



Digital maker-entrepreneurs in open design: What activities make up their business model?



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Abstract The business models of digital maker-entrepreneurs in open design are inextricably linked to the broader open design community. Digital makers share designs on online platforms such as Thingiverse and use digital manufacturing technology such as 3-D printing as a generative mechanism for their entrepreneurial activities. There is a general understanding of how sharing works in that community and the basic design parameters that determine the business models of these digital maker-entrepreneurs, which are based on a portfolio of activities. This study is based on in-depth interviews with 11 digital maker-entrepreneurs from the open design community. We investigate the activities that constitute their business models using activity theory as a lens with which better to understand them. This study provides a perspective on the complexity of the relationships in which these activities are embedded and analyzes the activities related to the production, distribution, and consumption of value. Finally, we examine the exchanges between digital maker-entrepreneurs in the community, shedding light on how digital maker-entrepreneurs share and exchange goods, services, and knowledge as peers.

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1. Digital maker-entrepreneurs in open design

The combination of accessible digital manufacturing technology with the connectivity of the internet serves as a powerful generative mechanism for recreational, educational, and entrepreneurial

activities. These activities have become known as the *maker movement* (Dougherty, 2012). Members of the maker movement are seen as “high-tech do-it-yourselfers, who are democratizing access to the modern means to make things” (Gershenfeld, 2015, p. 48). When they engage in entrepreneurial activities, we call them *digital maker-entrepreneurs*. Maker culture is based on the three principles of learning: hands-on creation, transdisciplinary collaboration, and sharing (O’Duinn, 2012).

In this article, we investigate the activities that constitute the business models of digital

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maker-entrepreneurs. To do so, we first elaborate on the concept of digital maker-entrepreneurs and the environment of open design in which they interact and share designs. We also briefly acknowledge the scholarly discussion around business models and explain our understanding of a business model as an activity system—introduced by Zott and Amit (2010). Then, we discuss an initial, high-level study of the business models of 11 digital maker-entrepreneurs and the particularities we found in these cases drawn from subject interviews. Following this, we introduce activity theory (Blackler, 1993; Engeström, 1987, 2000) as a different perspective on business models that allowed us to analyze them in more detail. Loosely following this perspective, we present three typical but contrasting cases for inclusion in this article: a couple with a web store, an entrepreneur in retail 3-D printing, and an incidental 3-D printing intrapreneur. In closing, we run a cross-case analysis and relate the detailed case descriptions to our earlier findings to create a rich picture of how digital maker-entrepreneurs shape the activities that make up their business models.

1.1. Digital maker-entrepreneurs

While the majority of digital makers mainly engage in leisure and educational activities, some of them turn a hobby into a business and become digital maker-entrepreneurs. In this study, we are particularly interested in digital maker-entrepreneurs who embrace the maker culture of co-creation and sharing. As Wolf and Troxler (2016) have shown, maker business models are inextricably linked with the wider maker community. They publish blueprints of designs on online platforms such as Thingiverse and YouMagine that offer the blueprints free for download and replication. They sell their goods on Etsy or eBay, or they promote their capabilities in designing and 3-D printing on brokering platforms such as Makexyz and 3D-Hubs.

1.2. Open design

There is a general understanding of how sharing works in the maker community (for a summary, see Wolf, Troxler, Kocher, Harboe, & Gaudenz, 2014). Digital makers share the blueprints of their designs online for others to reuse and repurpose. This is also known as *open design* (van Abel, Evers, Klaassen, & Troxler, 2011). Berlin designer Ronen Kadushin, a pioneer of open design, characterized the generative mechanisms of open design as twofold: (1) sharing digital design files on the internet under a permissive license and (2) being able to manufacture those

designs directly from the files without the need for specialist tooling (Troxler, 2011).

This corresponds to the way digital makers operate. With regard to business models, Cruickshank (2014, p. 23) noted that open design:

Includes models based on giving things away (free revealing), mass participation in design, co-creation and a range of other approaches that seek to develop new open methods of creativity . . . not necessarily based on conventional business models and a market economy.

2. Fundamentals of a business model

A business model, in its most high-level definition, describes how a firm creates, delivers, and captures value (e.g., Osterwalder, 2004). That said, there is no general agreement concerning definition, as Zott, Amit, and Massa (2011) found. The concept is developed in silos according to the specific interests of researchers. Zott et al. (2011, p. 1038) offer a minimal definition of a business model from an activity system perspective: “a systemic perspective on how to ‘do business,’ encompassing boundary-spanning activities (performed by a focal firm or others), and focusing on value creation as well as value capture.” While most business literature treats value as purely economic, this concept has been extended in various contexts to cover multidimensional value creation, including open design (Pekkola, Hirscher, & Fuad-Luke, 2013) or sustainability business models (see, for example, Schaltegger, Hansen, & Lüdeke-Freund, 2016; Stubbs & Cocklin, 2008).

2.1. The business model as an activity system

Zott and Amit (2010) defined an activity system as a set of interdependent organizational activities centered on a focal firm. These activities include those conducted by the focal firm and also its partners, vendors, or customers. The firm’s activity system transcends the focal firm and spans its boundaries. The system’s focus will remain firm centric in order to enable the focal firm to appropriate a share of the value it created together with its partners.

To analyze the business model as an activity system, Zott and Amit (2010) suggested two lines of inquiry. The first line concerned “the social aspects of relationships between business model participants, as well as the transactional dimension of their relationships” (Zott & Amit, 2010, p. 224).

The authors listed the three design elements—content, structure, and governance—to describe what a firm does (producing products and services in addressable market spaces), how the firm carries out what it does (linking factors of production and upstream and downstream markets), and who actually does it and where (internally and externally to the firm, thus including partners, suppliers, and customers). The second line of inquiry addressed “what goes on within the ‘black box’ of activities” (Zott & Amit, 2010, p. 224), the micro-mechanisms of the business model that “orchestrate and connect the elements of an activity system,” particularly “the system’s dominant value creation drivers” (Zott & Amit, 2010, p. 221). The authors called these *design themes* and labeled the four common ones: novelty, lock-in, complementarities, and efficiency.

3. Studying business models

Existing studies provide limited empirical insight into which activities form the business models of digital maker-entrepreneurs. We decided to use a qualitative multiple case study to shed some light on this question. Qualitative research helps to study complex phenomena when there is little or no previous research available.

3.1. Selecting cases

The cases involved in a multiple case study must include informants who are able to provide essential insights to answer a research question; this is called the *pivotal target group*. We derived our sample initially from the Thingiverse community, a community of digital makers who share their designs online via the Thingiverse platform, often for free reproduction. The sample of users was refined in a sequence of five steps.

- *Step One:* We used snapshot data of activities of users on the Thingiverse platform (Moilanen, 2013). From this dataset, we identified about 60 Thingiverse users whose designs were reused the most.
- *Step Two:* We extracted those users who also had their own company related to 3-D printing, which left us with 25 users.
- *Step Three:* We analyzed the information that was available from their Thingiverse user profiles and their corresponding company websites. This led us to a list of five salient business models: participation in commercial online platforms,

web shop, printer retail, customized prototyping, and research and education.

- *Step Four:* We deemed it necessary to hold at least two interviews per business model to capture variation, so we approached three digital maker-entrepreneurs per category; out of these 15 we were granted eight interviews.
- *Step Five:* We enlarged the sample by using the snowball sampling method, asking interview partners to recommend others who ran similar companies. This allowed us to identify three more cases.

This sampling strategy allowed us to arrive at a sample of manageable size that would still provide maximal business model variation.

3.2. Gathering and analyzing data

To collect data, we carried out a document analysis of the users’ Thingiverse profiles and their corresponding company websites. To expand this information, we interviewed the digital maker-entrepreneurs, asking them to describe the development of their enterprises from idea to business and inviting them to reflect upon their business model and its underlying activities. Interviews were held in April and May 2014 and lasted between 24 and 79 minutes. They were recorded and then transcribed, which resulted in a 146-page transcript.

This transcript was analyzed in several steps by two researchers to find meaning and identify patterns. In a first pass, we used the framework of Zott and Amit (2010) to identify the design elements and design themes of the business models. Two researchers coded the data individually. These findings were then discussed, reconciled, and refined into a common interpretation of the individual cases. Then, we compared the data across cases.

We provide a top-level summary of the results of this investigation below. The detailed results can be found in Wolf and Troxler (2016).

3.3. Business model portfolio

Already from the top-level sample description (see Table 1), it became evident that except in two cases the digital maker-entrepreneurs used several of the salient business models we had identified.

3.4. Mostly traditional design elements

Looking deeper into the business models as activity systems, their content, structure, and governance

Table 1. Salient business models and specific offerings

Case No.	Salient business models of digital maker-entrepreneur	Specific offerings
1.	Web shop; commercial online platform	Custom 3-D printed smartphone cases
2.	Web shop; commercial online platform	3-D printed open source design based objects
3.	Web shop	3-D printed design based objects and fan ware
4.	Prototyping; 3-D printer retail	Personalized merchandise, art performances, 3-D printers
5.	Prototyping; commercial online platform; research and education	Industrial prototypes and fan ware, courses
6.	Web shops; research and education; commercial online platform	Technical parts of 3-D printer (nozzles), courses
7.	Prototyping; commercial online platform; research and education	Neurobiological devices, 3-D objects for educational purposes
8.	Research and education; prototyping	Open Worm project, 3-D objects for educational purposes, courses
9.	3-D printer retail; research and education	3-D printer and services (training and tech support)
10.	Prototyping	Product prototypes for industry
11.	Prototyping; commercial online platform	3-D design objects and design exhibitions

consisted mostly of traditional elements that one would expect to find in other more conventional businesses. Rather unsurprisingly, we found new governance elements such as fairness, reciprocity, and sharing; however, not all digital maker-entrepreneurs applied these governance elements (see [Table 2](#)).

3.5. Innovating design themes

The main design theme used by the digital maker-entrepreneurs in our study to orchestrate their business models was novelty. 3-D printing had just arisen as a new manufacturing technology and was perceived to generate novel business opportunities of which the digital maker-entrepreneurs intended to make a profit. There emerged a couple of new design themes, too, which were rooted in the paradigm of sharing within the Thingiverse community:

altruism and hedonism. Altruism was identified as an imperative of giving back to the original authors or the community at large. Hedonism was understood as enjoying an outstanding reputation within (a section) of the community (see [Table 3](#)).

3.6. The question remains: How do they do it?

The analysis of the design elements and design themes hence revealed three facts about how digital maker-entrepreneurs innovated business models in an unconventional way: First, all but one of the digital maker-entrepreneurs operated a portfolio of several of the salient business models. Second, design elements included fairness, reciprocity, and sharing with the community as governance principles. Third, altruism and hedonism appeared as dominant value-creation drivers (design themes).

Table 2. Design elements used in salient business models

	Content (what)	Structure (how)	Governance
Commercial online platform, N = 4	platform, supply & demand	information exchange	facilitate, escrow, fulfilment
Web shop, N = 5	display, shopping	off-the-shelf technology	owner controlled, kick back (fairness)
3-D printer retail, N = 2	stock/sales of printers & supplies	retail shop	owner controlled
Customized prototyping, N = 6	prototypes, uniques	modeling, scanning, printing	owner controlled
Research and education, N = 6	courses, artifacts, engineering	ad hoc	knowledge sharing, reciprocity

Table 3. Design themes used in salient business models

	Novelty	Lock-in	Complementarities	Efficiency	Other
Commercial online platform, N = 4	✓			✓	
Web shop, N = 5	✓	✓			altruism
3-D printer retail, N = 2	✓		✓		
Customized prototyping, N = 6	✓	✓			altruism
Research and education, N = 6	✓	✓			altruism/hedonism

4. Digging deeper into business activities

Still, the question about what constituted the business models of digital maker-entrepreneurs in open design was not fully answered. While the activity system approach allowed us to partly unveil what went on “within the ‘black box’ of activities” (Zott & Amit, 2010, p. 224), we deemed the analysis was not enough to understand the micro-mechanisms of the business models we encountered in terms of the activities that comprise them.

4.1. Adopting a different lens: Activity theory

Working with the data on 11 digital maker-entrepreneurs from our earlier study, we decided to approach it with a new lens—the lens of activity theory (Blackler, 1993; Engeström, 1987, 2000) as suggested by Zott and Amit (2010). The framework of activity theory stipulates that an activity system serves a specific objective that creates a certain outcome.

The framework—customarily depicted with a set of interlocking triangles as in Figure 1—features, at its core, the crucial link between subject and object. Subjects collectively act toward the objective by employing tools, techniques, and

instruments—durable cultural artifacts. This activity is part of a social process, shaped by its context and shaping this context. Agency, thus, is not only located in the subjects but can also be found in the context in the form of formally appointed functional groups (division of labor), stabilized procedures (rules), and loose networks of people (community).

To gain access to an activity theory perspective on the business models of digital maker-entrepreneurs, we analyzed the cases from the interviews again using the elements of activity theory (see Figure 1) as our categories for coding. Finally, we again compared the analysis across cases.

5. Retail, innovation, and intrapreneurship

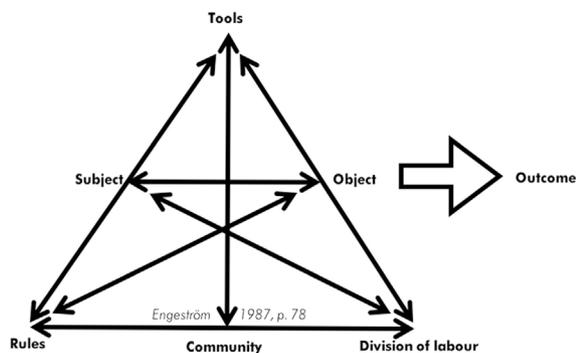
From the 11 interviews we conducted, we selected three for inclusion in this article: Claire and Stef (and Henry), a couple who principally run a web shop; Michael, a serial entrepreneur in 3-D printing; and Andy, an engineer who happened to become a 3-D printing intrapreneur and innovator. All three cases happen to be based in the U.S. These cases were selected because they represent typical but different business models that allow contrasting.

5.1. Case 1: Claire and Stef (and Henry)

5.1.1. Subject

Claire and Stef are a couple in their late twenties, she with a background in science and he “an engineer at heart.” They started their web shop for 3-D printed fan art, puzzles, and jewelry as a hobby shortly after they got their first 3-D printer. They initially “set up an Etsy shop on a whim,” which over the span of 2 years became a full-time activity: manufacturing items, regular maintenance and repair of the printers, finding events to sell their merchandise, and fulfilling orders from the web shop. They worked “at least 6 days a week on average.” Since there was more work than they could handle themselves, Claire and Stef started to work with Henry, a friend of Stef. Henry had a

Figure 1. The framework of activity theory



Source: Engeström (1987)

background in electronics and was “someone who loves to work with his hands and tinker.”

5.1.2. Object

Initially, they curated their products from Thingiverse, copying and modifying the designs “to make something into a product by adding a magnet, jewelry holes, etc., or to make it more reliable to print.” Over the years, they developed the capability to design their own products, which included “fan art for games and shows we admire and enjoy.” Claire and Stef tried to pick products they found interesting or fun: “If we wouldn’t buy it, we aren’t going to sell it.”

5.1.3. Tools

They sold their products online through the web shop platform Etsy and on Amazon, as well as in-person at local events such as craft fairs and Maker Faire. They also offered special 3-D printing services for prototyping and small-scale manufacturing. They acquired these jobs through brokering platforms such as Makexyz and Kickstarter. They planned to expand into teaching workshops and classes involving 3-D printing.

To manufacture their products, they used a range of seven 3-D printers: an UP! Plus, an UP! 2, two UP! Plus Minis, a MakerBot Replicator, a Rostock Max, and a PrintRBot. They preferred the UP!s for their ease of use. The MakerBot offered a larger build area that determined the maximum size of products the machine could print, and it had the capability to print two different materials so an object could actually have two different colors. The Rostock Max had an even larger build area.

5.1.4. Division of labor

Claire, Stef, and Henry had divided responsibilities among themselves. Claire “pretty much handle[d] the ‘business’ part of [the] business”—accounting, purchasing, finding events, and maintaining the listings on Etsy and Amazon. Stef managed the printer operation, maintenance and repair, and most of the design work. Henry helped with manufacturing, maintained the social networking, and was “an awesome salesman.”

Claire and Stef shared communication and shipping evenly. They strictly followed the rules of copyright and the Creative Commons licenses that people used when publishing designs on Thingiverse. They did not use any designs that were marked as non-commercial except for one for which they explicitly got permission to use from the rights owner. They attributed all designs to their corresponding owners on their Etsy page and with every order shipped. Their own designs were released

under licenses that required attribution only or attribution and sharing alike (i.e., under the same conditions).

5.1.5. Community

Claire and Stef were active members of the Thingiverse community. Not only did they use existing designs from the community, but they also contributed to it themselves by publishing their own designs. On top of that, they informed the designers of the objects they were selling about their business.

5.1.6. Rules

Claire and Stef were actually inventing new rules. They started a revenue-sharing program where the last (or in some cases the major) designer of an object they sold received a percentage of the profits from sales. Some designers, however, opted out of this program. Claire and Stef established the revenue-sharing program because they:

Liked to give back to those who made these items possible in the first place, and wanted to set up a medium by which people were encouraged to leave their designs open for commercial use without having to actually build and sell the items themselves.

5.2. Case 2: Michael

5.2.1. Subject

Michael was only 22 at the time of our interview, but he already had an extensive background in 3-D printing, particularly the software side of it. He contributed to several open source software projects related to 3-D printing. One was an alternative, improved firmware for the MakerBot 3-D printer, and the other was a piece of software that allows users to scan objects or people with a Kinect and create a printable 3-D model from it. He also created tutorial videos explaining the scanning workflow.

Michael described himself as “an entrepreneur of sorts.” For instance, he was using the scanning technology to create 3-D printed figurines of visitors at galleries and art exhibitions. And he was “making definitely some good money at galleries and exhibitions.”

Michael spent time as an intern at MakerBot Industries and when that concluded, he wanted to start his own 3-D printing shop with an artist friend. Yet, as there was another similar initiative in the same city, they decided to join that other venture instead. The other team consisted of three people—an entrepreneur, an educator, and a graphic designer. The other group’s idea was a basic one:

to open a retail shop for 3-D printing. Michael brought more robust technical experience to the team, and his artist friend added yet another perspective to the venture. Together, as Michael recalled, they “were able to use everybody’s idea to create a more well-rounded product, which was in the store.”

5.2.2. Object

Their offerings included advice on and sale of consumer-level 3-D printers and corresponding consumables such as filament. The store also offered 3-D design services, including web applications where customers could configure their own designs, classes offered on location where they would educate customers in 3-D designing, and service contract work. They also had a 3-D scanning booth and sold 3-D printed objects created by local and international artists.

Michael recalled one particular episode when a 12-year-old child visited the shop and asked them to reproduce an old Fisher Price toy that was out of production. He said:

We sat him down on the computer, taught him how to use the software . . . He redesigned his piece and printed it out on our machine. And he couldn’t have done that anywhere else in the world . . . he was able to do that for himself for \$20. So, that’s a great educational experience for a kid, but it also shows the real power of having our storefront and having the service side of it, which is really a powerful tool. So, it was really about not having just passive consumers, just going into a shop and buying something. We really wanted . . . active creators.

The company also worked for commercial clients, creating mass-customized marketing objects like key chains or mugs. Some of these included 3-D printing and assembly, while others involved a web application with which the recipients could individually customize the items.

5.2.3. Tools

To manufacture their products, they mainly used MakerBot 3-D printers. But they also had access to a professional grade 3-D printer, “bringing in the world’s first industrial 3-D printer accessible to the public.” Michael also brought his 3-D scanning experience into the shop, where they built a spinning platform on which they would place people to scan them. This “looked really cool and futuristic and gave the customer a really great experience of being involved with technology.” They also used web technology for customers to commodify

and customize standard designs into personalized items.

5.2.4. Community

According to Michael, the 3-D print shop operated almost as a small community: “It did feel at times like almost an open source project because everybody had such different perspectives that it really created a stronger model.” The 3-D print shop also attracted a wider community of active creators, some of them developing prototypes or having prototypes built that were used for crowdfunding campaigns on Kickstarter. This community appeared to be the main business driver indeed.

5.2.5. Rules

From his past when he was involved in software development, Michael appeared to obey the rules of open source software development quite naturally. For example, he decided to join a strong team to make it even stronger instead of opting for competition in a developing but probably still small market.

Michael has since left the 3-D print shop and moved to a different city where he started to provide 3-D prototyping services in more industrial applications such as medical or automotive and hopes to fulfill that “big nerdy dream: 3-D printing parts for a space shuttle.”

5.3. Case 3: Andy

5.3.1. Subject

Andy was a 55-year-old mechanical computer-aided design (CAD) engineer by profession and had worked in the computer manufacturing industry for several decades. He called himself a “CAD junkie,” owning “a copy of every CAD program known to man.” Next to his formal job, Andy had a history of running his own home businesses. Some of them included CAD work for clients. Others were more firmly in the world of fan art, such as airbrush designed t-shirts of Teenage Mutant Ninja Turtles, phone cases, and other ventures. Andrew described himself as a “sci-fi fan, a comic book fan . . . a fan of everything.”

5.3.2. Object

Andy bought a 3-D printer when they became affordable and brought it into work. “I had every manager and every engineer come through my office, marveling at it,” he said. The company immediately adopted the technology to produce early prototypes so they could detect design errors early. This could save weeks of time waiting for metal parts and several hundred dollars.

One of the first projects Andy printed was the space ship Jupiter 2 from the series *Lost in Space*. Andy had drawn a complete 3-D model of the ship, often at work during lunch and other breaks, which took him about two years. When he got the printer, he decided to print the model and he posted the pictures on Thingiverse. However, as he did not post the design files, he got harshly attacked by other Thingiverse users and eventually decided to pull the photos from the site. However, he got contacted by someone who wanted to build a life-size copy of the ship and Andy sold him the model and a copy of the CAD files for about \$300.

5.3.3. Tools

Being a CAD junkie, Andy also disassembled the printer completely, measured up all the parts and drew a 3-D model of the machine. This enabled him to start improving the machine whenever he thought something was designed badly.

5.3.4. Division of labor

Andy would have the machine shop at work to produce the parts—they would do it for free as they would be using the improvements for their printers as well.

5.3.5. Community

Andy would also post the design files of the improved parts on Thingiverse, “out of the goodness of my heart.” When another user of the same printer model posted images of the same object printed before and after installing the improved part, Andy quickly got orders for that part, even though it cost \$200 to manufacture—which, before seeing the actual results, people found way too expensive.

Andy’s improvements were also picked up by the manufacturer of the 3-D printer, who implemented them in a revised manner into the machine. This led to a significant improvement of the print quality and sales of the printer increased. As a reward for his contribution, Andy received VIP tickets to the Maker Faire and other shows and he got free plastic filament for printing.

At the Maker Faire, Andy would spend a whole day in the hall dedicated to 3-D printing, where virtually every 3-D printer manufacturer would be showcasing their machines. However, as an experienced mechanical engineer, he was slightly at odds with the industry and found some of the printer designs outright “hideous . . . designed by young kids who’ve just come out a college and really haven’t had the experience I’ve had with real world where you have to build something that builds twenty million things in, you know, a month.” So, Andy was rather unpopular with many

manufacturers: “Because I walk up and I point to their design and I say why did you do that, that’s terrible, that’s gonna fail.” Andy felt that the industry would need to make their products more robust and that they would need to bring in engineers to help design the machines.

5.3.6. Rules

Andy was familiar with the general rules of online communities from his airbrush experience. However, he had to learn the more specific rules of Thingiverse, where one is supposed to share design files and not just photos of one’s achievements. He also had trouble blending into the less engineering-minded field of the 3-D printer manufacturers who frequented Maker Faire.

Andy never decided to join any of the web shops, partly because he thought that many of his designs were too specialist, made for his own private purpose. Partly, he also disliked to promote himself and to directly interact with clients and he was not prepared to give up a well-paid job: “Why would I wanna give up that to do something that, you know, may or may not make me some money—in most cases will frustrate the heck outa me because I’m dealing with clients?”

6. Designing a digital maker business model

6.1. Basic business model elements

Along with the elements of the framework of activity theory, we attempt to distil some basic insights in to how digital maker-entrepreneurs design their business models—a summary of which is presented in [Figure 2](#).

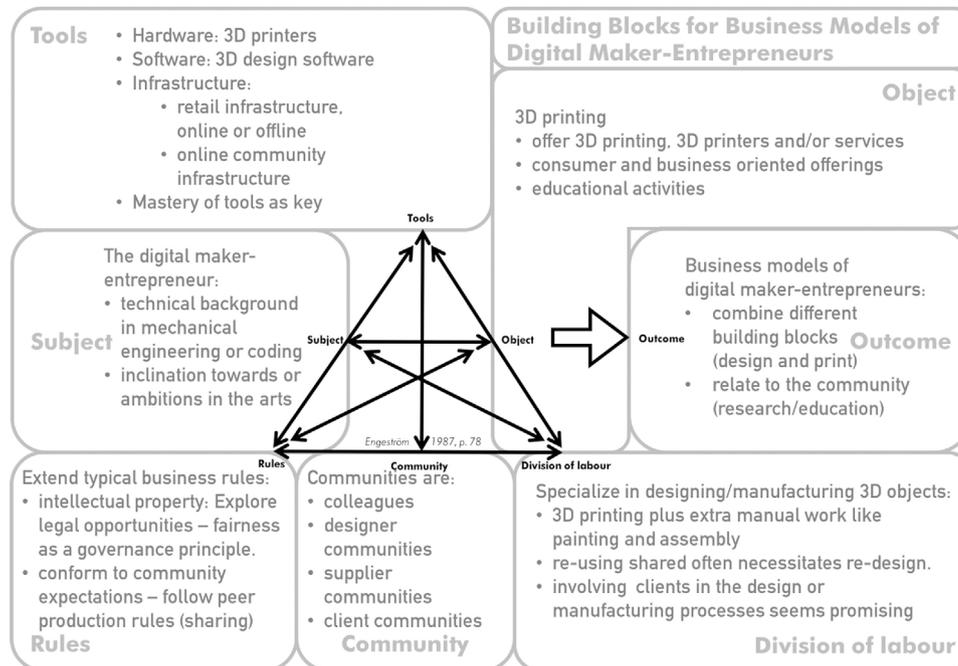
6.1.1. Subject

The business model of any digital maker-entrepreneur starts with the subject of the entrepreneurs themselves. Extrapolating from our sample, some technical background in mechanical engineering or coding appears to be useful. Additionally, participants have some inclination toward or ambition in the arts—producing artworks themselves, even if only fan art, or working closely together with artists seems to be an asset.

6.1.2. Object

Our case studies are limited to 3-D printing, which includes offering 3-D printed objects, selling 3-D printers, and providing 3-D printing services. Offerings can include business-to-consumer and business-to-business propositions. Typically, a combination of

Figure 2. Building blocks for business models of digital maker-entrepreneurs



both seems to be favorable, particularly as business-to-business transactions appear to be an easier source of revenue. A point of consideration is to include some kind of educational orientation. The resulting business model will center on a portfolio of offerings rather than a standalone proposal.

6.1.3. Tools

Quite obviously, the main tools of digital maker-entrepreneurs are 3-D printers, 3-D design software, and some retail infrastructure that is either online or offline. Some online community infrastructure can complement the tools if that line of business is to be emphasized (see Section 6.1.5.). The mastery of these tools is key to business success as interviewees stressed that actually designing objects for 3-D printing is not always straightforward and can take a lot of time (for instance in the case of Andy and his Jupiter 2 model). You cannot just hit print; “an easy-breezing manufacturing process . . . is absolutely not the case,” as Claire and Stef explained.

6.1.4. Division of labor

Digital maker-entrepreneurs would likely want to specialize in designing and manufacturing 3-D objects that would include 3-D printing and often some extra manual work like painting and assembly. Reusing shared designs would often require some redesign. Involving clients in the design or manufacturing processes seems promising, which Michael demonstrated with the web applications that he used to facilitate mass customization.

6.1.5. Community

It appears that the notion of community should receive special attention throughout the business model of digital maker-entrepreneurs. In the relationships with design communities, such as the one on Thingiverse, aspects of altruism and hedonism play a certain role. Moreover, entrepreneurs might consider working with suppliers as some sort of community relations. The interaction with clients can also be developed in a community spirit, as our cases demonstrated with Cindy and Stef selling at arts fairs, Michael facilitating a community of active creators, or Andy working with his own contacts in the engineering world. Finally, digital maker-entrepreneurs likely consider community aspects in a way that is similar to how they work with colleagues within their businesses.

6.1.6. Rules

The cases show that typical business rules—such as dealing with intellectual property, pricing, and revenue generation—remain valid but need to be extended. The discussion of intellectual property includes exploring the boundaries of legal opportunities such as reusing only designs that are officially labeled for reuse, adding to and modifying designs in order to introduce some amount authorship, and working in the area of fan art, which is considered fair use and thus not infringing on copyright. This is an expression of the notion of fairness as a governance principle. Furthermore, good community behavior and dealing with the implicit and explicit expectations in these communities is

important. These expectations, for instance, concern the field of peer production. Sharing one's own designs according to the rules of the community and the revenue-sharing program of Cindy and Stef were examples of following and implementing the community governance principle of reciprocity.

7. En route to understanding digital maker-entrepreneurs

Activity theory helped us to create a much richer picture of the activities that make up the business models of digital maker-entrepreneurs than the initial, higher-level activity system perspective. We shed some light on what activities constituted the business models of digital maker-entrepreneurs, particularly how they shaped their business model portfolios and how they implemented the community-related governance principles of fairness and reciprocity.

7.1. Can digital makers actually be profitable?

The crucial question, however, is this: Can digital maker-entrepreneurs actually be profitable? Revisiting our sample of 11 digital maker-entrepreneurs in April 2017 (3 years after the initial interviews) we observed that six of them were still in business, including the three we analyzed in greater depth in this article. As a matter of fact, Andy eventually quit his job to start a 3-D business himself. Four entrepreneurs from our initial sample have discontinued their business activities. For one business, the information was inconclusive. On that level, the answer would be a yes—digital maker-entrepreneurs can actually sustain their businesses.

The analysis presented above sheds some light on how digital-maker entrepreneurs shape their business models. For all cases that survived, their current business model combined different building blocks, often the combination of 3-D designing or modeling and 3-D printing. From our data, it was evident that the 3-D-modeling skills formed a unique proposition. The cursory analysis of the surviving businesses showed that 3-D modeling was something most of them offered quite prominently on their websites.

Another recurring element our data showed in the business models was some kind of relationship to the community. Our data showed this already in the top-level analysis of the business model portfolios in which aspects of fairness, reciprocity, and sharing were identified as governance elements. The previous in-depth analysis of the three cases

illustrated how digital maker-entrepreneurs shaped their community relations differently. Unfortunately, the cursory review of the surviving businesses did not allow us to analyze in more detail how they developed this aspect over the years.

In conclusion, we still consider our results preliminary, particularly because we were more interested in the diversity of how digital maker-entrepreneurs built their business models than in firmly establishing common patterns. There are several routes to expand on our initial research. One route would be to revisit some of the cases in more detail and investigate how the activity systems developed over time. Another route would be to gather more evidence for the findings. A third interesting route would be to investigate how we could translate the provisional findings into a more generative instrument and use it in an action research-oriented approach.

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