrast, a make-through is like a play-through: it is a personal account of a designer’s or design team’s experience developing a design. It is captured as the design is being created, rather than after it is complete, and it highlights the iterations and mistakes that may go into creating a project.

Sharing the social context around creating is also prevalent in the cooking community. While many cookbooks share recipes in an instructional format, cooking is strongly tied to cultural traditions, and recipes are sometimes accompanied by stories about their origins. Researchers have begun to explore how the relationship between familial interaction, family history, and recipe sharing can be integrated into the design of ‘homemade cookbooks’ [Davis et al., 2014].

In October, 2015, the New York Times published on article on how
written recipes and cookbooks are becoming more open-ended [Severson, 2015]:

Editors, professional cooks and booksellers and others say recipes have become more open-ended and broader in their approach. Instructions have shifted away from formulas towards deeper explanations of technique, offering context and lyricism.

This trend is especially representative in food blogging, where non-professionals share their own recipes alongside a short description of context on sites like Allrecipes. On the food blog Serious Eats, test cook J. Kenji López-Alt prefaces his recipes with a description of his process perfecting a recipe. As an example, Figure 10 displays the results of an experiment in which he varied the amount of baking soda in various batches of pancake batter [López-Alt, 2015].

In cookbooks, authors can embed recipes within stories of how they were inspired to make a particular dish. In My Paris Kitchen, David
Lebovitz writes of his first experience failing to make a crepe at Breizh Cafe in Paris before sharing a recipe for buckwheat galettes [Lebovitz, 2014]. Phaidon’s recently published anthology called Rene Redzepi: A Work in Progress includes a journal from the chef as well as a photo book of daily life in the kitchen alongside a book of recipes. The publisher describes this series as follows:

While the journal is the book’s heart, it is supported by the recipe book containing 100 brand new recipes and the flick book of 200 candid images which provide a stunning, and often humorous, insight into the inner workings of the restaurant and its talented team of chefs. ⁹

In this case, the recipes are supplementary to the journal and photo book that captures the chef and his team’s creative process. These examples show how recipes can be tightly integrated with stories of their creation, capturing the context in which they were created as well as the process in which they were made.

Summary

Creators have a range of motivations for sharing what and how they make. On one extreme, documentation is created for oneself through the use of personal logbooks or design journals that contain notes and sketches to externalize one’s thought process. On the other extreme, documentation is curated to showcase one’s abilities in artifacts such as portfolios. Other motivations mix these two formats through stories of process. When these types of documentation are
shared online, it enables designers to connect with collaborators or like-minded creators. These contexts for sharing also provide distinct benefits and opportunities for reflective practice.

While motivations for creating documentation are not mutually exclusive, Table 2 summarizes the main objective of different types of documentation.

<table>
<thead>
<tr>
<th>Motivation</th>
<th>Type of Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Design journal</td>
</tr>
<tr>
<td>Storytelling</td>
<td>Make-through</td>
</tr>
<tr>
<td>Instructing</td>
<td>Tutorial</td>
</tr>
<tr>
<td>Showcasing</td>
<td>Portfolio</td>
</tr>
</tbody>
</table>

This dissertation describes how make-throughs encourage transparency as makers share how they create throughout their design process. I want to underline that there can be overlap between make-throughs and tutorials – tutorials can embed stories, while make-throughs can contain some elements of instruction (Figure 12). However, with a focus on revealing the iterative design process, make-throughs have the potential to introduce new pathways to share and reflect, which I will describe in the remainder of this document.
3. Instructables Analysis

In this chapter, I describe an analysis of how authors and readers use the online DIY community Instructables. I share differences identified in the practices of these two types of users in creating and applying design documentation and how this distinction led to the conceptualization of make-throughs.

Design documentation takes on many forms online, from personal blogs to project repositories to online communities. Previous work identified motivations of users sharing documentation, including showcasing their technical expertise, crafting an online identity, and giving back to the community [Kuznetsov and Paulos, 2010, Torrey et al., 2007]. Rather than focusing on motivation, the study described in this chapter focuses on the methods by which people contribute to and utilize information from shared documentation.

Documentation shared through maker communities is part of a movement towards ‘pull’ models of developing resources, in which information is distributed, specialized, and ever-changing in response to shifting needs [Hagel III and Brown, 2011]. As the landscape of tools, materials, and techniques constantly change in the DIY community, user-generated content has become increasingly important as a form of knowledge sharing. The generation of design documentation can also be beneficial to the authors themselves, as reflection through documentation can be used to identify alternative approaches and understand decision making for both novices and professionals [Dalsgaard and Halskov, 2012, Lin et al., 1999]. Thus, an improved understanding of how people create design documentation as well as how readers appropriate it is critical to supporting knowledge distribution in these communities.

This chapter presents a study of how design documentation is created and used by authors and readers of Instructables, one of the oldest DIY online communities. In this study, conducted in 2011, I
investigated documentation practices through semi-structured interviews with 5 project authors, who spoke about how they documented their process and translated their process into a sharable format. Additionally, to understand the use patterns of Instructables readers, an online survey consisting of multiple choice and open-ended questions was distributed with a total of 230 respondents. The inclusion of authors and readers in this study helped elicit several distinct needs and practices of these two types of participation and is used to establish key design opportunities for supporting both types of creators. A summary of this work was published in Designing Interactive Systems in 2014 [Tseng and Resnick, 2014].

**Instructables**

![Sample Instructables project page](http://www.instructables.com/id/Rubiks-Cube-Lantern/)

Instructables is a popular online DIY community that serves as a "place that lets you explore, document, and share your creations" [Instructables, 2016]. It is one of the oldest and most established online DIY communities, having launched in 2005. As of March, 2016, it hosts over 80,000 projects in categories such as food, technology, and living. On the site, users share their projects by creating an "Instructable," or a step-by-step guide describing how they built their
project. Within each step, users can add text descriptions, photos, and videos (Figure 13). The steps are organized in a blog-like format, with each step described one after another on a project page. A guide is typically published on the site after a project is complete and all the steps of the project are documented. This enables others to follow the guide to build their own version of the project, at which point they can click the “I made it!” button on the project page.

By sharing on Instructables, users contribute to a large community of creators that can view and provide feedback on their work. As of January, 2015, the site supports 30 million unique monthly users. Users can leave comments on project pages and can also socialize on the community forum, with subforums dedicated to topics such as art, games, and kids. Finally, the site hosts contests in which users submit Instructables under a particular theme, and prizes are given to the top projects. For example, the site hosted a Valentine’s Day challenge in February, 2016, where the grand prize winner received a projector and runners up received Instructables t-shirts.

**Methodology**

This study of the Instructables community characterizes authors and readers through an analysis of the following research questions:

1. How do makers create design documentation online?

2. How do makers utilize online documentation in the context of their own projects?

To understand how both authors and readers use Instructables, a mixed-methods approach employing semi-structured interviews and online surveys was used. All of the data collection took place in the Fall of 2011. Semi-structured interviews were conducted individually with five members recruited through a forum post on Instructables and e-mails sent to mailing lists at a private university. During the interviews, authors discussed aspects of documenting and sharing their projects through the site. Several questions from the semi-structured protocol are listed below:

1. **Motivation**

   (a) What are your motivations for documenting your projects and
sharing them on the site?

2. Documentation Tools

(a) Describe the process of documenting your project.

(b) How do you decide what to document?

(c) What tools do you use to help you document your project?

3. Writing an Instructable

(a) At what point do you determine that your project is Instructable-ready?

(b) How do you determine what level of detail to provide in your Instructable?

(c) Are there any tricks you have for making writing an Instructable easier?

4. Feedback

(a) Have you ever received useful feedback from others who have viewed your Instructable?

(b) Have you ever edited or updated your Instructable as a result of feedback you received?

Each interview was an hour in length, and all but one was conducted in-person; the exception was conducted online via Skype. The interviews were audio recorded and transcribed, and thematic codes were identified through line-by-line coding of the transcripts.

To gain a broad understanding of how readers use Instructables documentation, an online survey was distributed through a forum post on the website and through mailing lists at a private university. The survey comprised of 15 multiple-choice and open-ended questions pertaining to ways members use the Instructables site and their experiences recreating and applying Instructables to their own projects. The survey was intended to take approximately 10 minutes to complete. The full survey is included in Appendix A, with several of the questions shown in Figure 14.
The results of the survey were analyzed using one-way ANOVA tests to test for differences in responses between groups based on age, frequency of using the site, and whether or not participants had experience authoring, recreating, or applying Instructables (where authoring means that the participant had previously authored an Instructable project, recreating means that the participant replicated a project shared by another user on the site, and applied means that the participant used only a component of someone else’s documentation without fully replicating it).

**Findings**

In this section, the insights drawn from authors are first described in *Authoring design documentation*. Next, a description of how readers incorporate the tutorials they find on Instructables is provided in
**Using design documentation.** The implications of these findings are then outlined in the Discussion.

**Authoring design documentation**

The five interviewed authors ranged from 21 to 43 years old and represented a broad spectrum of experience, authoring anywhere between one to over 100 Instructables. One of the five authors was female. Examples of projects documented by these users included a baby-changing table, musical instruments, and street art. Images from the authors' projects are displayed in Figure 15.

![Figure 15: Images from interviewed authors' projects](image)

**Documenting a project**

Creating an Instructable tutorial involves two stages: documenting the making of a project through photographs and notes and writing and publishing the tutorial on Instructables.

Interviews with authors revealed three distinct strategies for documenting a project. The first was to **write after you make**, as displayed in Figure 16.

With this strategy, authors would continually capture photographs of their process while they were making a project and, after the project
was complete, would write their Instructable using these images as reference. However, the process of documenting while making a design can be challenging, as described as Participant A:

I was in the middle of wanting to tinker and solve problems. But I had to break out of that in order to be like, “Oh wait, I have to take a picture,” and I don’t want to. It’s sort of annoying.

A problem described by the authors was that documenting can easily be forgotten in the midst of making. This especially posed a problem if a project could not easily be reverted to an earlier stage. Three out of the five authors had the experience of realizing they forgot to document a step after having completed their design.

To address the issue of forgetting to document particular steps, some designers employed a second strategy of writing after replicating, as shown in Figure 17.

With this second strategy, authors would complete a design and then proceed to recreate the entire project from scratch in order to carefully document each step. For example, Participant D stated that reconstructing a project purely for documentation was a good practice because the author becomes more aware of what needs to be documented the second-time-around. However, recreating a project...
was only possible for projects that could be easily rebuilt; for larger scale projects, recreating was not practical or feasible.

A final strategy is to simultaneously write and make, rather than leave the writing process until after a project is complete (Figure 18). This strategy was used by a single participant, Participant E, who described writing out his entire process, sometimes in past-tense as if he had already finished it, before he actually starts designing. He described this strategy as helping make the Instructable "happen in [his] head," thus assisting with planning ahead of time what components might be needed for the final tutorial.

In summary, creating DIY documentation requires first collecting the media (photographs or video) needed to show the steps in creating a design. A challenge with DIY documentation is remembering to document while a project is being built. To address this issue, authors may replicate a project solely for the purpose of documenting it carefully, or they may plan the written documentation ahead of time to anticipate the pieces they will need.

**Translating Documentation to Online Publication**

After compiling media showing how a project was made, authors were then tasked with translating their documentation into a step-by-step format that could enable others to build their project. The process of creating online documentation is a complex and involves several distinct tools. All interviewees delineated the process of sifting through the many photos they took throughout their process,
editing and resizing the photos, determining where to host their photos, using a separate editor for writing text, and then finally combining photos with their supplementary text. All five participants begin their documentation by first forming a pictorial timeline of their process and then writing text to supplement the images.

The authors distinguished between designing a product and documenting the most efficient way to recreate it. Participant B would heavily edit out what he considered to be extraneous information: “When I make the Instructable, it’s the one goal of you making the thing. So I don’t want to cloud it with too many words or too much information.” To make the steps of an Instructable as concise as possible, many authors would omit mistakes they made in their process of designing. For example, Participant D felt that a step was only worthwhile to include if it would help someone make something functional: “It’s always been about ... how do I get from point A to point B ignoring all the ways that I could not get from point A to point B.” Author C also discussed a similar process of relating to her expected audience: “I can’t think I’m doing it for myself. I have to put myself in the mindset of someone approaching it for the first time.” For these designers, their documentation was an edited recipe conveying just enough process and context for others to replicate their design.

For two of the interviewed authors, online documentation served as a story of how the product was created. For example, Participant A felt that describing his entire process, including mistakes and changes, painted a more realistic picture: “So many people think it’s like magic from on high; I had this idea and I made it and it’s brilliant and there was no struggle. And that’s not really accurate.” Participant E also includes mistakes in his documentation: “If you explain where you went wrong, it saves them [readers] from going down the wrong path.” However, unless he is able to pinpoint exactly what caused the problem, he would not share his design or ask others for advice: “I have a reputation for knowing an awful lot ... If I started asking too many people for help, I’ll ruin that reputation.” Thus, for some authors, incorporating their thought process into their documentation is part of an effort to demystify the design process and prevent readers from making similar mistakes. However, in revealing mistakes, one may risk damaging his reputation in the community.

Finally, although creating documentation is a time-consuming process, authors saw it as valuable and necessary for sharing their work. Similar to prior literature on motivation for sharing DIY projects
Kuznetsov and Paulos, 2010, Torrey et al., 2007, all the authors saw their documentation as a form of participation with the community and a way to preserve their process. For example, Participant A described how sharing design files helps proliferate their use:

If you make just the artwork by itself, it will get old or forgotten, but if you release a pattern or diagram, then it kind of keeps living, and I just like the idea of that.

As Participant E concisely stated, “If it’s on the Internet, people use it. People make it.”

**Using design documentation**

A total of 230 Instructables users responded to the online survey. The respondents were, on average, between the ages of 22-30, although the reported ages of participants ranged from the below 18 age bracket to above 60 years old (Figure 19).

![Graph of age distribution of participants](image)

Figure 19: Age of participants responding to survey

The majority (90%) reported viewing Technology projects over the site, and over 60% of respondents have viewed Instructables in each of the remaining categories (Workshop, Play, Outside, Living, and Food). On average, respondents use the Instructables website multiple times a week, and 58% have authored at least one Instructable. Most participants (59%) had experience recreating an Instructable (or building someone else’s shared project from scratch), and 71% had previously applied part of an Instructable to their own project—in other words,
they had applied part of someone else’s documentation without having created the entire project.

**Ways of Using Instructables**

A subset of 137 respondents responded to a survey question asking them to rank, in order of importance, the reasons why they use Instructables. The response *Getting ideas for a project* was ranked as being the most important reason, followed by *To learn a particular technique* and *To look for projects I want to recreate* (Figure 20).

![Figure 20: Responses to the question “Please rank, in order of importance, the reason why you look at Instructable”](image)

Further differentiation was noted between authors and non-authors. On average, those who have previously authored an Instructable placed less importance on learning techniques than those who have no experience authoring projects ($F = 4.89; p < 0.05$); of people who listed *Learning a technique* as the most important reason for using the site, 47% have never authored a project compared to 29% who have. In addition, authors considered getting ideas for a project to be more important than those who have not authored an Instructable ($F = 4.79; p < 0.05$); getting ideas for a project was rated as most important by 48% of authors compared to 28% of non-authors.

There were no other statistically significant differences in how readers ranked these three reasons for using the site based on age, fre-
quency of use, and whether or not they ever recreated an Instructable or applied parts of an Instructable to their own projects. These results suggest that Instructables readers may place greater importance on using the site to get inspired and learn techniques than finding projects to recreate.

Recreating an Instructable

Over half (59%) of respondents have had experience recreating someone else's Instructable. However, many stated that they used the Instructable as a reference rather than a strict guide. For example, one respondent stated, "I never reproduce anything for a 'me too' experience, only for verifying or learning some interesting concept, idea, or technique." One reader even reported trying to recreate projects from memory, only referring to the Instructable if he got stuck.

Modification and personalization are important practices to people who recreated Instructables. Modification can be a necessity arising from differences in resources: "I usually do not have all the materials or tools required, so I have to improvise. Sometimes this works out... interestingly. But it also adds some personal touch." Personalization is "the fun part"; one reader stated, "Just replicating seems a little pointless / boring."

Finally, other readers enjoyed improving Instructables they found online. Some spoke of improving the process by modifying particular steps, such as optimizing a circuit diagram or making a step easier and cheaper. However, these modifications could not be easily shared on the site beyond posting a comment on the Instructable page. Participant A from the interviews relayed a similar frustration, feeling it was not worthwhile to contribute his design change because he felt his comment could easily be overlooked.

Applying an Instructable

Readers found ways to apply techniques found on Instructables to their own projects, with 71% of respondents having experience doing so. Reported methods of applying other people's documentation include repurposing digital design documents such as code or electrical schematics and using methods described within an existing project such as woodworking, cooking, and electronics techniques. Readers also found ways to combine tips from different Instructables in new ways. For example, one reader stated,
Combining elements from more than one Instructable is one of my favorite things to do. The Instructables website is the perfect environment for taking ideas from multiple sources and combining them into something new or improved.

Another spoke of his experience transferring techniques from one discipline to another and recalled utilizing a technique outlined in a jewelry tutorial to create a folding pocket knife. These responses indicate that online documentation is combined and repurposed in unique ways to create new personalized projects.

Discussion

Through examining how shared project documentation is created and used by authors and readers, this study suggests several approaches for improving the structure and design of online documentation platforms.

Seamlessly integrating designing and documenting
Current documentation techniques require designers to constantly switch between two modes: designing and documenting, with documenting often interfering with the former. As a result of this burden, some designers are forced to completely recreate their project from scratch to fully document how it was created, a time-consuming process that is especially unreasonable for large projects. Furthermore, designers undergo a convoluted process requiring the use of multiple distinct tools for organizing and assimilating photographs, design files, and notes into publishable documentation. This problem is a unique challenge to documenting physical artifacts compared to digital artifacts, where physical processes are not inherently captured in a digital format [Kuznetsov and Paulos, 2010]. While some authors may make the extra effort to fully document their work, all interviewed authors wished that the process was easier and faster. It is clear that designers require a more seamless way to capture their process. Tools that help authors document their process as they design may prevent them from missing key steps from their final documentation. Furthermore, tools enabling designers to capture their workflow over time may help mitigate the burden of creating publishable documentation only after the project is complete.

Process-oriented documentation
Many authors approach design documentation with a recipe-making
mentality of showing the fewest steps required to recreate a project. However, the surveyed readers considered Looking for projects to recreate as the least important reason for using the site. Instead, they customize and personalize, drawing relevant steps from multiple projects to support their designs. Readers often need to make substitutions due to differences in materials and tools. Because of these substitutions, readers could actually benefit from knowing what materials, tools, and techniques were tried by the author before they determined the best one. Online documentation that emphasizes process over product can enable readers to make more informed decisions about techniques to use. This is similar to the “component” guides described in [De Roeck et al., 2012].

**New tools for contributing improvements and remixes**

Although readers are remixing and repurposing documentation, ways for them to share their changes are limited. Users typically share changes by way of comments found on the bottom of the page, which can be overlooked, difficult to sift through, and decontextualized. Systems that enable readers to contribute changes, ranging from materials substitution to process optimization, can help foster a more collaborative community.

**Next Steps**

The discrepancy between how authors create step-by-step guides and how readers personalize through substitution and modification made me consider what a community might look like whose focus is on revealing more of the design process. In particular, I was inspired by the recipe versus story approach to documenting and wanted to consider ways to support more transparent ways for people to convey what goes into creating a design. What if authors showed how a design evolved, rather than edited out elements of their process for the sake of creating efficient instructions? Additionally, would breaking up documentation into stages that are shared throughout a process rather than compiled after a project is complete reduce the documentation effort?

These questions ultimately inspired the design and development of Build in Progress, an alternative platform for designers to share how projects evolve over time, which I describe in the next chapter.
4. Build in Progress

This chapter describes the design and study of Build in Progress, a platform for makers to share how their DIY projects evolve over time. I share the guiding design principles for the site, an overview of the core features of the platform, and stories of how it was used by makers for capturing, sharing, reflecting, and situating design practice.

Making often involves an iterative cycle of testing and re-designing in response to setbacks as well as serendipitous discoveries. Anyone that has designed before knows that projects rarely work on the first try; instead, they are constantly tweaked and refined to function as intended. Yet, this iterative process is rarely shared in traditional forms of recipe-style documentation, where parts of the process are edited out when creating step-by-step instructions. What might documentation look like that captures the full story of how a project was created?

To support a storytelling approach to documentation, I developed an online community called Build in Progress (BiP) in which makers can share their personal journey of developing a project as the project is being built (rather than after a project is complete). BiP consists of a website and companion mobile applications that were designed to enable authors to represent their iterative design process in a non-linear format, all in the context of sharing with like-minded creators.

This chapter begins with an overview of the design principles that guided the creation of BiP followed by a description of its features for supporting open, process-oriented documentation. I then describe my methodology for studying the use of BiP, which consisted of content analysis of shared documentation as well as interviews with select users who pushed the tool in new directions. I share their stories across four sections, each representing a component of the make-through documentation framework: capturing, sharing, reflecting, and situating.

http://buildinprogress.media.mit.edu/
Design principles

Several design principles were identified at the start of the project for grounding the creation of a DIY community for sharing process-oriented documentation:

1. **Bring transparency to the design process**
   The platform should be a venue for sharing experimentation and iteration throughout a design process. The visual representation of design process should convey its iterative nature. Additionally, the community should encourage knowledge sharing about successful and unsuccessful techniques in an effort to help others.

2. **Encourage feedback in progress**
   Users should be able to solicit feedback as they develop their projects by reaching out to others in the community for advice. By documenting throughout the design process, authors continually build context for others to refer to as they provide feedback.

3. **Create opportunities for authentic reflection**
   The social community of the site should foster authentic reflection, enabling designers to communicate their process in ways that can help serve other like-minded creators.

While BiP could have alternatively been designed as a personal digital design journal, I chose to embed documentation within the social context of an online community for several reasons: The social aspect of sharing has the potential to provide motivation for connecting with others with similar interests, introduce opportunities for garnering feedback, and enable learning from one another.

**Design**

I built BiP using an iterative design philosophy, with new features continually being developed and introduced over time to improve usability, help users connect with one another, and provide new opportunities for users to reflect on their design process. BiP was launched in May, 2013 and has an open registration process, meaning that anyone can create an account and share projects on the site. In almost three years, the site has supported over 1,300 shared projects and 1,700 registered users. While I have collaborated directly with
institutions using BiP, including the Computer Clubhouse network of after-school centers and university courses at NYU, RISD, and MIT, most use is from people who discover the site on their own.

In this section, I describe core features of the BiP platform, organized around the project page, social features, and companion mobile applications.

**Project page**

![Project page diagram](image)

Designed to highlight pathways in a design project, project pages consist of two sections: the *Process Map* and *Step Detail View* (Figure 21: Build in Progress project page layout)
Users can add steps to their project and share images, videos, design files, and text descriptions for individual steps (Figure 22). These steps can then be hierarchically ordered in a two-dimensional tree-structure called the Process Map.

![Edit step form](image)

**Figure 22: Edit step form**

1. Upload media: Users can upload photos or videos, or embed videos from Youtube or Vimeo

2. Add text descriptions: Text descriptions with basic formatting options can be added to steps. Users can also add formatted code snippets.

3. Ask a question: Specific callouts for advice can be added to a step, which flags the project and adds the question to the homepage.

4. Upload design files: Users can upload any file associated with the step, such as a schematic.

With the Process Map, users can share iterations of their project in distinct branches. It presents a birds-eye perspective of the design process in an effort to make navigating iterations easier. Users can annotate branches through the use of *branch labels*, which can be colored to signify the nature of the branch; for example, red labels typically represent unsuccessful attempts while green labels are commonly used to lead into final versions. Steps and branch labels can be rearranged through a drag and drop interface.
Project pages are viewable in three modes. The first (default) mode is the *map mode*, displayed in Figure 21. Users can navigate through steps within a project chronologically by clicking the left and right arrows at the top of the Step Detail View, at which point the corresponding step is highlighted and brought into view in the Process Map. Alternatively, they can click individual steps in the Process Map to reveal corresponding information in the Step Detail View.

There are two additional viewing modes beyond the map mode: the *gallery mode* and the *blog mode*, both displayed in Figure 23.

In the *gallery mode*, all images in a project are displayed in a grid. When a user hovers over a particular image, all other images within the step are highlighted, and the corresponding step description is visible on the right. Labels within a project act as filters and are visible on the left side of the gallery page. When a user clicks on a label, all images from steps under this label are highlighted.

In the *blog mode*, users can read through steps chronologically in a scrollable format. Step names are listed on the left side of the page, and users can click on individual step names to navigate to the step in the blog. On the bottom left is a list of all labels in a project. Clicking on a label highlights all step names that fall under the particular label. This feature reveals the non-linear nature of projects where the author switches back and forth between different branches during the course of a project (Figure 24). Both the gallery and blog modes are view only and are automatically generated based on the map mode.
The project page has undergone numerous iterations, largely centered around balancing the screen real estate of the Process Map and Step Detail View (Figure 25). In earlier versions, all the steps in a page were loaded into a vertically scrollable blog on the right side of the page (Fall, 2013 and Fall, 2014), with the Process Map in a separate container on the left. The latest version features a Process Map that spans the full screen of the browser window and a Step Detail View that shows a single step at a time, focusing attention on the current step and reducing the load time to load all steps at once.

Social features

To encourage feedback on work-in-progress, BiP incorporates several social features. The most fundamental is the commenting system in which users can leave text-based comments on any step. Users
receive email notifications when comments are left on their own projects.

To explicitly solicit feedback, users can embed questions in a step, which flags the project with an orange question label and adds the question to the Community Activity section of the homepage (Figure 26). The Community Activity section cycles between recent questions and comments left on the site to draw users into projects.

The site also implements a following system in which users can follow one another and view recent activity from users they follow on an Activity Feed embedded on the homepage.

*Mobile applications*

During early workshops with BiP, I found that adding media to a project page was a critical step in documenting projects, and that having to transfer photos from a device to a computer and then upload to BiP was a significant barrier. To reduce the friction between documenting and designing, I created mobile applications (Android
and iOS) with which users can upload images and videos to their BiP projects straight from their devices. By default, steps in a project are organized in a list, and users can rearrange the steps through the branching interface as displayed in Figure 27.

Technical description

The BiP web app was built using the Ruby on Rails framework and is hosted on the Heroku cloud platform, with assets stored on Amazon Simple Storage Service (S3). The Process Map is built from the jQuery OrgChart plugin which creates tree structures from an underlying list structure [https://github.com/wesnolte/jOrgChart#readme]. The companion mobile apps are native Android and iOS apps.

A full system diagram is displayed in Figure 28, highlighting the website, mobile applications, and Computer Clubhouse Village, which is another website for sharing projects that was integrated with BiP such that users can register for BiP with their Village account, and projects shared by Village users on BiP are automatically published on the Village. In addition, an entity relationship diagram for the BiP database is shown in Figure 29.

BiP was my first foray into building a web app and mobile apps, which involved learning programming languages I had no prior experience with and the corresponding tools and frameworks for building applications with them (such as Xcode and Android Studio).
Since designing BiP was a learning process in and of itself, I practiced transparent documentation by openly sharing the development of BiP through BiP project pages that show how new features are designed.

**BiP features summary**

Overall, BiP was designed to encourage users to be transparent about their design process. Incorporating questions and comments on the homepage draws attention to the idea that projects on BiP are under development rather than complete, and that the platform can be used to get advice and feedback. Projects that incorporate branches and iteration are featured on the top of the homepage, further emphasizing that the site is designed for sharing process-oriented rather than product-oriented documentation. By default, project pages are publicly viewable to encourage users to share as their projects are being developed, rather than only once they are complete.

**Methodology**

Since launching BiP in May 2013, I have been studying how makers incorporate the platform to support their design process. The questions I seek to answer include the following:
- What motivations do BiP users have for sharing process-oriented documentation?

- What factors influence the ways in which people communicate process using BiP?

- In what ways do users represent their process using the Process Map?

- What strategies do authors employ for determining when and how to document?

- What types of supports (both through the BiP platform itself and educator facilitation) help contribute to a positive and open community for sharing process?

In my analysis, I use predominantly qualitative methods that include content analysis of the shared documentation on BiP (text descriptions, images and videos, and organization of Process Maps), and interviews with select users. These interviews consider not only how people use BiP, but the context in which they use it, employing a design-based research approach in which the learner, the activity the learner engages in, and the environment in which learning takes place are necessarily interwoven [Barab and Squire, 2004].
The data collection has been ongoing from 2013 to 2016, all while new features on BiP were continually being introduced. There are three major types of usage I have been studying: out of school, site-wide challenges, and in school.

Out of school

BiP has been incorporated in after-school programs and by independent makers working on personal projects. In 2014, I reached out directly to authors who have used BiP in unusual or creative ways to learn more about their experience. This data collection consists of both interviews with these users (lasting approximately 60 minutes and taking place online) and document analysis of the projects publicly share on the site. Three authors were interviewed from after-school centers, including two teenagers and one adult facilitator, who described her strategies for situating BiP in a multi-week workshop.

Additionally, I have conducted 7 workshops for children, teenagers, and educators using BiP. These workshops have ranged from two-hour-long workshops to 6-hour day-long workshops with activities such as building paper circuits with copper tape and LEDs, designing interactive musical instruments with the littleBits construction kit, and building a superhero gadget with craft materials. I draw from my own experiences running these workshops and observing how BiP was used to further add to examples of situating BiP usage.

In 2014, I invited 14 users to contribute sketches of alternative ways to visually represent their design process. These users were randomly selected from users who had fully documented a project from start to finish using the site. The users were asked to take one of their existing projects on BiP and hand draw how they would want to communicate their process to others. In total, 5 project authors responded with sketches of their process, which were scanned and emailed to the research team.

BiP Arduino Challenge

In the Summer of 2014, I hosted an Arduino-based challenge on BiP to study how makers with prior experience documenting DIY projects would respond to creating make-throughs. During the 3-week challenge, 10 participants received a free Arduino Bluetooth-Low-Energy (BLE) device and used the board to create a project of their choice. During this time, they documented its development using BiP.
Participants were recruited through mailing lists for local universities and hackerspaces, and all had prior experience documenting DIY projects. I required applicants to have basic experience using Arduino (lighting up an LED) and access to an Android device to run the BiP app. I received 28 applications and selected 10 participants that struck a balance between experience, interest, age, and gender. Participants ranged from 14-54 years old and had experience documenting their projects on sites like Github, Instructables, or their personal blogs. Table 3 summarizes the challenge participants and the projects they ultimately created.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age</th>
<th>Created Project Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>slittle</td>
<td>M</td>
<td>14</td>
<td>Internet Monitored Sprinkler System</td>
</tr>
<tr>
<td>laurmic</td>
<td>F</td>
<td>17</td>
<td>DIY Breathalyzer</td>
</tr>
<tr>
<td>drwho</td>
<td>F</td>
<td>19</td>
<td>RFID Spoofe</td>
</tr>
<tr>
<td>mechd</td>
<td>F</td>
<td>19</td>
<td>Touchless Trash Can Opener</td>
</tr>
<tr>
<td>sharpshooter</td>
<td>M</td>
<td>19</td>
<td>Smart Shutter</td>
</tr>
<tr>
<td>artbot</td>
<td>M</td>
<td>20</td>
<td>Rotary GraffitiBot</td>
</tr>
<tr>
<td>pedaller</td>
<td>M</td>
<td>21</td>
<td>Automated Fitness Motivator</td>
</tr>
<tr>
<td>brainwaves</td>
<td>M</td>
<td>31</td>
<td>Telemetry Link and Autonomy for RC Car</td>
</tr>
<tr>
<td>steampunx</td>
<td>M</td>
<td>54</td>
<td>Steampunk Ambient Indicator</td>
</tr>
</tbody>
</table>

Participants were sent weekly surveys asking them to estimate the number of hours they worked on their project, which served as a reminder to work on their projects throughout the 3 weeks. At the end of the challenge, 9 projects were documented (one participant dropped out), and all 9 project creators were interviewed, either online or in person depending on geographic constraints. The semi-structured interviews ranged from 25-60 minutes in length and consisted of questions pertaining to representing iterations, determining the amount of detail to share in public documentation, and comparing BiP to other documentation tools. The interviews were coded line-by-line to identify themes related to documentation practices.

In school

There were two explicit data collection efforts to understand how BiP supported users in-school. The first took place in 2014, where undergraduate music education students from NYU captured a class assignment on designing a musical construction kit over the course of two weeks. I interviewed two of the project groups in person to learn more about their experience using the tool. The 60-minute interviews...
were video recorded and audio transcribed for post-analysis. In total, eight students participated in the group interviews, and each received a $20 gift card for their participation.

In the fall of 2015, BiP supported several K-12 schools, where middle school and high school students captured class projects on the site. I reached out to educators at three of the schools to learn more about how they were using BiP in the classroom. All three schools are private K-12 schools in the United States, summarized in Table 4. The three teachers using BiP within these schools filled out a 10-minute online survey consisting of multiple choice and open ended questions about their motivations for using BiP. Additionally, a team of researchers including myself and two interns from the Harvard Graduate School of Education collectively analyzed 85 projects pages created by students from these three schools (determined by the school email addresses used for their account registration) to identify themes around learning outcomes and design practices of making. During the process, we had regular meetings to discuss emergent themes and compare our coding and went through two passes of the data using this process. All 85 projects were analyzed by at least two of the researchers.

### Table 4: Summary of schools using BiP

<table>
<thead>
<tr>
<th>Grades</th>
<th>Project Type</th>
<th>Example Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 8th</td>
<td>Class-wide group projects and student-initiated group projects</td>
<td>Designing a backpack for a classmate, laundry folding machine</td>
</tr>
<tr>
<td>B 9th-12th</td>
<td>Student-initiated independent projects</td>
<td>3D printed chess pieces, Foosball Table</td>
</tr>
<tr>
<td>C 9th-12th</td>
<td>Class-wide independent projects</td>
<td>3D printed cellphone cases for a classmate</td>
</tr>
</tbody>
</table>

Across all three contexts, I explore how make-throughs are created and what types of supports, both social and technical, facilitate its use. Over the course of 3 years, 20 BiP users were interviewed and 100 projects pages were coded.

### Findings

I organize the findings for how BiP supported the creation of process-oriented documentation in the following four sections:
In sharing, I describe the motivations users had for sharing their process on BiP and the ways BiP supported these motivations.

In reflecting, I share how make-throughs became a rich source for capturing how people reflected on making, design process, and their own values and identity.

In situating, I describe ways of integrating documentation into a design activity, drawing from how educators and myself utilized BiP in workshops.

In capturing, I outline several strategies for documenting projects with BiP and highlight some standing challenges with capturing documentation.

Early work analyzing BiP in an undergraduate course at NYU was published in iDETC 2014 [Tseng et al., 2014], while interviews with youth using BiP during the Arduino challenge and as part of after-school activities is summarized in Fablearn 2015 [Tseng, 2014] and Makeology [Tseng, 2016a].

Sharing

A major question with deploying BiP was whether users would be comfortable with creating open documentation that captures their experiments, especially when these types of iterations may be excluded in traditional forms of DIY documentation. In this section, I describe four motivations BiP authors had for sharing process-oriented documentation: facilitating feedback, creating engaging documentation, representing effort, and helping others.

Facilitating feedback

Shortly after the platform was launched in the spring of 2013, a 17-year-old user named blamb began sharing how he was designing a sword inspired by the online Anime series Sword Art Online. In his project Elucidator’s Kirito’s Blade, blamb documented how he created an electronics-enhanced replica of the sword from scratch over the course of 5 weeks as a final project for his art class (Figure 30).

In Elucidator’s Kirito’s Blade, blamb shared an expansive 22-step project that describes his conceptualization of the design (from early sketches...
and prototypes) to fabricating the wooden sword in a machine shop and integrating color-changing LEDs along the side of the sword.

After ‘finishing’ his design, blamb shared a step he titled ‘The Final Product’ which included a video of the sword powered by an AC adapter plugged into the wall. When this step was shared, several users on the site commented on the possibility of using batteries to self-power the sword, which would eliminate the need for a tethered power connection. Upon receiving these comments, blamb began working on a wireless version of the sword, which he shared in a new branch within his project (Figure 31). He asked other users on BiP for their opinions on battery options, which led to a chain of comments about the pros and cons of using different types of batteries and power considerations for his application.

Ultimately, blamb added another step in his project titled “THE FI-
NAL wireless product” where he shared pictures of a sword powered with two 9V batteries connected in series. He wrote, “I tried the 2 9-volt batteries as was suggested and it worked! they were able to power the sword AND they’re space efficient.”

When I interviewed blamb about using BiP to capture his design process, he contrasted his experience with using Instructables:

This isn’t like an Instructable where you have to do this then do that. You can just ask out questions and roll out your problems, and other people try to help out. That encouraged me to be more vulnerable with the weaknesses of my projects, so that if anyone would try to do it [remake the project] they could see the mistakes I made and go about it however they want.

Through this quote, blamb reveals how sharing his process throughout his project’s development enabled him to get advice he could incorporate into its design. In particular, he comments on how this format encouraged him to be “vulnerable,” as opening up about the shortcomings of a project can invite others to provide input. In addition, documentation became a way to help others who might find the project and use it to guide their own design (“they could see the mistakes I made and go about it however they want”). This, documentation with BiP was helpful both for facilitating feedback but also providing a resource to others.

Other descriptions from his project show how blamb openly spoke about problems he faced in creating his project. For example, he described how the construction of the hilt of the sword might be improved in a future iteration: “In hindsight this was not the best idea and it led to the wood cracking and me trying to fix it with wood glue.” His reflection shows how blamb thought critically about his own design in an effort to share his experience and learning.

Elucidator’s Kirito’s Blade reveals how sharing the ways a project develops (and its associated challenges) opens up opportunities for others to contribute. By documenting throughout his design process, blamb provided context with which readers could leave suggestions. These suggestions ultimately helped him achieve an even more desirable end product, highlighting how make-throughs can provide new opportunities for fostering dialog between makers.

Creating engaging documentation

In the summer of 2014, several high-school interns at a Computer
Clubhouse on the West Coast developed games centered around promoting a social cause, and they documented their progress using BiP over the course of several weeks. One of the teens was a 16-year-old named joekol, who created the majority (20 / 24 steps) of the documentation on his team’s collaborative project *Tower Defense Arcade Game and Box*. The group’s project involved creating an Action-Script-based video game in which players eliminate carbon-emitting enemies such as cars in order to save the natural landscape (Figure 32). Through the team’s BiP documentation, joekol shares the team’s experience learning how to program a game for the first time and invited other users on BiP to test and resolve bugs.

A distinguishing feature of joekol’s BiP project was the descriptive language he used to describe the team’s process. At the time their project was shared, BiP projects contained 350 words on average. In contrast, *Tower Defense Arcade Game and Box* project has over 3300 words. Upon interviewing joekol after the project was complete, I...
learned that he enjoys creative writing but had never shared his writing publicly online before. He told me that his intention was to share his team's entire process of developing the game: "It would start from our initial thoughts and the way we changed our minds about something and removed some things and added aspects." He was especially keen on creating documentation that others would enjoy reading:

I know reading about projects is usually really boring...I didn’t want to make something that people would be bored and click away from after a couple minutes.

As a result, much of the documentation in the project is lighthearted and humorous. As an example, joekol described an early accomplishment in the project as follows:

While the following days are certain to be wrought with terror and distress, I alone seem to have total confidence in our group’s future, progression, and completion of our project.

As for now, bottles of Martinelli’s Non-Alcoholic Sparkling Cider are flying open, cheers being given, glasses clinked, and our under-aged group is rejoiced with the happiness and enthusiasm of a professional game development studio.

Similar to blamb, joekol used BiP to solicit feedback on his team’s game. He organized different iterations of the game into branches and invited others to test bugs (Figure 33):

Any help with any of these bugs will be GREATLY appreciated, and anyone who helps lead to their arrest will be duly compensated with a spot on the Credits section giving our many thanks, hugs, and kisses!

Finally, though his BiP documentation, joekol constantly reflected on his experience, culminating in a final post in which he shared reflections on his internship, his team’s project, and the documentation they created on BiP:

This internship, and project, has been one of the greatest experiences of my (and hopefully my group's) life. I am VERY proud of all the work we have done, all the things we have learned and the achievements we have strived for.

...Thank you everyone who gave advice, feedback, suggestions, and help. There are too many to name, so you know who you are!! Thank you for making this the most favorited, most posted-upon, and most commented project on Build in Progress.
Through his reflection, *joekol* shares a sense of accomplishment not only for the design he and his team created by also for the documentation they shared throughout his internship experience. This suggests that documentation can be a meaningful artifact that makers both enjoy developing and take pride in creating.

The *Tower Defense Arcade Game and Box* BiP project interweaves technical descriptions with the personal experiences (the frustrations and the rejoicing) that accompanied each iteration. This rich storytelling begins to show how make-throughs can become a medium for creative writing, supporting people creating engaging rather than efficient documentation that captures the emotional experience of undergoing and conquering a design process.

**Representing effort**

One of the participants of the Arduino BLE challenge that took place in August, 2014 was a 17-year-old named *laurmie*, who created an Arduino-based breathalyzer. The goal of her project was to develop an inexpensive yet effective breathalyzer that would lock the steering wheel of a car until a user passed the breathalyzer test; if the user failed, they would be prompted to call a cab from their mobile device. At the end of the challenge, she created the first prototype of her breathalyzer, with an LED that would change color based on the detected alcohol levels measured by an ethanol sensor (Figure 34).

Due to the lack of documentation around the new BLE board, none of the challenge participants ended up using the Bluetooth features of the Arduino, but many documented their frustrations attempting to do so. Over the four weeks, *laurmie* shared a six-step project on BiP, where the first two steps described issues connecting to the board:

> After spending all week with connecting issues, little progress has been made. We can connect to the Coin and it detects SOMETHING coming in, but no matter which characters I send, it receives non-English gibberish. The Arduino Mega’s we use work perfectly and receive data, but not the Coin. It’s frustrating.

Two weeks into the challenge, she decided to switch to using another Arduino board, which gave her more success. This led to a series of steps around testing an ethanol sensor and 3D printing an enclosure for her DIY breathalyzer, which was functional at the end of the challenge.
When I interviewed laurmie afterward, she discussed the importance of sharing her frustrations in her documentation:

The fact that I had connection issues...I feel like that was the most important part of my [BiP] project, actually. I looked at a lot of projects, and they were like, I just plugged in a couple wires into the breadboard and it worked, and that's not what happened for me. So I think it's to show other people that it doesn't work on the first try and it's ok and just try something different.

In this way, laurmie shared her documentation as a way to support others in challenge, showing that they were not alone if they were facing similar difficulties. She later went on to describe the BiP documentation as a representation of her efforts: "When I started putting up steps for this, I definitely wanted to show a good representation of where my time went, and a good chunk of that time, which is 2/6 steps, is connection issues, which is absolutely how I spent my time."
Thus, her BiP documentation became a proxy for the effort and time spent debugging.

Through our conversation, laurmie contrasted BiP with her personal website, where she shares photographs of art projects only after they are complete. By documenting throughout the process, laurmie shared that she received feedback she felt she would not have gained otherwise:

For BiP, I was ok showing intermediate steps as opposed to just the final product because I know it’s a lot of engineers using it, and everyone was asking questions and giving feedback and stuff throughout the process, so that was really cool.

I got some pretty cool ideas from people…someone commented about the weight and height of the person, which would affect the levels, which I didn’t think of because I was just making it for me. So it was really helpful to get feedback during the process, as opposed to, “Here’s my final project. What do you guys think?”

In this quote, laurmie describes how feedback from other makers on BiP gave meaning to sharing work-in-progress. Her make-through showcased her efforts and persistence in creating her project.

Helping others

Another participant in the Arduino BLE challenge was a 14-year-old named slittle, who created an Internet Monitored Sprinkler System to help him remotely water his lawn from a web interface. Similar to laurmie, many of his steps are devoted to troubleshooting the Arduino BLE board, representing various attempts in distinct branches (Figure 35).

He first tried connecting to the BLE board with his laptop but quickly realized that Bluetooth 4.0 is required to use BLE, which was not supported with his computer. He then tried using Python modules to connect with the device but found a lack of support, since most BLE software is written for mobile devices using objective-c or java. Finally, he purchased a replacement Bluetooth Arduino-compatible board that would enable him to connect to the device using his computer, bypassing the BLE features, which were ultimately unnecessary for his sprinkler project. These different iterations are represented in branches within his project (Figure 36).

When I asked slittle why he shared his troubleshooting steps in his
BiP project, he said that his main motivation was to help others participating in the challenge:

The amount of detail I included was definitely to help other people who were working on it, because I knew a lot of people were going through the same thing. I thought I'd try to be as helpful as I could and include as much code as I could.

Thus, sharing his connection problems became a way to support others using the same hardware and hopefully prevent them from running into the same problems. Additionally, a side benefit to creating this documentation was the ability to use it as a personal reference:

Looking back at what I've created, there's a lot of trials, which I probably would have forgotten about. But after I've documented it, I'm able
to look back and maybe use it. Hopefully other people can look at it and improve what they do, but I can see what worked and what didn't work.

For *slittle*, documenting unsuccessful attempts served as a memory aid and a way to reach out to others participating in the challenge, who could be facing similar issues.

**Reflecting**

What types of reflections do makers have as they create design projects? Using the documentation shared on BiP as a source for analyzing reflection, I coded, along with two Harvard Graduate School of Education interns, 85 projects shared by teenagers at three different schools in the United States, categorizing their reflections into three groups: reflections on making, reflections on process, and reflections on values and identity.

**Reflecting**: How do makers reflect on their projects, their design process, and their identity when they create make-throughs?

In this section, I attribute quotes from student projects using the convention *(School-ProjectID)*, where each project can be found on BiP at buildinprogress.media.mit.edu/projects/ProjectID. (The school letters can be found in Table 4.)
Reflecting on making

While all 85 BiP projects included descriptive reflections in which features of the specific artifact being designed were discussed, a common theme across the different projects was reflections around materiality and physicality. These ideas arose from hands-on activities in which the teenagers manipulated different materials such as cardboard, paper, and plastic; in the process, they learned about basic properties of physics such as weight and balance that govern how their artifacts are fabricated.

Material affordances

In all three schools, students used a variety of materials at different levels of resolution, from paper, cardboard, and duct tape to plastic and aluminum. From manipulating these materials in support of building prototypes, students learned about affordances and limitations of the different materials, including stiffness and durability, ultimately realizing that material properties needed to be accommodated in the design of a project. Reflections on material affordances were represented in 33% of the BiP documentation and equally represented across all three schools:

Throughout the course of the design process of this phone case I found myself [sic] constantly having to go back and revise my design so that I could fit into what kind of ability I would have based on the materials we had at hand. (C-3165)

It was hard to build [it] out of paper because [sic] it bent easily [sic] and the tape was barely strong enough to hold the paper together. (A-2742)

I did water [it] down to try to make it similar to water color but the paint wasn’t fooled. Acrylic is a very thick paint and when you add too much water the paint separates [sic] and leaves holes. (B-3067)

Tradeoffs between time, ease-of-use, and material quality were also recognized, with students reflecting on differences between using low-resolution materials compared to more robust options. As an example, one student described the pros and cons of using duct-tape for low-resolution prototyping:

The plus side of making it from duct tape was that it was faster and easier to work with. On the other hand, it was not very sturdy at all, and it was misshapened [sic] wherever I tried to store it. (C-3044)
Thus, while duct-tape was easier and quicker to work with, it had its limitations in terms of stiffness. With 3D printing, tradeoffs in quality and time were also reflected upon. For example, a student creating 3D printed chess pieces commented on the finish at different quality settings: “While the pieces turned out well appearance-wise, the quality and durability both being noticably [sic] lower” (B-3066).

Students’ explorations with materials led to questions of accessibility, with comparisons of the materials on hand with those used in commercially available products. A student building a paper prototype of a backpack stated, “When we had to build the backpack, it was hard, because we didn’t have the real materials, but only paper and tape” (A-2756). This reference to “real material” was echoed from students building cell phone cases in School C, who noticed that the ABS plastic material they had could not be as thin as plastic typically used in mobile device cases.

Using BiP, students reflected on their experience exploring concepts related to material affordances, including quality and stiffness, and its relationship to ease-of-use and accessibility. The manipulation of materials accessible in their makerspace helped students consider and compare the materials used in everyday products.

**Physicality**

Another dimension of materiality represented in students’ documentation on BiP was physicality, or concepts around the physics of real-world objects, including dimensional constraints, weight and balance, and manufacturing processes. An understanding of physicality aids in the combination of materials when creating prototypes. Statements about physicality were found in 53% of the projects, with 23% of students from (A), 53% of students from (B), and 88% of students from (C) making explicit references to physicality.

Principles around dimensional constraint were discussed in projects that integrate with other physical objects, such as a bracelet designed to fit around a wrist (A), an ergonomic wooden handle (B), or a 3D printed phone case to fit an existing device (C).

Dimensionality was present in virtual and physical workflows of creating tangible objects. In the process of generating three-dimensional models, design software supported the visualization of dimensional qualities of physical artifacts: “Using these drawings [generated in TinkerCAD], I could see the dimensions of the case, as well as the
different parts of the case that could be seen from different angles” (C-3037). When transitioning between digital representations and physical manifestations, the students dealt with issues of scale: “I know for next time that my designs on the computer look much smaller than how they look in real life” (C-3152). Thus, digital models mimicked the physical dimensions of the object, but students needed to also consider scale to ensure that their produced products would meet their specified requirements.

The process of programming physical behavior also needed to consider physical constraints. For example, students in (A) building a moving sidewalk discussed adjusting the length of their conveyor belt to integrate with a motor whose movement was programmed using an Arduino (A-2776). The digital workflows used in making, including 3D modeling and programming actuators, needed to take into account physical constraints.

Students investigated physical properties of weight and balance for projects in which stability was a critical element. For example, when designing balsa wood chairs, several students from (A) wrote about modifying their prototypes to ensure the chair stood upright: “Building the wood chair was a challenge because the back of it was so heavy, that it kept falling down” (A-2767). Another student from (B) who built a paper quadcopter compared the weight of different materials and its impact on balance:

> While I like the idea that it [paper] provides greater lightness and modularity for the product, it crumpled too easily when I was assembling the quadcopter, which ruined the orientation of the motors. In the future, I could go with a stiffer material, such as cardboard, but it would also be denser and heavier. Plastic seems to be the best option at this point. (B-2713)

A final type of physicality comes from the manufacturing process in which objects are fabricated. For example, one student described how the lack of structural support in his models led to complications when 3D printing:

> Due to most of my designs having some sort of over-hang and the 3D printer being restricted to printing from a single angle, the printer attempted to print parts in mid-air or made support beams of a sort that were unable to hold up parts of the pieces. (B-3066)

In this example, the manufacturing process needed to be considered when modeling of the object to remove overhangs that would not be
Principles related to the physicality of real-world objects were acknowledged in BiP projects from all three schools. By designing physical objects both using virtual tools and tangible manipulation, students reflected on design considerations concerning dimensional constraints, weight and balance, and manufacturing processes.

Reflecting on process

Another category of reflections evidenced in the 85 student projects was reflecting on design process. The students reflected on the value of iterating, which they described as a helpful and necessary process for improving their designs. A distinct style of reflection exhibited in the BiP documentation was sharing tips as a way to guide other makers; the teens reflected on their own experiences and alternative approaches by highlighting how others might build on their design.

Iterating

Like most design processes, making is commonly seen as iterative, where prototypes are refined over time. The practice of iterating was found in 59% of all projects, ranging from 45% at (A), 40% in (B), and 84% at (C). These iterations often involved first stepping back and evaluating a given prototype and determining changes to make for a next pass. For (C), iteration was built into the class assignment itself, with students beginning with sketches to then producing low-tech cardboard prototypes and finally high resolution 3D prototypes. In (A) and (B), iterations occurred naturally within the scope of the student-driven projects and included iterating due to an evolving understanding of technical feasibility (such as a jetpack backpack that then became a drone-powered book bag carrier in A-2740), incrementally adding features to a design (such as modifying the physical structure and movement of a moving walkway over time in A-2761), and re-thinking a design due to unexpected challenges (such as resolving connectivity issues with a Raspberry-Pi game controller in B-279).

Several BiP projects contained explicit reflections on iterating, with students seeing it as a productive and necessary process:

I realized that even though we are designing small things, it is important to listen to each other, and fix things to get thing more incredible and awesome. (A-2747)
I learned more about the growth mindset mainly by hands-on experiences with failure, feedback, and new ideas based on my failures (C-3019)

It can not be stressed enough that even after this seemingly final iteration, the work is never finished and you can always make improvements. (C-3026)

The failures led to giving me the chance to make something I was genuinely proud of. (C-3044)

Through these statements, students shared reflections that go beyond the specific project they were building to generalize about design process. Their reflections reveal how, through making, students realize how iteration enables them to create even better designs and how each creation is a prototype that can be continually improved.

Sharing

Clearly, all 85 students shared their process through their BiP documentation, the basis of our data. While this is a type of sharing, I instead want to focus on explicit statements of advice based on one’s own making experience. This type of sharing, found in 13% of all projects, with the majority (9) from (B) and 1 each from (A) and (C), included descriptions of challenges the students faced as a way to help others avoid similar pitfalls, as well as general advice on alternative ways to approach a project:

I didn’t print out an outline for the letters but if you want yours to be more precise [sic] you can print the letters of your name out and trace them on the foam board. (B-2704)

This step was very hard it took a long time and the bottoms are very tough, I recommend cutting the edges of the bottom (take your time) (B-2828)

I decided that I would test out all three [CAD] programs first, just to see which one I might like best...I only really skimmed through SketchUp and Fusion360...I’d suggest going through each one yourself and not taking my word for them. (A-2763)

When working with all these wires it is important to either leave them alone or document where they are and remove them- I would recommend taking a photo and leaving alone it as much as possible- You will spend an hour soldering if you don’t (We made this mistake) (B-2877)

I distinguish this form of sharing from purely instructional docu-
mentation that describes what should be done but does not reference alternatives; for example, the following was not coded under sharing.

You will cut the top off the 2nd can. You cut the top off with the razor knife at the ridge where the can starts to get smaller in circumference. (B-2708)

This type of sharing reveals substitute methods for carrying out a process, either by sharing a less successful attempt or by acknowledging the possibility of differences in materials or tools. Through these reflections, students exhibit an awareness of distinct paths that can achieve similar goals.

Finally, while all students in (C) were required to upload their CAD models to their BiP projects, one student provided a rationale for sharing these files:

In this step, I again attached my files containing the second phone case I have designed in the file formats of a PDF document and an STL. I am doing so, so that others may download these files and continue to build on what I have begun with this phone case, in an ultimate effort to produce the greatest phone case of its kind. (C-3037)

This quote adds to the idea that sharing within the maker community serves to help other makers by providing advice and examples that other people can build off of.

Reflecting on identities and values

Students reassessed their values and capabilities in the process of reflecting on their making experiences, describing a feeling of empowerment in which they were able to bring their ideas to life.

Examples of empowerment, or recognizing one’s own ability to design and create meaningful projects, were identified in 13% of BiP documentation, with 8 projects from (A), 1 project from (B) and 2 from (C). Empowerment stemmed from a combination of recognizing one’s own ability to work independently and realizing an idea through a physical manifestation:

I enjoyed this step most because I could see my visions in and object that I could touch. (A-2752)

It was completely independent and involved actually building something physical, which are the two things that I like most in these types of lessons. (A-2698)
I have always wanted to create something from my imagination and actually see it in use and for my client I could and I did. (C-3040)

I realize that this is simple stuff, but it's still cool to create something that otherwise would not have existed. (C-3041)

I'm looking forward to building more things like this because I liked the challenge and it was fun to design something that you had planned out. (A-2745)

In my Technology and Engineering class I wanted to combine the tech part and my creative side to create something. (B-2704)

For several students in (A), this process of creating something from scratch was particularly enjoyable because of the freedom they had to realize their own ideas:

While I was making the chair the fun thing that made me excited about the project was that we can make whatever we want even though we had to make it small. (A-2747)

I liked the freedom we were given to make our own ideas. (A-2765)

In these examples, the students describe how they were able to take an idea they had in their mind and bring it to life through the physical prototypes they created. They saw how their own knowledge and skills crafted the products they created, which led them to recognize their own capabilities and, in some cases, taken on new identities:

I can speak for both me and my partner in saying that we both found the project very helpful in our growth as future makers. (C-3164)

This project helped with the development of me as a student, and as a maker. (C-3044)

This third category of reflection is perhaps the most transformative in which students assess their values, or what is important to them (such as “building something physical” and combining “the tech part and my creative side”) while forming an identity as someone who can design and create (a “maker”).
Situating

The previous sections have discussed how the branching and social features of the online BiP community supports makers sharing process. Here, I describe in-person strategies for situating process-oriented documentation to facilitate meaningful documentation practices. These strategies are especially important for framing documentation with audiences who have never documented a project before. I draw from an interview with an educator who used BiP with youth to capture a 4-week making workshop series as well as my own experiences leading workshops with BiP.

At a Computer Clubhouse on the West Coast, an adult coordinator named anetten hosted a series of “soft circuits” workshops in which children between the ages of 10 and 13 built felt bracelets incorporating electronics (Figure 37). Throughout the workshops, she actively involved youth in building what she called “Living Documentation,” or documentation that is collaboratively built over time.

Figure 37: Process map and selected images from Remix: Soft Circuits
During each workshop session, which lasted an hour, anetten and two mentors (a teenager and an adult) were on hand to assist with the activity and with documentation. In total, 11 people (3 staff and 8 children) were involved in all four sessions. They collectively created a BiP project page titled *Remix: Soft Circuits* which was kept open and visible on a large 45” display in the space throughout the workshop sessions (Figure 84). She stated,

> We had the screen open while we were working so individual youth could see their past project and look at how the website actually functioned...it let them know how they were going to be sharing.

The display gave the documentation a physical presence, serving as both a reminder to document and as a means to reflect on the workshop experience.

![BiP on display in workshop space](image)

The BiP project page was updated both during and after each workshop day. During the sessions, several youth volunteered to take photographs of the activity and would typically come in and out of this documentation role, switching between building and documenting. While the youth photographed the experience, the two mentors organized the BiP project page, incorporating the photographs and writing accompanying text descriptions. Many of the descriptions were drawn directly from physical Post-it notes in which youth wrote reflections about their experiences. These Post-it notes were created through group discussions taking place at the beginning and end of
the sessions and included the following quotes, which were shared on BiP both through images and text transcriptions:

It [the activity] was hard because I was running out of thread. It was fun because I learned and had new experiences.

The part that I thought was hard was the conducting wire making sure that it wasn’t touching the other but it was fun because later the work would be all cool and creative.

At the start of each session, the group would begin by reviewing the BiP documentation to catch up any participants who may have missed the previous session. The coordinator spoke of the youths’ excitement in seeing themselves represented in the documentation through photographs of their work.

The fact that this documentation was built throughout the four workshop sessions contributed to an idea anetten called “Living Documentation,” in which the mentors collaboratively built the documentation with the youth over time. She contrasted this with creating “static postings” of “past history.” For example, over the summer, her Clubhouse had participated in Maker Camp, a DIY summer camp in which sites around the world host Making activities and share media from their projects on a Google Plus community. While her Clubhouse shared photos of products they had made on the Google Plus community, the “in-the-moment” documentation on BiP gave the youth agency to edit and contribute to the documentation at any time. She described this as “narrative, descriptive, and rich storytelling as the project develops.” Additionally, BiP gave the entire group a sense of where the workshop was going by providing opportunities to look back at their experiences.

Remix: Soft Circuits goes beyond sharing a final product by sharing an entire group’s making experience, embedded with individual stories of the youth’s experiences. In this example, BiP provided opportunities for reflection by being visibly present in the space and thus easily editable at any moment as “Living Documentation.”

My own experiences using BiP in workshops has been in shorter contexts, with hour-long to day-long workshops with children, teens, and adult educators. Generally, I found that documentation was most successful when the time to document was minimized (encouraging the use of the mobile application over the website for easily capturing media of projects, for example) and there was explicit time left for documenting. In a workshop with BiP and littleBits that I organized
in 2013, we left time both halfway through the workshop and at the end of the workshop for children to update their BiP documentation. Importantly, a formal sharing and reviewing process at these stopping points helped facilitate conversation about what children were making and any questions they might have.

Yet, when all of the activity is contained within a single in-person workshop, the motivation to share documentation online versus describing and showing the artifact in person becomes less clear. One of the reasons why anetten's use of BiP is powerful is because the documentation was reviewed and added to over multiple weeks. While I believe that youth can derive value from sharing their process with others online even with short projects, the immediacy of feedback they receive online is less certain than sharing and celebrating their physical artifact with others during a workshop. Therefore, I believe that BiP is best suited for projects built over a longer period time, where there is more space to iterate, review, and reflect.

Capturing

An underlying quality of creating process-oriented documentation is that process is captured throughout the development of a project rather than after it is complete. How do authors determine which stages to document, and what strategies do they use to do so? What factors into the granularity of the documentation they share?

For the Arduino BLE challenge, all 9 authors were interviewed about their experience capturing documentation. Figure 39 shows how the number of steps in their project changed over the three weeks of the challenge, revealing how the weekly surveys had an impact on when users updated their projects on BiP, with many updating their projects in response to the email reminders. Three participants continued to develop their projects (and update their corresponding BiP pages) even after the study ended.

Five of the nine participants used the Android app to upload photos of their projects before adding text descriptions through the website, which they preferred to use for writing. The remaining authors had established workflows for wirelessly transferring their photographs to their desktops, including services like iCloud Photo Stream and Google+ photo syncing. These users predominantly used the website for updating their BiP projects.
For several of the participants, documenting throughout rather than after a project was complete forced them to break down their process into individual tasks:

I thought it was pretty useful because it was sort of getting me to do a clearer job of breaking the task down into steps. I’ve accomplished something, document this, onto the next piece. And so getting it together in chunks instead of having to work on everything at once or get distracted or unfocused. (brainwavez)

I just really liked being able to document it as you go so it’s not a big burden that you keep procrastinating once you’re done. You can kind of do it as you’re going, and it doesn’t seem like it takes much extra time. (slittle)

Further elaborating on the time it takes to capture as you go, slittle said, “It’s not at all a disruption. In fact, it helps keep you on track.” Thus, consistently updating BiP documentation was a way to break down a larger project into subtasks, serving as a tool to organize and capture one’s process. Others described how capturing during development encouraged constant reflecting on how they were making:

But as a build in progress, I was trying to write down everything I learned at each step, which I may not normally do...the reminders about “Why did you do this?” kind of made me want to write more about what I learned step by step (steampunx)

I thought it was good actually to have more work to do with the documentation because it made me think about the project a lot more
deeply. There are different kinds of thoughts that I noticed I was having at each stage... and I think that ends up producing a better end product and better documentation too. (artbot)

These quotes suggest that the act of writing project updates promoted regular reflections and potentially more purposeful making as a result.

When determining at which points to document, authors’ strategies varied from capturing steps in-process and capturing subtasks after they were complete. While two of the participants, laurmie and slittle captured steps in-process (as described in Sharing), the majority (7 of the 9 participants) documented when a component of their project worked as expected:

I can’t remember consciously thinking that this is what I want to post on this step. I just thought it feels like I’ve reached a stopping point where I’ve got a complete design that I can go upstairs and cut out, or I have some code and I can hit run and it would do the thing that I intended it to do. (artbot)

I only put something up when I think I’ve found a solution that I’m going to stick with. (drwho)

Relatedly, for two of the authors, the lack of a complete step meant that there was more work to be done first:

For me, it just didn’t make sense to spend the time complaining or being like, ‘This doesn’t work!’ rather than actually just doing it...It’ll work eventually. You just gotta put in the time. (sharpshooter)

If something isn’t working...the absence of doing it doesn’t fit in my head as a step. It’s something I’m not doing, rather than something I’m doing...It’s the absence of a step” (brainwavez).

These users were confident in their own abilities to figure out how to produce functional prototypes and did not use BiP was a tool to get feedback on work-in-progress. This may be because the authors have more experience and therefore might be more self-sufficient, or perhaps because they did not necessarily see BiP as a venue for gathering feedback. Several factors may have contributed to this perception, particularly that many of the existing projects on BiP are created by younger and less experienced makers. It would be interesting to see whether or not advanced authors would be more open to describing their challenges in a different online community that has an older audience.
Finally, one author described how capturing successful iterations projects a level of professionalism and can also make documentation more accessible:

I want to project a brand of professionalism if you will. I want people to also not be scared off. Because sometimes if there’s a lot of details that may or may not be relevant, that can scare off beginners. (steam-punx)

Notably, the two participants who captured incomplete work were the youngest that participated in the study. For example, slittle, at 14-year-old, described how he documented even before he started a step. When he created a step, he would outline his goals, his research around the step, and what he plans to do to finish it. Upon completing the goal, this participant would either edit the existing step and change the wording to past-tense, or if something worked differently than he expected, he would create a branch and explain what went wrong. On reflecting on his process of documenting this way, this user stated the following:

I found that using Build in Progress isn’t really just a tool to document your project, but it’s more of a way of doing your projects. Because as you’re working through the project...I was creating it [a step] before or while I was doing the step. It was just much different where I kind of wrote about what I planned to do. (slittle)

These mixed responses to sharing work-in-progress suggests two potential factors. First, it may be that novice designers may benefit more from sharing work-in-progress, especially if part of their intention is to use the documentation to reach out to others. The responses from older participants suggest that capturing development was largely helpful for themselves to organize and reflect on their process. Thus, documentation systems should consider both the expertise of the authors and the goals of their documentation – whether it is to support self-reflection or an external audience.

The points at which a project was captured can be further deduced from branching structures shared within BiP projects more generally. There were four categories of branches identified across all shared projects:

1. Stages of a design process (time-based)

2. Types of design processes (category-based)
3. Contributions of individuals (people-based)

4. Versions of a design (iteration-based)

For projects where stages of a design process are represented in branches, steps are usually organized chronologically top down and left to right, with later phases of a design progress shown on the right. For example, Figure 40 displays a student’s laser-cut project, which evolves from several distinct stages including asking, imagining, planning, and creating.

Figure 40: Stages of a design process in a laser-cut project
http://buildinprogress.media.mit.edu/projects/3242
Types of design processes can include categories such as hardware and software or digital design and fabrication. As an example, Figure 41 shares an integrated software and hardware project. Unlike projects organized by stages of a design process, users creating projects organized by categories of steps often move back and forth between branches as sub-components of an assembly are prototyped independently before integration.

Students collaborating on a single project commonly shared individual contributions in distinct branches; for example, teams creating musical construction kits represented each team member’s work in branches as shown in Figure 42.

Finally, iterations of a design could be encapsulated into branches, as shown in Figure 43 where a student creating 3D printed chess pieces developed a second version of his design once he realized there was not enough structural support for overhangs in his model.

These four types of branching structures reveal distinct strategies for decomposing projects into steps. Importantly, they are not necessarily independent, as users can incorporate multiple representations in the same project. For example, the 3D-printed chess pieces project shares two different iterations as well as the digital modeling and fabrication components of the design in branches.

Figure 41: Types of processes in an integrated hardware and software project http://buildinprogress.media.mit.edu/projects/1739
Figure 42: Individual contributions to a collaborative project http://buildinprogress.media.mit.edu/projects/1949
DESIGNING AND 3D PRINTING CHESS PIECES

- Needed Materials
- Project Inspiration
- Specific Piece Sizes

Starting the Design and Printing Process

First Try and Failures

Design
- Designing the Pieces
  - Designing the King
  - Designing the Queen
  - Designing the Bishop
  - Designing the Rook
  - Designing the Knight

Printing
- 3D Printing the Pieces...

Second Try

Design
- Redesigning the Pieces
  - The New King Design
  - The New Bishop Design
  - The New Rook Design
  - The New Queen Design
  - The New Pawn Design
  - The New Knight Design

Printing
- Printing in a Lower Quality
- Printing in a Higher...

Figure 43: Types of design processes and versions shown in branches http://buildinprogress.media.mit.edu/projects/3066
Summary & Future Work

The examples shared in this chapter shed light on how creating make-throughs with BiP can support both authors and their readers. This dual purpose is important for several reasons. It motivates reflective practice by fostering micro-documentation patterns in a community of practice. Rather than editing out process, authors incorporate experimentation into their documentation as a means to assist like-minded creators. Consequently, the documentation serves as a rich source of data for educators and researchers to understand how people learn to design. BiP projects provided evidence of reflections on making, design process, and identities and values as makers. As the teacher in School B described, make-throughs create opportunities for more holistic and nuanced ways of assessing learning:

[Before BiP] I found it troubling that I was mainly assessing the end product which should not be the most important piece. BiP has been really helpful for me to communicate to students the value of tracking their progress and recording their process (especially mistakes!).

It was not an explicit goal to create a platform for a particular audience of makers. Yet, the greatest uptake of BiP has been from novice designers in K-12 settings. In Connecting, I shared some of the different perspectives on process-oriented documentation from amateur and expert authors. Future work can further reveal the unique needs of an older maker audience, who may already have their own established workflows for sharing their work and thus may not derive the same value from sharing on a centralized community. On the other hand, the use of BiP in K-12 settings suggests a demand for tools to support new makers capturing and sharing their creations.

I began BiP with essentially no experience with software development, so I am both surprised about and thankful for the ways in which makers all around the world have used the tool over the past few years. If I were to redesign BiP with the skills I have developed since beginning the project, I would make significant changes to the underlying structure of the process map. More specifically, I believe that a more free-form canvas for annotating one's workflow would open up new doors for creative expression and personalization.

When I asked select users of BiP to sketch out how they would visualize their process, I received some fascinating responses, two of which are shown in Figures 44 and 45. The first sketch shares an alternative representation for constructing an LED mirror, while the
second captures multiple attempts at cooking a dish. Annotations highlight functional parameters missing in the current implementation of the process map, such as the role of time and merging of processes. In addition, annotation adds character and emphasizes stages that the authors considered to be especially important.

With BiP, I largely focused on how process is visually represented and shared by designing the process map and creating a community for which documentation was shared. While I developed BiP mobile applications to aid with capturing, BiP does not fundamentally change the way in which users capture media of their projects. What would documentation look like that streamlines the process in which an artifact is captured? How can the act of capturing process be engaging and motivating in and of itself? As a result, what new audiences might we be able to engage through expressive and playful forms of documentation?
Preparation

Cooking

Project Overview

Making soy milk

Getting the soy powder

Making the dough

2nd attempt

Adjusting the amount of flour added

Letting the dough rise

Waiting for the dough to rise

Cooking the dough

30 min

4 hr

30 min

15 min

Figure 45: Annotated sketch of process for Soy Flatbread. http://buildinprogress.media.mit.edu/projects/113/steps
5. Spin

This chapter describes the motivation, design, and use of Spin, a photography turntable system for generating playful documentation. I show how Spin streamlines the documentation process while enabling people to make with documentation.

Creating public design documentation involves capturing one’s process and communicating this process with others. With BiP, I focused on the latter by creating new ways for people to visualize and share work-in-progress. To explore new methods of capturing process, I began considering how the act of documenting could become more streamlined into the workflow of a design activity. I was particularly inspired by the strategy of giving digital documentation a physical presence (Chapter 4 - Situating) and combined this objective with making documentation a joyful activity, ultimately leading to the design of Spin, a photography turntable system for creating playful documentation.
This chapter describes the design principles for developing Spin, the existing work it builds off of, and an analysis of its use in makerspaces around the world. I summarize the major findings of the work, which include introducing and motivating documentation practice with a younger audience and rethinking documentation as a modular rather than complete output.

**Design principles**

The design of Spin has been guided by the following principles.

- **Make the act of creating documentation fun**
  Documentation is sometimes perceived as necessary rather than desirable. Can the act of creating documentation be fun so that users are more motivated to do it?

- **Create an engaging documentation format**
  I wanted to take advantage of rich media options to create a compelling format that would draw audiences in to learn more, without necessarily conveying all the detail normally included in DIY documentation. I was especially interested in formats that could appeal to a more general audience than just other makers.
• **Reduce the effort needed to create documentation**
  Continually capturing one’s process can be difficult, especially for audiences documenting for the first time. I sought to reduce the effort needed by incorporating automated ways to generate documentation.

• **Connect to existing communities**
  Rather than create another community, I wanted to leverage networks that makers already use so they could more easily share their work with their peers. A design requirement for the system was to output to a common file format that can be embedded on existing social media platforms.

*Prior work*

Before beginning to develop Spin, I was inspired by two existing projects. The first is a DIY turntable for DSLR product photography created by Geoff Tsai for the MIT Media Lab class How to Make Almost Anything in 2013 (Figure 48). His turntable connects to the shutter release of a DSLR camera and incorporates components such as a one-way clutch so that the turntable can rotate freely and a worm gear to support heavy loads. After capturing photographs of an object placed on the turntable, a user can transfer the photographs onto a computer and employ design software such as Photoshop to compile the images into a video.

The second project is another turntable called Catch-Up 360, developed by researchers at the Media Interaction Lab at the University
of Applied Sciences Upper Austria [Perteneder et al., 2015]. Catch-Up 360 supports remote collaborators designing physical objects and combines a motorized turntable, a camera- and projector-based capture and viewing system, and a software interface for reviewing iterations of tangible prototypes. With the software, users can interact with the turntable remotely to view the object from particular angles and add digital annotations to the captured footage.

I wanted to combine the automated procedure of capturing 360-degree views of physical artifacts with an accessible motorized turntable that makerspaces could build and software that automatically generates sharable animations. This starting point led to the design of the Spin system, which reduces the number of components used in Tsai’s turntable design and pairs the physical turntable with custom software for generating animated documentation.

**Design**

The Spin turntable system is comprised of three elements: a motorized turntable, a mobile application, and a web server and viewer, as shown in Figure 50.

With Spin, users create playful 360-degree animations of physical design projects. When the turntable is paired with a mobile device running the Spin iOS application, it automates the process of taking
15 images of the object from different angles (Figure 51) and compiles the photographs into a short, 3-second long video or GIF (called a *spin*). Spin animations can be combined into a *set* that shows a progression of *spins*, conveying how a project evolves over time. The entire process of creating a spin animation from start to finish takes less than a minute, and users can share their animations directly to social media (Twitter and Instagram) through the app.

Additionally, all created animations are uploaded to a server so that users can view a portfolio of their spin animations directly on the Spin website. I provide a more detailed description of the hardware in a publication for IDC [Tseng, 2015].

**Turntable**

The Spin motorized turntable runs on a geared (10:1) stepper motor drive and an Arduino microcontroller and custom shield I designed for controlling the turntable (Figure 52).

The turntable was designed to be as inexpensive and accessible as possible to enable others to build their own. It consists of purchased
and fabricated parts, which total approximately $150. All of the hardware can be purchased from the popular vendors McMaster, Sparkfun, and Digikey and include the turntable bearing, stepper motor, and electrical components. The custom shield incorporates an off-the-shelf motor controller (the Easy Driver\textsuperscript{13}) and audio processing circuitry, enabling the turntable to communicate with mobile devices via audio signals. The Spin PCB is shared on the site OSHPark and can be purchased there as well\textsuperscript{14}. Fabricated components include laser-cut pieces (such as the platform) and 3D printed pieces (such as the phone stand and motor gear).

All of the design files and instructions for building your own turntable are openly shared on the Spin website at http://spin.media.mit.edu/build, as shown in Figure 53. Additionally, I document how the entire system, from the turntable to the website to the mobile application, are developed with project documentation on Build in Progress (http://buildinprogress.media.mit.edu/projects/2330/steps).

In addition, I created a modified turntable design to enable makerspaces with small laser cutters to fabricate a Spin. Many makerspaces utilize laser cutters that cannot accommodate materials larger than 12” in a single dimension. The original design incorporates some laser-cut components that are 13” in diameter, constrained by the 13” diameter turntable bearing from McMaster. While the

\textsuperscript{13} https://www.sparkfun.com/products/12779

\textsuperscript{14} https://oshpark.com/shared_projects/LB4bMHgC

Figure 53: Spin build instructions at http://spin.media.mit.edu/build
modified turntable has the same overall footprint (since it uses the same turntable bearing), all of the laser cut components fit a 12" laser cutter bed by employing 3D printed feet to extend the width of the base (Figure 54). This modified turntable design is available at http://spin.media.mit.edu/build_modified.

Mobile application

The turntable functions with a companion iOS application for controlling the movement of the turntable and capturing photographs. Any iOS device (iPhones, iPads, and iPod Touches) running iOS 7.0 or later can run the app, which is available for free on the Apple App store. The app runs through a short setup process in which it tests its ability to communicate with the turntable before a user is able to register for an account using either Facebook or Twitter.

With the mobile app, users can view all their spin animations and create new ones. The entire interaction flow is conveyed in Figure 55. A user creates a new set by tapping the “create set” button, at which point the app opens the camera. After the user adjusts the distance between the phone and the turntable to ensure their entire object is in view (Figure 56), they tap the “start” button in the app, which triggers the turntable to start rotating in 24-degree increments. The app proceeds to take 15 photographs of the object from each angle.

After the full revolution is complete (which takes approximately 40 seconds), the images are compiled to create a 3-second long animation, a process which takes about 5 seconds. In earlier versions of the app, all 15 images were uploaded to a server, where they were pro-
cessed to create the animation. However, the image uploading was prohibitively slow for makerspaces with inconsistent Internet connectivity, so the animation compilation process was moved directly into the app. Animations are automatically uploaded to the Spin server upon creation, saving a record of all of a user’s animations. At this point, the animation is shown within the app, and the user can share it directly to Twitter or Instagram, or they can download the video (as a mp4) or GIF to their device. We log whether users choose to share their animations, and which platform they share it to. Users can optionally add audio description of their project, which can be up to 20 seconds in length. Videos of animations can be exported with or without sound.

To add multiple spins to a set, a user selects an existing set and taps the “+” button in the app to create a new spin (Figure 57). When the spin is complete, it is automatically appended to the existing set animation, leading to a compiled video that shows each spin sequentially. The video compilation happens on the web server and uses FFmpeg (https://www.ffmpeg.org/). This compiled video can be shared or exported directly in the app.

Finally, to aid with organizing sets, users can add tags to individual spins and search for spins by tag. For example, a spin could be tagged with the name of the child who created it, enabling her to filter out her own spin animations in the app.

Communication Protocol

Spin uses a two-way serial modem interface, enabling the Arduino to “talk” to a mobile device using audio signals. Audio signals are generated by both the Arduino and the mobile app and are transmitted via a 4-pin 3.5mm audio cable. The protocol requires the use of the mic-line to enable communication from the Arduino to the app, which is why a 4-pin audio cable is used as opposed to a standard 3-pin cable. The SoftModem Arduino library\(^5\) and FSK-iOS-Arduino library\(^6\) were utilized.

Audio communication was selected to reduce cost and make connecting to the turntable as quick and seamless as possible. If an alternative such as Bluetooth were employed, users would potentially need to toggle their Bluetooth setting on their device and go through a pairing process to connect to the turntable. Additionally, using

\(^5\) http://arms22.blog91.fc2.com/blog-entry-350.html

\(^6\) https://github.com/ezefranca/FSK-Arduino-10S
bluetooth compatible hardware would increase the overall cost. With audio communication, users simply plug into the audio jack of their device to start using the turntable.

The communication protocol has been refined over several iterations. In its current implementation, when a user taps the “start” button to begin a spin, the app sends a signal to the turntable and waits for a confirmation. It will make five attempts before it alerts the user that it cannot connect to the turntable (the user can bypass this alert and take images without the turntable connected, if desired). After a confirmation is received, the app sends a signal to trigger the turntable to rotate, at which point the turntable proceeds through its entire 360-degree revolution. A user can cancel the rotation at any time, at which point a cancel signal is sent to the turntable.

Figure 58: User profile page on Spin website

Website

The Spin website serves as an animation repository, with all animations publicly viewable through each user’s profile page. Profile
pages display a grid of the user’s created sets, with the animations set to auto-play and loop (Figure 58).

Clicking on a set brings up the set viewer (Figure 59). On this page, users can view playback of their animation and manually control it by dragging a slider beneath the video (in the timeline); the user can also control the position using arrow keys on their keyboard. Animations can be shared directly to Twitter or Facebook or downloaded as a video or GIF file; similar to the mobile app, we log whether users share animations externally. Users can edit tags for individual spins by selecting a spin within the set (by clicking the i icon next to the corresponding thumbnail in the timeline).

Sets with multiple spins have two viewing modes: the default viewing mode (Figure 59) and an alternative filmstrip mode (Figure 60). In the filmstrip mode, each spin within a set is shown side-by-side, enabling direct comparisons between different iterations.

The entity-relationship diagram for the Spin PostgreSQL database is shown in Figure 61, and the architecture of the entire Spin system is outlined in Figure 62, where the Spin server is hosted on Heroku, and all assets are hosted on Amazon S3.
Methodology

With Spin, I have been exploring the following questions regarding how animated documentation is created and used:

- At what points in a design process is Spin used, and why?
- What strategies do educators use to integrate Spin into their makerspaces?
- How do makers use the animations they create with Spin?

To answer these questions, I studied the animation artifacts created with Spin, conducted interviews with educators and children using Spin, and observed how Spin is used in makerspaces.

Analysis has been conducted over three phases. The first was an ex-
The exploratory phase that took place in the summer of 2015, where the goal was to understand the range of projects that can be supported with Spin and refine the system for long-term use. Pre-assembled turntables could be borrowed for 2-4 weeks via a request form on the Spin website. I screened requesters through email or video interviews and selected K-12 educators associated with an organization (rather than independent designers) with a history of leading making activities. Educators were also interviewed after their rental, and when possible, students who used Spin were interviewed. Interviews followed a semi-structured protocol and were conducted online or in-person, lasting approximately 45 minutes each.

In the second phase, turntables were used for an extended period of 2 months in the fall of 2015. Participants included educators who requested the turntable through the website as well as two that built their own Spin (on their own volition) using the instructions on the site. Data collection included weekly online surveys to learn about how the turntables were used from week-to-week, including questions such as, “Did you use any new strategies to motivate youth to use the turntable?” and “Were there any surprising uses of Spin that you observed?” An online get-together was organized 4-weeks into the study and enabled educators to share strategies for using Spin. At the end of the study, each educator was interviewed using a semi-structured protocol for approximately 45 minutes, and students were
also interviewed online when permitted for approximately 15 minutes each. All interviews were recorded, transcribed, and analyzed to identify themes around supporting documentation.

In the third phase, ongoing since Winter 2015, Spin has continued to be used by educators both borrowing and building their own turntables. I conducted in-person observations of Spin in two schools in New York City, one of which participated in Phase 2 of the data collection. During these visits, I observed how 10-12 year-old children documented class projects and had informal conversations with students about their experience using Spin. I also photographed children using the turntable and observed how the educators introduced the tool and encouraged its use.

For all phases, one-way shipping costs for the turntables were paid for, with no preference for location; turntables were mailed to makerspaces around the world. Upon receiving their turntables, educators were given a short tutorial on how to run Spin but were otherwise not given specific guidelines on how to use it, including when, how often, and for what types of projects. My intention was to avoid biasing how the turntables were used and encourage users to be creative with how they incorporated Spin.

Spin locations summary

From May 2015 to March 2016, Spin has been used in 30 schools, libraries, museums, and after-school spaces and workshops around the world, spanning four continents (Figure 63). Collectively, over 1,000 spin animations have been shared in the 10 months the project has been active.

Of all the locations, 4 did not use the turntable beyond demoing the technology. An online survey with these makerspaces revealed that the most common barriers were a lack of access to an iOS device for running the app (n=3) and lack of time to introduce the turntable to youth (n=2). This left 26 locations, summarized in Table 5, where children were under 18 years old and teachers and adults older than 18. Each makerspace is unique in the audience they serve, the frequency with which they meet, and the types of activities they support. Five of these spaces built their own turntables using the instructions shared on the Spin website.
<table>
<thead>
<tr>
<th>Name</th>
<th>Audience</th>
<th>Length of Use</th>
<th>Example Projects</th>
<th># Sets</th>
<th># Spins</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-CS</td>
<td>Children</td>
<td>4 weeks</td>
<td>LED jar lights</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>B-S</td>
<td>Teachers</td>
<td>1 week</td>
<td>LEGO robots</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C-AS</td>
<td>Adolescents</td>
<td>4 weeks</td>
<td>Laser cut containers</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>D-CS</td>
<td>Teachers</td>
<td>1 day</td>
<td>Arbtots</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>E-AS</td>
<td>Children</td>
<td>3 weeks</td>
<td>Craft structures</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>F-AS</td>
<td>Children</td>
<td>1 day</td>
<td>Paper circuits</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>G-CS</td>
<td>Children</td>
<td>1 day+</td>
<td>Arbtots</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>H-CS</td>
<td>Children</td>
<td>1 day</td>
<td>LEGO creations</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>I-CS</td>
<td>Teachers</td>
<td>1 day</td>
<td>Art projects</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>J-CS</td>
<td>Children</td>
<td>1 day</td>
<td>LEGO creations</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>K-S</td>
<td>Children</td>
<td>8 weeks+</td>
<td>Solar-powered machines</td>
<td>60</td>
<td>77</td>
</tr>
<tr>
<td>L-S</td>
<td>Adolescents</td>
<td>8 weeks</td>
<td>Vinyl stickers</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>M-S</td>
<td>Children</td>
<td>7 weeks</td>
<td>Craft projects</td>
<td>44</td>
<td>70</td>
</tr>
<tr>
<td>N-S</td>
<td>Children &amp;</td>
<td>7 weeks</td>
<td>Laser-cut picture frames</td>
<td>84</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td>Adolescents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O-S</td>
<td>Adolescents</td>
<td>6 weeks</td>
<td>Light up wooden Christmas tree</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>P-CS</td>
<td>Children</td>
<td>6 weeks</td>
<td>3D printed figures</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>N-S</td>
<td>Children &amp;</td>
<td>22+ weeks</td>
<td>Laser-cut nightlights</td>
<td>163</td>
<td>276</td>
</tr>
<tr>
<td></td>
<td>Adolescents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-S</td>
<td>Children</td>
<td>11 weeks+</td>
<td>3D printed cities</td>
<td>88</td>
<td>96</td>
</tr>
<tr>
<td>R-AS</td>
<td>Children</td>
<td>11 weeks+</td>
<td>Paper circuits</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>S-CS</td>
<td>Teachers</td>
<td>1 day</td>
<td>Craft projects</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>T-CS</td>
<td>Teachers</td>
<td>6 weeks+</td>
<td>Robotics</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>U-CS</td>
<td>Children</td>
<td>6 weeks</td>
<td>Wooden chair models</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>V-S</td>
<td>Teachers</td>
<td>1 day</td>
<td>LEGO robotics</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>W-S</td>
<td>Adults</td>
<td>1 day</td>
<td>Arbtots</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>X-CS</td>
<td>Adults</td>
<td>3 weeks+</td>
<td>Ceramic figures</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Y-S</td>
<td>Adults</td>
<td>6 weeks+</td>
<td>Wooden slingshot</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Z-S</td>
<td>Children</td>
<td>1 weeks+</td>
<td>Race cars</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 5: Summary of Spin makerspaces
(S: school; AS: after-school; CS: community space. + indicates the turntable is still active at the site as of 3/31/16)
Findings

In the following section, I begin with four case studies of how Spin was used, including a library makerspace, a science museum, and two K-12 schools. Each case study highlights different elements of the documentation framework (capturing, sharing, reflecting, and situating). Following the case studies, I describe general patterns of documenting with Spin, incorporating examples from all 26 makerspaces to show how users can begin to ‘make’ with documentation. This work will be presented at DIS 2016 [Tseng, 2016b].

Case studies

Capturing collaborative documentation at A-CS

One of the first organizations to borrow a Spin was the library makerspace A-CS, where Spin was used over the course of 4 weeks to support summer maker programming. In August, 2015, a technology librarian at A-CS integrated documentation with Spin into a series of 2-hour-long workshops for elementary- and middle-school-age youth where they created projects such as propeller-powered cars, jar
Figure 64: Stills from propeller-powered car set, viewable at http://spin.media.mit.edu/sets/378 (A-CS)
lights, and arcade games. Incorporating documentation within the timeframe of short workshops can be challenging, especially given the limited amount of time to finish a project. However, this librarian developed a unique strategy that enabled the youth to capture their process throughout the workshops.

Each workshop centered around building a particular creation. For example, the propeller-powered car workshop involved constructing a toy vehicle out of balsa wood, a DC motor, and a playing card, and each participant constructed the same design and left with their own toy. Throughout the workshop, the librarian invited different children over to the Spin to capture the current state of their prototypes. Since all were creating the same design, they collectively contributed multiple spins to a single set showing the creating of the final car model. Figure 64 presents four stills from four different children capturing how the car was constructed (Figure 64).

Using this technique, the librarian facilitated the capturing of collaborative documentation where each child contributed a spin to a larger set. At the conclusion of the workshop, the librarian shared the compiled animation, and each child was excited to identify their own contribution in the context of the group’s collective effort.
My interview with this educator further revealed how spin animations were just one of several types of documentation captured. An active member of an online Google+ community for makerspaces, the librarian shared Spin videos alongside photographs of the students actively building their project: "One [the photographs] is documenting the process of the kids at work, while the other [Spin] is capturing the process of the kids' work." In other words, the spin animation highlighted the project that children were creating, while the photographs of the activity captured the children creating the project. An example of sharing these two types of documentation is displayed in Figure 65. Combining multiple forms of documentation became a way to "tell our story from different angles." Thus, spin animations were valuable for sharing with other makerspaces the artifacts children created along with photographs of the activity.

Building visible documentation at G-CS

To better capture projects created by youth on the museum floor, G-CS constructed their own Spin turntable. I collaborated with the museum research staff to design a 4-hour-long drop-in workshop open to all museum visitors in September, 2015 (Figure 66). During the workshop, 13 children participated by creating their own drawing

Figure 66: Artbot activity at museum G-CS, with feed of animations on left and Spin turntable set up on right
robots, or artbots, that used a combination of a vibrating motor and markers to generate unique artwork (Figure 67).

Throughout the workshop, we invited the children (approximately between 6-10 years old) to create an animation with Spin, which was set up adjacent to the central activity table.

Before creating their spin, youth ran their robot on a rectangular sheet of paper to generate a design. Their artwork was then pinned up behind the turntable, serving as a backdrop with their completed robot at the center of the animation (Figure 68). This gave children an opportunity to capture their creations through customizing their spin animations with their robots and the art it created.

A large vertical display at the entrance of the workshop shared a feed of the animations being created (Figure 69). We used a browser extension to automatically refresh the museum's Spin profile page every 15 seconds, ensuring that animations were constantly added as they were captured. Because of the display's proximity to the entrance, the animations situated the activity by communicating its purpose and motivating new museum-goers to join. Furthermore, as children completed their creations and left the workshop, they could point to their animation on the display to show their parents what they had made. The latter feature was especially important because children could not take their robots home with them, as the materials were recycled for subsequent use.
In addition, the documentation created opportunities for reflecting, both for the children and the facilitators. In one instance, a child wished to create a robot capable of drawing straight lines. To get started, he looked through examples on the Spin project feed to identify structures that could produce straight lines. By analyzing the creations made by other children, he was able to reflect on the properties and parameters that may control the path of his robot.

At the conclusion of the workshop, the feed supported a reflective conversation among the facilitators. With the grid of animations, we could, at a glance, see the range of creations the children developed, both through their robotic creations and the artwork they generated. One facilitator remarked on how the visual documentation provided evidence of the generativity of the activity. Further, the documentation sparked a discussion on how to support children capturing prototypes, with suggestions that the turntable be embedded into the activity table itself to encourage a flow of testing and documenting.

**Celebrating design moments at Q-S**

In the last two case studies, reflections supported with spin animations were enacted outside of the Spin system through conversations between youth and educators. In an effort to integrate reflections directly within the Spin platform, I created an audio recording feature with which users can add 20 second audio descriptions to their spins. This feature does not prompt users with specific questions; instead, I was interested in observing what types of descriptions youth would add when given the opportunity to record whatever they wanted.

In February, 2016, I visited a private, all-girls school (Q-S) that had been using Spin for four weeks and whose students had just begun to use the audio recording interface. The latest class project they were documenting with Spin was a 3D printed colonial cities assignment in which 6th grade students (approximately 11 years old) created digital models of colonial cities in the United States using Autodesk's TinkerCAD software. After designing the models, the technology teacher 3D printed them outside of class.

On the day of my visit, the children had received their 3D printed models for the first time, with multiple students in the class creating models of the same city; for example, a group of 4 had created models of colonial Boston, while another created models of Philadelphia. Each group was invited to arrange their 3D printed “squares” on the turntable and create a spin of their final projects (Figure 70).
I observed how capturing projects with Spin was a celebratory moment for the students, where they could admire their finished work with one another. While the turntable was capturing photographs of their cities, all of the students stayed to watch it finish its 360 revolution and passed around the iPad after the animation was complete, commenting on what it looked like. I had expected students to start the spin within the app and occupy themselves with a different activity while the turntable proceeded through its 40-second revolution, but the students enjoyed watching it turn.

After the children's designs were 3D printed, students were invited to create an audio recording, and 7 students chose to participate in this reflective activity. The students that created recordings took an iPad running the Spin app to a quieter part of the classroom to record their descriptions. The recordings were, in some senses, performative, with students doing multiple takes of their recordings, listening to each take, and then saving their recordings once they were satisfied with the output (Figure 71).

The reflections exhibited in the audio recordings included descriptive, evaluative, and analytical statements. For four of the students,
the audio recording was purely descriptive, stating what the different elements of their 3D printed design were:

There is a Congress hall, a market street, a free Quaker meeting house, and a Robert Bell print shop. There also is a florist.

This is my city from New York. There are four trees, one church, a dock, and two boats.

In the other three recordings, students evaluated what they liked about the assignment: “I really love this project. I love designing and building the city on TinkerCAD.” In one of the three, a child analyzed what she valued about the project more generally: “One of the things that I like about it is that I got to make it my own.”

The girls’ reflections on finished work reveal some of the opportunities and limitations of the audio recording interface. First, the performative nature of creating an audio annotation, particularly in front of one’s peers, may have limited which girls chose to participate, with ones less comfortable with recording their voice in front of others shying away from doing so. Perhaps the act of recording oneself should be situated in more of a private setting in which the child can collect her thoughts before adding a narration. Further work is also needed to better understand how to support a range of reflections, from descriptions of the specific projects to more general conclusions about participating in a design activity.

Capturing and sharing process at N-S

In school, the ‘d’ word (documentation) rarely gets a positive response. As the teacher in N-S stated, “Document...they [my students] hate that word! I haven’t even called Spin a documentation tool. I don’t want them to know that’s what they’re doing,” When introducing Spin to his students, the teacher framed it as a tool for creating a digital portfolio of projects, an idea he hoped would resonate with eighth grade students already thinking about college applications.

This educator built his own turntable for his school’s makerspace,
and over seven weeks in the fall of 2015, Spin was used in N-S to capture 84 laser-cut projects, of which 25 (30%) captured how prototypes evolved over time, such as the laser-cut nightlight in Figure 72.

A conversation with one of the students at N-S revealed her intention to use her spin animation to share her entire design process. When asked if she hoped to use the animations for any particular purpose, she stated,

I think I would share it with my family. They’re in Canada, so I can’t bring it home to them and show them like I can with my parents. For my parents, I bring it [prototypes] home...they see the process and do it with me. But my family [in Canada], they only see the finished project. They don’t see what I had to go through to get to the finished project.

Thus, the compiled set showing how her project evolved over time became a way to communicate her efforts to her family remotely.

I spent a day observing how Spin was used at N-S by a range of middle school students. Organized as open make sessions, class periods enabled children to build projects at their own pace. Because each child completed their prototypes at different points, capturing took place continually throughout the class period. As shown in Figure 74, each child would bring their prototypes over to the turntable to create a spin themselves, and their creations were exhibited on the large display for the class to see (Figure 73).

Figure 73: Display of spin animations in N-S makerspace

Sharing: Spin animations enabled a student to easily share her animations with her family outside of the United States.
Similar to the previous school Q-S where children watched their spins, every child I observed using Spin stayed with their project until the animation was complete. While watching her project spin, one child commented on how she appreciated that the documentation “doesn’t take too long.” In contrast, the educator at N-S described how he thought it was useful that Spin automated the documentation process, enabling him to do other things while it was capturing:

Sometimes you’re so focused in flow that you’re working on a project and you just want to keep working on it rather than stop, take pictures, and write about what you’re doing. But what I like about Spin is that it takes care of a lot of stuff for you because you put it down and you can walk away. I’m never just Spinning and watching it Spin. I’m always doing something else.

Perhaps as the children become increasingly comfortable with Spin, they will have less of a desire to watch their projects spinning on the turntable. Yet, another hypothesis is that creating their spins introduced a welcome pause in their activity. I observed the high energy of the classroom, where children continuously moved around the room to gather materials and tools to build their projects with. Watching their prototypes spin seemed to be the only time in which the children paused and took a breather from the high intensity of the makerspace. As Spin continues to be used in makerspaces, it will be interesting to see how the patterns of use change based on the users’ familiarity with the tool.

**Documentation as making**

Documentation often integrates writing, where design decisions are communicated in written form. However, the act of writing can be a barrier, especially considering the contrasting hands-on nature of building. The educator at K-S described this tension as follows: “The purpose of the tinkering environment is that it allows kids whose academic competencies aren’t in 5th grade paragraph writing to show that they have confidence over a diverse areas of things.” As the teacher of O-S concisely summarized, “My students like to make, but not to write.” Finally, making and writing are separate processes that require different tools and mental states: “Part of the overhead of asking kids to document is the exercise of writing, and even before the exercise of typing, asking them to get to the device and opening up the program that will let them type” (K-S). Thus, reducing the friction between making and documenting is a standing challenge.
Spin bypasses this writing requirement by using a purely visual format. What I observed as a result was that visual documentation introduced new opportunities for customization and created a pathway for even younger audiences to participate; young people began to "make with documentation," reimagining documentation as a creative design activity.

Spin was used with youth of all ages, many whom may not yet know how to write. For example, the pre-K students from K-S and similarly-aged children from G-CS were young enough that writing would not be developmentally-appropriate, yet they were still able to document their projects in ways that enabled them to share their creations with their peers and parents. Figure 75 shares some of the LEGO numbers created by pre-K students from K-S.

People's engagement with Spin was playful and creative, supporting a 'maker-like' approach to documenting. Through the flexibility of the physical hardware and the mobile application, users personalized their animations, built extensions, and created alternative animations. Perhaps as a result of being installed in makerspaces next to fabrication machines and construction material (Figure 76), the turntable became another tool to make with.

Seven makerspaces highlighted their turntables by constructing custom backdrops, including collages of inspirational images and children's artwork, signage of makerspaces' logos, and whiteboards with written annotations (Figure 77). When describing the process of collaborating with her youth to build their backdrop, educator E-AS stated, "I wanted to create a sense of space...for them to realize their own ingenuity" (Figure 78). Creating around the turntable became a way to spotlight Spin in the makerspace and enable personalization.
Figure 77: Custom Spin backdrops (E-CS, P-C, B-S, R-AS)

Figure 78: Girls constructing backdrop for Spin at E-AS
Selfies constituted a special type of backdrop in which designers pop into the frame while the animation is being captured (Figure 79). Selfies were created in 7 of the makerspaces, combining the designed objects and their creators. (This type of engagement was not possible at all locations, particularly schools that restricted children's faces from appearing in publicly viewable media.)

The physical setup of Spin afforded opportunities to build extensions. Three of the spaces from Phase 2 made impromptu stands to prop up flat objects, including laser-cut stands for LEGO baseboards, helping hands, and clip stands made with pegboard hangers and clothespins (Figure 80).

Several users also repurposed the animation format. While desktop-sized projects were well supported on the 13”-diameter turntable platform, six of the spaces reported having projects too large to fit comfortably on the platform. Three educators captured animations without the assistance of the turntable by simply running the mobile application on its own. This includes a life-size “manual spin” for
a masking-tape boa constrictor, which hung around the neck of the child who created it while he spun round to mimic the movement of the turntable (Figure 81).

Another example of creating with the animation format was realized by an educator from Q-S, who discovered that the 15-frame animation could be used to create zoetrope-like stop animations as displayed in Figure 82.

Finally, Spin also supported the construction of narratives similar in format to stop-animations. Rather than capture a still object, three children from H-CS and J-CS moved their LEGO creations across the turntable while it was spinning to act out a scene, such as an evil scientist defending his lair (Figure 83), or a battle scene between two warring states.

These examples reveal how visual forms of documenting begin to merge making and documenting practices, with people creatively personalizing their animations with custom backdrops, selfies, and stands. Further, people found ways to repurpose the animation format itself, creating stop animations, sometimes even without the use
of the turntable. While the documentation created with Spin may not have the same level of detail that a BiP project typically contains, reducing the barrier to creating documentation and introducing an alternative format for sharing ultimately opened up opportunities for new forms of expressive documentation created by new audiences.
6. Discussion

In this chapter, I compare the ways Build in Progress and Spin support different aspects of the documentation framework, describe three parameters that influence the design of documentation experiences, and synthesize the insights from both platforms through a set of design principles for supporting make-throughs.

With Build in Progress and Spin, makers create publicly shared documentation that captures their personal journey of creating a project. Through developing two distinct platforms, I was able to adjust several design parameters to support different goals and types of interactions: Build in Progress enables users to visualize and reflect on their process within a larger community of makers, while Spin reduces the barriers to documenting by automating the process of generating it in a playful format.

In this chapter, I discuss differences between the design of BiP and Spin across the four dimensions of the documentation framework: capturing, sharing, reflecting, and situating. I contrast how the tools were used and distill these insights into a set of design principles for virtual and physical spaces supporting the creation of make-throughs.

Design differences and outcomes of BiP and Spin

The ways in which BiP and Spin were used reflected both deliberate design decisions and emergent practices from makers repurposing the tools, summarized in Table 6.

For capturing, the combination of non-textual media and an automated capturing process enabled a younger audience to document with Spin than traditionally seen with BiP; in the context of adult-
facilitated workshops, children as young as four years old used Spin. For example, pre-kindergarten children at school K-S used Spin to capture their LEGO creations (Documentation as making in Chapter 5), while young children under 10 years old used Spin in a museum context to share their artbot craft projects (Building visible documentation in Chapter 5). In contrast, the uptake of BiP is largely seen with users in middle school, high school, or even university-level.

From a usability standpoint, Spin has a lower barrier to entry, since the system automates much of the process of creating an animation. As a result, Spin was more developmentally appropriate than BiP for very young children, especially those just learning to read or write. Further, the visual format of Spin was flexible enough for users to personalize the look and feel of their documentation, as witnessed through custom backdrops and stands created by Spin users (Documentation as making in Chapter 5). While users can create branches to organize their projects on BiP, the branching visualization has a similar aesthetic across very different projects. This standardization was implemented to help maintain consistency and readability across shared projects; however, future work can explore how to help users further personalize their BiP project pages.
The choice of when to document and how to represent a stage in a project led BiP users to deliberately plan and organize their BiP branches as described in Capturing (Chapter 4). This led to a practice of reflecting distinct from that observed with Spin. An analysis of BiP projects revealed how makers reflected on the material aspects of making, their experience engaging in an iterative design process, and their changing values and identities as designers (Reflecting in Chapter 4). While users can add reflective descriptions to Spin by embedding audio recordings with their animations, currently only a fraction (4%, n=43) of all shared animations contain audio recordings, and the majority do not go beyond describing the object that was created. There are several parameters at play (such as the 20-second time limit for audio recordings, the younger audience of Spin users, and the lack of a browsable interface for viewing other people’s spins) that may contribute to differences in depth of reflection.

While BiP projects take longer to create, they, in general, contain much more detail about a project through textual descriptions users provide for each step of a project. In contrast, conversations with educators using Spin revealed that reflections often happen outside of the platform through one-on-one conversations or reflective written assignments that children do alongside their projects. With BiP, reflection is embedded within the tool and community; at the moment, reflection with Spin largely exists outside of the platform.

Both platforms offer distinct methods for sharing make-throughs. BiP is an online community for makers where people can ask questions and comment on one another’s projects. On the other hand, Spin potentially enables users to tap into larger, more diverse personal communities by sharing on external social networks like Twitter or Instagram. However, the types of sharing that occurs with Spin, at least to this point, has predominantly led to people ‘liking’ animations, but not necessarily starting conversations or leaving specific feedback. Additionally, while sharing on these external social networks appeals to educators and older users of Spin, the younger children seem content with simply creating the animations themselves, with no explicit desire to share what they make with others beyond their peers or their parents using the Spin website.

In contrast, on BiP, the process of sharing work in progress helped facilitate conversations between makers as they helped others, received feedback on their projects, and represented their efforts, as described in Sharing in Chapter 4. For example, when the user blamb shared his sword powered by a plugged-in adapter, users suggested battery op-
tions that ultimately helped him create a self-powered design. User *slittle* shared his challenges with connecting to an Arduino Bluetooth device on his publicly-viewable BiP project in an effort to help other participants in an Arduino-based challenge on BiP. Thus, an area for future work is balancing the ease of use of automated documentation systems like Spin with the powerful opportunities to spark conversations on work-in-progress facilitated with BiP.

Both tools facilitate the creation of digital documentation, and educators found that giving a physical presence to digital documentation was a constructive strategy for *situating* documentation practice (Figure 84). Displaying BiP projects or Spin profile pages on a large display within a space served as a reminder to document and as inspiration as users reviewed projects created by others. For example, the facilitator *anetien* used a large 45” display within her after-school center to visibly share a BiP project that was updated throughout her workshops. The display facilitated reflective conversations with the youth, where everyone would review previous sessions by referring to BiP images of their work (*Situating* in Chapter 4).

Similarly, the museum G-CS used a large display in a workshop space to share what was happening during the workshop with other museum visitors and invite them to participate (*Building visible documentation* in Chapter 5). The display also supported one of the youth with reviewing other people’s creations to help guide his own design. Overall, highlighting process through visible examples was a powerful way to support documentation throughout an activity, and the practice of documenting was most successfully supported when educators budgeted time for reflection and consistently encouraged their students to document by suggesting that they take their projects “for a spin.”

![Figure 84: Visible displays of digital documentation using BiP (left) and Spin (right)](image-url)
Design parameters

The differences between BiP and Spin can be further reduced to three design parameters: time, audience, and resolution. Below, I describe what types of questions should be considered to help drive the design of new documentation platforms and experiences, using examples from the use of BiP and Spin.

Time

What is the timescale of the projects being supported?
The timescale can range from an hour-long workshop to a multi-year design project. The time it takes to create a project should be in line with the time it takes to create documentation – that is, the time to document should be in proportion to the complexity of the project.

While both BiP and Spin were designed to support capturing iterations, the majority of documentation created with Spin represents short craft projects, created on the timescale of minutes or hours. As an indication of time, 79% of all Spin sets consist of a single 360-degree spin. In contrast, only 24% of all BiP projects are created within the scope of 1 day, with projects on average updated over the course of a little over a month (39 days). These results suggest that platforms should carefully consider the investment of time makers have in creating the projects they are documenting and should incorporate capturing features that are appropriate to this timescale.

Audience

What is the audience participants wish to share their documentation with?
Audiences can be a large, public community; a sub-community for an organization or group of makers interested in a particular topic; or oneself (that is, an audience of one). Audience encompasses both the size and makeup of the community and will influence the format of the documentation; documentation intended for a teacher will look different than that intended for family, friends, or other makers.

When users share their projects on BiP, they share within a community of makers and DIY enthusiasts. In contrast, by design, Spin does not have its own internal community and supports sharing externally to social media. Both audiences have their benefits and limitations.
A community of makers may be better suited for the types of interactions observed on BiP, including leaving feedback and suggestions on projects and asking questions to the community. On the other hand, because the video output of Spin is inherently embeddable on other platforms, the animations have the potential to reach a wider audience. This feature was leveraged by teenagers sharing their Spin animations on Instagram with their friends and family, many who may not necessarily identify as makers themselves. However, integrating with existing social networks means that interactions are influenced by the social norms of these communities. Perhaps as a result, it is much more likely for people to 'like' Spin animations than to leave suggestions or feedback on a design. The tradeoff, then, largely depends on the purpose of the documentation artifact, which, in this case, includes sharing one’s interests with a general audience and getting feedback or connecting to like-minded creators.

Resolution

What amount of detail is ideal for the documentation to be useful, for the author and or the viewers? Determining how much information is valuable will drive how it is visualized, as well as the amount of effort that authors will need to allocate for documenting.

With Spin, users are generally interested in spatial resolution, as the animations share what a physical object looks like from multiple angles. The resolution of BiP projects revolves around steps in a process, thus lending itself more to sharing stages of creating a project. With BiP, resolution can be classified as temporal but also categorical, with project authors using branches in the Process Map to tease apart stages of a design process (such as brainstorming and fabricating) or types of design practices (such as hardware and software).

Design principles for supporting make-throughs

Based on the affordances and limitations of BiP and Spin, I synthesize insights from both platforms into design principles for learning environments, virtual and physical, supporting makers creating make-throughs. The following design principles are organized around the documentation framework of capturing, sharing, reflecting, and situating.
Capturing

Balancing automation and intentionality
Documentation tools can employ automation to reduce the amount of effort and time it takes to document. In the case of Spin, the process of capturing photographs and compiling animations of tangible projects is largely automated. Yet, reflection and synthesis take time to do and are often most valuable when they involve stepping back and engaging in conversations with others. Thus, documentation tools require a balance of automation and intentionality: they should enable moments of intentional effort where designers engage in meaningful reflection while employing automation to minimize the time needed to create useful artifacts upon which to reflect on.

Making the act of documenting engaging in and of itself
If documentation is fun to create, people will be more motivated to take the time to do it. This may seem obvious, but few documentation systems make the actual process of assembling documentation enjoyable, instead relying on potential feedback and recognition as motivators for sharing. Both the process of documenting and the resulting documentation should be something people see as being worthwhile. With Spin, users injected humor and playfulness into their documentation by taking selfies with their creations. Further, in my observations of children using Spin at two different middle schools, children were engaged in watching the Spin capture process (rather than starting the app and walking away while the automated capture process took place). As described with joekol’s BiP project, documentation can serve as an outlet for creative writing. People often see “documentation” as a necessary chore rather than an enjoyable activity. To address this bias, we must develop tools that introduce expressive forms of documentation that enable creators to add their unique personal touch.

Sharing

Visualizing process
If design is considered to be an iterative, cyclical activity, we should explore representations that can most accurately depict this process. With BiP, users incorporated the branching feature to showcase versions of a design, differentiate between processes being developed simultaneously (such as hardware and software), and distinguish among team members’ contributions. With Spin, multiple viewing modes enable prototypes within a project to be unveiled chronologically or side-by-side to support comparisons. Further, comparisons
across distinct projects are encouraged with Spin, as animations from multiple projects can be viewed simultaneously on a user's profile pages. Alternative, non-linear representations and multiple viewing modes flexibly support different patterns of documenting as well. Some BiP users described *documenting-in-action*, where designers share what they intend to do in advance of competing a step and then reflect on its outcome and share their insights after the step is complete. For others, documentation happened after a stage of their project is executable. Providing a range of viewing modes supports varying documentation strategies.

**Re-thinking documentation as modular**

With both BiP and Spin, users repurposed their documentation to appeal to different audiences, whether it was a teacher, their peers, or a potential employer. For example, several users reported including a link to their BiP documentation within their portfolio or resume; while they summarized their final product within their portfolios, they could link to BiP to provide additional detail on how that product came to be. With Spin, users embed their animations on social media, including Instagram, Twitter, or Google+, sharing as much context or textual description as they see fit for a chosen medium and audience. This result, coupled with the goal of reducing the barrier to capturing process, suggests that re-thinking documentation as a modular construction rather than a single comprehensive entity creates opportunities for users to combine and repurpose their documentation to suit different audiences.

The idea of modular documentation has several implications. First, it suggests a refocusing of documentation tools as capturing snapshots that can be returned to and added to, as opposed to "complete" documentation that requires a significant amount of effort to compile (described in *Chapter 2*). Many of the surveyed Instructables users felt that the time to create documentation prevented them from authoring their own tutorials. If documentation is instead modular, it can be added to over time, as done with BiP, thus potentially reducing the documentation load after a project is complete. Second, modular documentation promotes repurposing artifacts to support a wide range of documentation styles. One of the main contributions of this dissertation is broadening documentation to include not just instructions but also stories of process. With both BiP and Spin, I show examples of how expressive documentation enables people to take pride in their own creations while connecting with others.
Reflecting

Community as a context for reflection
Reflection is a core component of evaluating one’s learning experience. With both platforms, reflection was situated in a social context, in which users captured their learning in a community of practice. Reflection became a way to get feedback, share process in order to help others, and simultaneously showcase skills and problem-solving abilities in a public sphere. Users took pride in the documentation they created and described how their documentation would be able to assist others building similar projects. Thus, reflection became a meaningful practice that benefited not only the author themselves, but the community in which the reflection was shared. Incorporating reflections with design documentation, particularly online, opens new opportunities for users to connect with others, motivating documentation practice.

Situating

Leaving space for documentation
Even as automated forms of documentation are implemented, there is still significant value in leaving space for the act of documenting. This space includes both physical space, or visible cues to document, and time, which should be factored into the scheduling of workshops, courses, or other events in which making happens. The physical presence of the Spin turntable, combined with decorations users created around it, signaled to members of a makerspaces that documentation was valued and supported. Even with virtual forms of documentation, digital displays showing Build in Progress projects or Spin animations became a way to showcase projects and highlight process within a space. Finally, educators who successfully integrated Build in Progress and Spin were explicit about leaving time to document and encouraged documentation throughout an activity rather than leaving it solely for the end of an activity. These results highlight that time and space should be dedicated to documentation in order to support its practice.

The design principles shared here are a working set of guidelines rather than fixed criteria. I believe that the space of capturing digital artifacts for physical processes will continue to develop, as more and more of the objects around us become aware of how they are used (the vision of the Internet of Things). This presents interesting oppor-
tunities for furthering automation with documentation. Additionally, as project-based learning and making grow in popularity, there will be even more efforts, from educators, researchers, and designers, to help people share what they create with others, enabling even more varied and diverse ways for reflecting on making.
7. Conclusion

In this chapter, I return to the original research questions posed in the introduction, summarizing the affordances of make-throughs for enabling makers to share and reflect on their process. I end with several directions for future work to further aid with supporting and studying documentation practice.

This dissertation contributes a new form of design documentation called a make-through, in which makers publicly share how a project evolves over time, including the iterations and experiments that shape how a project comes to be. This style is distinct from the dominant format of product-oriented documentation in which only the final product, or instructions for replicating a final product, are shared (as described in an analysis of the Instructables community shared in Chapter 3). Through the design, deployment, and analysis of two novel platforms, Build in Progress and Spin, I explored several dimensions of capturing and sharing process from the perspective of project authors, including youth, adult hobbyists, and educators, ultimately revealing how make-throughs create distinct pathways for getting feedback, reflecting on process, and creatively making with documentation.

Summary

Here, I return to the two original research questions and summarize the ways in which BiP and Spin address these questions and expose new questions to explore through future research.

How can tools be designed to motivate and support the creation of process-oriented documentation?

The ways in which process is visualized played a central role in help-
ing makers organize and reflect on their process. With BiP, authors represented iterations and parallel process through branches in the Process Map. Spin animations capture different angles of a design to more fully represent a three-dimensional physical prototype, and the software stitches animations together to share how a project changes over time. The design of both tools considers how to represent a designer’s process as true to form as possible, encouraging users to include unsuccessful experiments that are important learning experiences.

Spin and BiP provide a social context for sharing design work while enabling conversations on work-in-progress. Through sharing work-in-progress, makers represent their efforts while providing background for others to refer to when leaving feedback and advice.

Finally, the act of creating a make-through involves capturing how a project evolves over time. Thus, designing for ease of capture was especially critical. This led to the development of mobile apps for BiP to aid with adding photos and videos to project pages and influenced the design of Spin to automate the animation-creation process. This ease of capture should be coupled with making the process of documenting engaging in and of itself; through customizing Spin animations by creating backdrops and selfies, makers found playful ways to capture their making.

What role can make-through documentation play in enabling reflective practice?

Reflective practice was evidenced in two ways: through the creation of the documentation artifact itself (reflection-in-action) and through the use of the artifact as an object for external reflection (reflection on action).

The first, in which reflection is embedded within the documentation, was observed through written reflections on BiP where students reflected on making, process, and identity and values (Reflecting in Chapter 4), and through audio descriptions created alongside Spin animations (Celebrating design moments in Chapter 5). Through the act of creating make-throughs, authors reflected on the elements of their process that they wanted to share with others, whether it was specific to their design, or more generally about their perspectives on designing or process of designing. Further, as make-throughs incorporate iterations, reflections often included design rationale, an aspect which may be less prevalent when only sharing the final
instantiation of a design.

Reflection also occurred externally from the platforms, using the documentation artifacts as objects to reflect on. For example, *Situating* in Chapter 4 describes how a BiP project page was used throughout a workshop series to review what had happened in previous sessions and plan for what was happening next. Further, educators often asked children about their creations while Spin animations were underway. In both examples, facilitators played a key role in facilitating reflective conversations using the documentation artifacts as a basis.

**Contributions**

Through BiP and Spin, I expand notions of what constitutes documentation by creating venues for sharing stories of design process. This document begins with an analysis of the established DIY online community Instructables and highlights how elements of process are often edited out of instructional documentation. I also forefront a discrepancy between the tutorial format and ways in which readers personalize and modify the documentation they find.

Based on these findings, I designed two platforms (BiP and Spin) for users to share work-in-progress, and by studying how they were used, I describe the emerging opportunities for supporting capturing, sharing, and reflecting with documentation, as well as facilitator strategies for situating documentation practice. I share how makers use make-throughs to get feedback, share their efforts, and reflect on their learning, all while employing documentation as an expressive medium. I characterize the relationship between time, audience, and resolution in designing documentation experiences. Finally, based on these insights, I share design principles (*Chapter 6* - *Design Principles*) for physical and virtual learning environments supporting process-oriented documentation.

**Future work**

**Analyzing uses of process-oriented documentation**

The scope of this dissertation highlights the perspectives of makers creating documentation. How do readers, in turn, respond to shared make-throughs? Future work can analyze the users of shared
make-throughs, potentially uncovering ways in which parts of make-throughs may be repurposed for new projects (an activity observed with Instructables users as described in Chapter 3).

An original intention with BiP was to support remixing and modding of shared projects, or, in other words, building off of or describing alternative ways of executing different steps within a project. However, I believe that the personal nature of make-throughs may inherently lend themselves less to remixing (which is often done with finished products) and more to other forms of re-use, yet to be studied. A possible consequence of this line of research is determining ways to recommend related projects that use similar tools or techniques as a way to highlight prior attempts and lessons.

Users of documentation may also include the authors themselves if they return to the documentation after some time away from it. Within this dissertation, I largely interviewed users within several weeks of having completed their documentation. How might their perspectives change as they become more distant from the project?

Supporting documentation trajectories

As documentation can serve many different purposes, from personal design journals to outward-facing portfolios to publicly shared work-in-progress, I believe it will be increasingly important to build bridges that can help compile a maker’s full learning trajectory. How do we enable users to customize repurpose work-in-progress make-throughs to create portfolios highlighting essential elements? How can design journals more easily be inserted into make-throughs to aid with sharing?

Spin animations are designed to be embeddable on other platforms, while BiP helps users collect all documentation in one place. Having a multitude of platforms provides users the freedom to choose their audience, which has both benefits and disadvantages – on the one hand, specific platforms enable users to tap into particular expertise, but this often comes at the cost of lack of flexibility with sharing elsewhere.

As making continues to grow in educational settings, the question of connecting documentation across platforms will become increasingly important as a way to aid with assessment and for learners to
showcase their skills and interests in more nuanced ways.

**Visualizing digital and physical processes**

In Chapter 6, I described how technology can play a role in automating aspects of the documentation process. In particular, the digital elements of design, which are beginning to encompass more and more of what we create due to digital fabrication, can already be version-controlled using existing tools. The question, though, is how this digital documentation can be integrated with visual representations of designed artifacts in ways that support sharing, reflecting, and learning.

There are many different ways to address this question. One potential approach is retrofitting existing fabrication tools with digital documentation platforms such that our process of manufacturing is embedded along with our design files, an idea I outlined in [Tseng and Tsai, 2015]. Further, systems may be able to use visual ‘diffs’ of digital design files to emphasize important parameters to others to aid with creating future designs. This is yet another potential area for future work: How can we use the digital data associated with design iterations to bring to light aspects of our design process that we may otherwise be unaware of? What would the fitness tracker of design documentation look like? A first take on this approach is a logging system I have been developing for BiP that enables playback of changes made to projects over time, showing how the Process Map evolves as projects are developed. This logging mechanism may further shed light on strategies for when and how to document that can inform design education, particularly novice designers learning to document.

**Epilogue: Documentation as 'part of me'**

In the Summer of 2015, I volunteered at a local makerspace for eight weeks, assisting high school students learning about the entire workflow of digital fabrication, from creating 3D models using digital modeling to laser-cutting prototypes in the shop. As their designs manifested in physical form, several teens were introduced to Spin to capture their prototypes. One teen, Jewel, shared how her “sharkbox” was modified to include a lid with holes, enabling users to decorate it
with their own design (Figure 85).

After the summer workshop had completed, I sat down with Jewel to learn about her documentation experience. When asked about any prior experiences with documentation, she told me that her only experience was creating lab reports in science class, which she never shared outside of class: “I never needed to yet.” In contrast, she proudly described how she shared her Spin animations:

I messaged it to my friends and was like, “Look at this!” I wanted other people that I don’t really know to see it. I post my whole life on Instagram, so this is a big part of me now.

When I asked her to clarify what she meant by ‘this,’ suggesting the after-school makerspace, she replied:

Yes, and the box because I really like it. I put a lot of time into it, and I like it a lot, so it’s part of me.

Our conversation continued as she excitedly shared other ideas she had for using Spin:

I’d use it to show the evolution of something, or a plant...oh my goodness. If you had a plant as it was growing, that would be so cool. Oh my gosh. Anything that evolves and changes gradually. That’s what I would use it for.

She closed by describing her overall impressions of Spin, stating,

I think it’s really cool. I like the whole phone thing that it just connects with your phone and starts spinning. I just love the idea. The way it turns and you can see it changing. And I just have the video on my phone.
For me, this quote highlights my ultimate goal with creating documentation tools: to enable makers to share their experiences in meaningful ways. The pride that she had, not just for what she created but the process by which it was improved over time, exemplifies how make-throughs can support identity-building; as Jewel stated, the box and her experience become a “part of me,” and her make-through became a vehicle for sharing this with the world.
Appendix A: Instructables Survey

The following online survey was distributed through university mailing lists and on the Instructables forum in the Fall of 2011. In total, 230 users responded to the survey.

Read more about the results of this analysis in Chapter 3: Findings
Instructables User Survey

This survey is part of a research study on the use of online project documentation, particularly use of the Instructables site. If you have any questions, please email ttseng@mit.edu.

* Required

How often do you use the Instructables site? *
- Multiple times a day
- Once a day
- Multiple times a week
- Once a week
- Multiple times a month
- Once a month

Which categories of Instructables projects have you looked at? *
- Food
- Living
- Outside
- Play
- Technology
- Workshop

Have you ever recreated an Instructable? *
- Yes
- No

If so, can you describe your process?
Did you change any steps? Was any information missing from the Instructable that made it hard for you to recreate it? Did you personalize your project?

Have you ever applied part of an Instructable to one of your projects? *
Example: Looking at an Instructable to learn how to solder and applying tips from the Instructable to your own project.
- Yes
- No
If so, can you describe what you used and how you applied it?

Please rank, in order of importance, the reasons why you look at Instructables. *
1: Most important, 3: Least important

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To look for projects I want to recreate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>To learn a particular technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>To get ideas for projects</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Any other reasons you use Instructables?

Have you ever authored an Instructable? *
- Yes
- No

If so, how many Instructables have you published?
- 1
- 2-5
- 5-10
- >10

If you haven't, what prevents you from writing one?
What other sites do you commonly use to look at projects / get project help? *

- Sparkfun
- Lynda
- Stack Overflow
- Wiki How
- Dorkbot
- Adafruit
- Craftster
- Ravelry
- None
- Other:

What is your age? *

- <18
- 18-22
- 22-30
- 30-40
- 40-50
- 50-60
- >60

What is your gender? *

- Female
- Male

Any other thoughts?

If you're interested in participating in future studies, please leave your contact information (name and email address).

Submit

Never submit passwords through Google Forms.

Powered by

This content is neither created nor endorsed by Google.

Report Abuse - Terms of Service - Additional Terms
Bibliography


[Blikstein, 2013] Blikstein, P. (2013). Digital fabrication and mak-


cookbooks: A recipe for sharing. In DIS. ACM.


157

rss. [Online; accessed 26-March-2016].


