The emergence of new networked business models from technology innovation: an analysis of 3-D printing design enterprises

Cabirio Cautela · Paola Pisano · Marco Pironti

C. Cautela
Politecnico di Milano, Via Durando 38/A, Milan 20158, Italy
e-mail: cabirio.cautela@polimi.it

P. Pisano (✉) · M. Pironti
Università degli Studi di Torino, Corso Svizzera 185, 10149 Torino, Italy
e-mail: pisano@di.unito.it

M. Pironti
e-mail: pironti@di.unito.it

Introduction

The strategic relevance of design and the different ways in which design can be employed to gain competitive advantage came to prominence in the mid-1980s (Kotler and Rath 1984; Lorenz 1986; Dumas and Mintzberg 1989; Walsh 1996). Considerable ground has since been covered in design studies, and design management has become an important topic that has been explored from a number of perspectives and in various disciplines. Whether as a means to radical innovation (Verganti 2006, 2008, 2009), as a tool to manage strategic renewal (Ravasi and Lojacono 2005), as a way to establish new forms and new languages in technology breakthroughs (Hargadon and Douglas 2001), or as a bridge to transfer technology among sectors (Hargadon and Sutton 1997), design has increasingly been regarded as a lever for value creation.

Across the different bodies of literature, the role of design management has typically been analyzed according to the classical Fordist industrial paradigm: a manufacturing company engages designers (Bruce and Jevnaker 1998; Bruce and Bessant 2002; Capaldo 2007; Dell'Era and Veganti 2010; Cautela and Zurlo 2011) with the aims of differentiating its value proposition, creating innovative product languages and meanings, and changing the competitive rules (Verganti 2009). Under this framework, designers are "interpreters" (Verganti 2003, 2008) of socio-cultural factors who translate the vision, research, and innovative features proposed by manufacturing companies into workable models.

The emergence of an innovative technology, 3-D printing, appears to be having a strong impact on the business model of design enterprises and on the manufacturing system as a whole, increasingly conferring on designers a more central role within these industrial systems. Despite studies describing the main features of 3-D printing technology and its likely future pervasiveness (e.g. Berman 2012; Gobble 2013), there is a paucity of research to show how this technology may be embedded in a business model. In this paper we describe and critique the main features of the business models that have been adopted by 3-D printing technology-based design enterprises. The research questions that we address are: What are the main elements of the business models adopted by design enterprises that use 3-D printing technology, and how do the features of this technology interact with and shape the 3-D printing industry's business models?

Our analysis is framed on the concept of the open business model (Chesbrough 2006) given that 3-D printing enterprises rely heavily on external sources of creativity. Qualitative case studies have been developed on three organizations, two new ventures and an established firm. Based on our insights on processes of 3-D printing in these businesses we develop propositions on the relationship between radical technological innovations and the consequential changes to industry business models. A discussion follows that draws links between each proposition and emerging production and economic trends.

A technological innovation: 3-D printing

Few studies in management or design have focused on 3-D printing manufacturing technology, despite this technology having permeated other bodies of literature such as healthcare, material science, physics engineering and manufacturing. Writers in these and other sectors who have engaged with this technology (Petrović et al. 2011) have examined the technical aspects related to material experimentation (Sachs et al. 1990) and the integration between CAD systems and prototyping.

Some of the technical aspects of 3-D printing include (Berman 2012):

- The complete integration of printing with Computer Aided Design (CAD) software that enables a fully integrated design-cum-production activity (this includes the possibility of sharing the technical codes of the product via the web and reproducing it in different places and with different printers);
- The possibility of using different types of materials on the same printer (aluminum, stainless steel, titanium, polymers, ceramics, etc.);
- The option to personalize products based on customer preferences, and perform product modifications by simply making some adjustments using CAD software;
- The reduction of inventory risk and the need for inventory management thanks to 3-D's ability to print desired artifacts on demand; and
- The reduction of materials and wastage in producing a single product unit.

In a recent article examining the characteristics and applications of 3-D printing compared to mass customization and other manufacturing processes, Berman (2012) suggested that "*3-D printing employs an additive manufacturing process whereby products are built on a layer-by-layer basis, through a series of cross-sectional slices. While 3-D printers work in a manner similar to traditional laser or inkjet printers, rather than using multi-colored inks, the 3-D printer uses powder that is slowly built into an image on a layer-by-layer basis. All 3-D printers also use 3-D CAD software that measures thousands of cross-sections of each product to determine exactly how each layer is to be constructed*". However, these features are counterbalanced by some limitations that are inherent in the technology (Finocchiaro 2013; Berman 2012), for example the impossibility of producing high volumes and associated economies of scale, a lower precision than with other manufacturing technologies, and the reduced possibility of employing a wide range of materials (e.g. leather). Here 3-D printing appears to have an impact on many aspects of the manufacturing industry. In the first place, it is changing the relationship between design and production.

The open business model

The recent literature on open organizations (Chesbrough 2006) appears to be appropriate for analyzing 3-D printing based companies and examining their business models and asset management strategies. Chesbrough's open organization model involves organizational characteristics that are suitable for managing innovations, including the process of acquiring and integrating new ideas into the organization and marketing them. Specifically, companies can commercialize internal (external) ideas through channels outside (inside) their current businesses to generate value for the organization. The vehicles for accomplishing this goal are contingent upon the organization's ability to create connections with external actors to absorb different types of knowledge (Ahuja 2000), improve survival rates (Baum and Oliver 1991), increase innovativeness (Baum et al. 2000; Stuart 2000), improve performance (Hagedoorn and Schakenraad 1994; Shan et al. 1994), and to grow quickly (Powell et al. 1996; Stuart 2000).

The open innovation model as a theoretical framework has largely been noted in technology-intensive industries. In design-intensive contexts, it has been identified in the dyadic relationships between manufacturing companies and designers (Dell'Era and Verganti 2010), assigning the former to a mere production function and the latter to creative activity. This perspective seems to limit understanding of how manufacturing is evolving, and the designer's role in the process. The manufacturing world now encompasses models of self-production and a "making culture" where users with different tools and technologies- including 3-D printing - are able to make products for their own use.

The evolution along this trajectory sees the advent of a new global community driven by an interest in new forms of craftsmanship (Friedman and Mandelbaum 2011; Micelli 2011; Sennett 2009; Yair et al. 1999). The role of designers within the manufacturing system is changing, moving from the role of a concept and creative insight provider (for manufacturers) to that of an entrepreneur who is able to market his/her own designed and "handmade" productions (Bianchini and Maffei 2012).

This new entrepreneurial role provides a new sense of being designer, where the typical creative asset and capabilities have to be coupled with the development of relational capabilities and the capacity to manage networks of actors (providers of materials, providers of equipment, other designers, distributive channel, communication channels).

The open business model is thus a suitable lens with which to analyze these developments in the business models of design-based ventures because of the way designers and other actors in the community leverage external sources of creativity to develop their products.

The 3-D printing companies we studied have been assessed against the following building blocks- or components - of business models (Johnson et al. 2008) although we have not been able to include a financial evaluation due to a paucity of comparable and consistent data among our cases:

- *Customer value proposition* involves defining the specific "job done" for the customer that alternative offerings do not address;
- *Key resources* are elements that create value for the customer and the company, often from the interaction of those elements; and
- *Key processes* are those that are needed to build and deliver value propositions to targeted customers.

Using this open business model framework, we examine the new network-intensive business models in the design and manufacturing sectors that have resulted from a radical technology innovation (3-D printing).

Methodology: building propositions through case studies

Scholars have used case studies to develop theories about topics as diverse as group processes (Edmondson et al. 2001), internal organizations (Galunic and Eisenhardt 2001), and strategies (Mintzberg and Waters 1982). Building theories from case studies is a research strategy that involves using one or more cases to create theoretical constructs, propositions and/or midrange theories from case-based, empirical evidence (Eisenhardt 1989b). Case studies are rich, empirical descriptions of particular instances of a phenomenon that are typically based on a variety of data sources (Yin 2008).

Theory emerges from a practical case and is developed by recognizing patterns of relationships in constructs and cases, while the theory building process occurs via recursive cycling between case data, emerging theory, and the extant literature (Eisenhardt 1989a; Mintzberg 1979; Pettigrew 1988; Yin 2008). We decided to select three cases because while single-case studies may richly describe the existence of a phenomenon (Siggelkow 2007), multiple-case studies typically provide a stronger base for theory building (Yin 2008).

As case studies can accommodate a rich variety of data sources we included three interviews with professors in technology management at Stanford University, Westminster University, and the University of Turin, to understand the phenomenon of 3-D printing from different perspectives. In addition we used secondary data to identify worldwide uses of 3-D printing technology in order to understand which organizations were mentioned most often as using this technology (please see Table 1 in the Appendix for more details) and moreover we analyzed three blogs on 3-D printing to learn about public views of the technology (Table 2).

From this reading we were able to identify and investigate three of the most important 3-D companies in order to analyze their business models. In the following paragraphs we will briefly illustrate the three cases in respect of the three categories we outlined above, of customer value, key processes and key resources. See Fig. 1 for more details.

Quirky

Quirky is an American consumer products design company founded in 2009 that turns crowd-sourced inventions into retail products using a manufacturing process based on 3-D printing technology. The process, from idea to final product, involves a plethora of different types of actors. Each week the two most popular ideas are decided by a community of “hobby inventors, students, retirees and product-design enthusiasts” (Tumblr 2012), who vote on the submissions. These are sent to an in-house team of engineers and designers to “research, render and prototype” (ibid). Ben Kaufman, Quirky’s founder, and his team review the results, sort out potential patent conflicts or production problems, and then make the final decision on the winner of the week. At every stage of the design process, including the design of colours, name, logo, etc., the community chips in and helps set a price for the product. The best suggestions are incorporated, earning secondary “influencers” a portion of any subsequent profits. Even if a product gets community approval, it will only make it to market if enough products are pre-ordered so that production costs are covered: “This is where we find out if a good

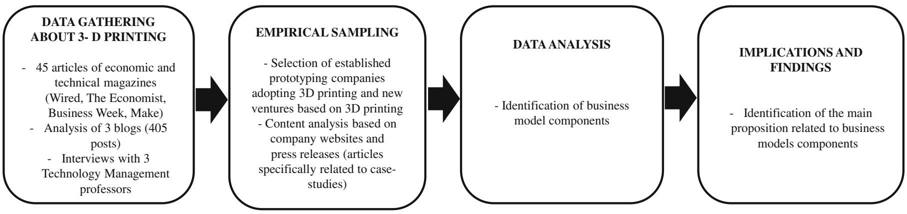

Fig. 1 The research process

idea is a good product" (Parade.com 2010). As a result of its access to a knowledgeable community, Quirky collects a wide range of multi-disciplinary skills necessary to turn an idea into something tangible. Necessary skills such as design, electrical engineering, marketing, and fund raising as well as access to retailers and manufacturers are all to be found in Quirky's community, helping it to complete and sell its products.

The manufacturing process takes place in a small factory with 3-D printers, a laser cutter, milling machines, a spray-painting booth and other equipment with which Quirky's product development team makes prototypes. Users review this online and contribute towards its final design, packaging and marketing. Quirky then looks for suitable manufacturers (Economist 2012).

i.materialise

i.materialise is a Belgian company that positions itself on the basis that people have an inherent and increasing need to express themselves in a world where standardization has become the rule. Its mission is to offer "everybody the possibility to turn (their) ideas into 3-D reality" (i.materialise.com 2013). They hope that this will help make 3-D printing more accessible and allow more people the opportunity to become designers and inventors. However, it positions itself at the higher quality end of the sector, focusing on 'demanding' designers and inventors and the use of high quality materials and processes (*ibid.*).

The designer uploads a project file (3-D file, pictures and text description) to the service, and selects material, size and quantity with the aid of a Template. A quote will then be given and, upon receiving confirmation and online payment, the product will be made and delivered. The designer may also sell their project and earn a percentage of subsequent sales. i.materialise allows designers to sell their products through its worldwide distribution network: potential buyers can access a unique collection of products that can be built on demand, or if desired, just a single piece.

Fab labs

A Fab Lab (**fab**rication **lab**oratory) is not a large formal company like Quirky or i.materialise, but is one of many small-scale workshops offering digital fabrication facilities to individuals. They are normally equipped with a range of flexible computer-controlled tools that cover different scales and materials. These tools include equipment that is usually regarded as suitable only for mass production. For example, the Fab Lab in Airedale, UK uses CNC routers, laser cutters, 3D printers and laser scanning technologies as well as a team of mechanical engineers and product designers (Fab Lab Airedle 2013).

Fab Labs have opened around the world including in Italy Spain, the USA, Ghana, and Afghanistan. A global network of over 150 Fab Labs now exists (Fab Lab Manchester 2013), which allows people to collaborate and brainstorm ideas. In Ghana, people have made a truck refrigeration system powered by the vehicle's own exhaust gases, while in Afghanistan, people are fashioning customised prosthetic limbs (*ibid.*). The Fab Labs help to develop and test prototypes of the customer's product ideas, which may then be sold commercially. An important part of this process is education: Fab Labs run workshops in schools and elsewhere in association with universities to educate users in the knowledge and technical skills needed to be designers and manufacturing entrepreneurs of the future.

Data analysis

Having identified the three case organizations, we collected qualitative data about their business models from the following sources:

- The organizations' websites;
- The articles and reports listed in Tables 1 and 2 which discussed 3-D printing in our case firms; and
- Three 3-D design- related blogs (Table 3).

To analyze the websites we used computer-assisted content analysis (CATA). Similar to human coding schemes, CATA analyzes word usage (Morris 1994). In relying on texts we assume that insights on the organizations' business models can be detected through the occurrence and frequency of those concepts that are normally used to define it (Carley 1997; Short et al. 2010). In our analysis we identified the concepts –the "business model block"– through a set of words from Chesbrough's (2006) definition of that concept (Table 3). As the phrase content analysis suggests, when creating a dictionary it is important to contextualize each word in accordance with its specific context (see Table 4). The CATA software, after learning all our dictionaries, was able to extract sentences containing the words selected. The advantage of using CATA in multiple texts is associated with the deletion of errors and bias that are associated with human coders (Stevenson 2001). The output was a list of sentences including at least one word from each dictionary.

Once the list of sentences were defined, each author provided a score to each sentence depending on the relation between the sentence and the corresponding business block. The relation was defined reading each sentence. If the sentence was highly addressed to the matching business block, the score was labeled as "high correspondence". Otherwise, if the sentence was in line with the corresponding business block, the score was "medium correspondence". Finally if the sentence was weakly essential for the business block definition, the score was "low correspondence".

In conclusion the authors compared each score finding out an agreement on the diverging scores. As Robert Philip Weber (1990) notes: "To make valid inferences from the text, it is important that the classification procedure be reliable in the sense of being consistent: different people should code the same text in the same way".

Table 5, the construct table, summarizes the evidence for each theoretical construct and indicates how the focal construct is measured with a score (high, medium and low correspondence).

Data analysis and propositions

The case organizations employed 3-D printing technology in two different ways: (i) first, as an additional service to client firms from a company that already specializes in prototyping services (i-materialise; Quirky, as *incumbents*); (ii) second, through the creation of a new type of organization (Fab Labs, as the *newcomer*). 3-D printing technology is used by these companies both as an advanced technology means to keep offering prototyping services to manufacturing companies and to create new business services for digital platform consumers, where the final consumers and/or designers can create their own concepts and designs with the intention of using and/or selling them.

The first type of organization originally offered services that were engaged mainly in the terminal phases of the innovative process, where prototyping and materializing concepts were used to provide input and feedback on the quality and characteristics of products. Such organizations, by materializing objects, provide companies' designers and R&D offices with the inputs and the insights that they need for the revision of engineering and conceptualization phases of their process, thus strengthening the relationship between "thought" and "practice" typical of creative processes (Schön 1984). These platforms are mainly supported by three types of users: (i) designers who produce their own ideas and creations and sell them via their personal channels (customization-driven designers), (ii) designers who propose their own products and market them on the platform (market-oriented designers), and (iii) users looking for products that are not standardized or sold in great volumes or even on an industrial scale (customization-driven users).

These organizations typically have:

- A small number of designers and creators: for example, Quirky has eight designers on its staff out of 40 employees;
- Specific knowledge resources needed to deal with idea selection and product management when those ideas come from external sources: for example in Quirky ideas submitted receive a double evaluation, one from the user community and the other from Quirky's staff members; and
- The ability to promote the potential of 3-D printing technology despite their own limited creations: for example, Fab-labs lend 3-D printing (and other technological devices) to those inventors who can prove their ability, or who have been educated by the Fab Lab Academy to use these technologies properly.

Open innovation in all these organizations begins with the dis-integration of the conception-conceptualization-engineering-production-sales activities chain of business processes. The breakdown of integrated value chains (Porter 1980) gives rise to companies specializing in micro-activities and, above all, to a number of "knowledge brokers" and "bridging ties". Such specialist firms link those actors with new ideas and innovative products with which other actors are then able to implement, develop, and sell their ideas and products.

In those specialist organizations the adoption of 3-D printing is thus coupled with the creation of a market place where products developed by external and internal creative sources are sold. External creative resources connected with design crowdsourcing processes and physical capital, such as 3-D printers and machines, form the two main assets for both activities of conceptualization and production.

Based on the foregoing we suggest the following proposition:

> P1: 3-D printing technology encourages the creation of open business models such as new market or online design shops using crowdsourcing.

Marketing the different products generated from 3-D printing is entrusted to the management of distinct distribution channels and strategies. These features are found in both established prototyping companies and new design ventures. Quirky and i.materialise, for example, being keen on the idea of a creative community and a market for ideas, have developed on-line shops that offer users an opportunity to buy products created by independent users and designers. With this feature, Quirky – mostly in line with the logic of a "push" distribution strategy – combines a retail network for products with a platform for their own products. Firms specializing in organized distribution, such as Safeway, Target, Barnes & Noble, Amazon, or Toys "R" Us, are a few examples of retailers where crowd-sourced designs made by Quirky are available for purchase. These bring important innovative elements, including speed to market, to the classic models of relationships between manufacturing organizations and distribution channels.

Another business model is the open design shop. Fab-labs are a global network of over 50 laboratories open to designers, production self-learners, and users who seek to personalize small products, such as accessories, musical instruments and toys. Fab-labs introduce a further innovative element, their territorial presence, which, being often highly integrated with local socio-productive resources, allows for the direct involvement of the final client, bypassing any intermediaries in the distribution channel. The client then becomes the buyer but also an important tester of product effectiveness or of ideas conceived in the laboratory. In other words, 3-D printing technology is not aligned with established distribution chains, which means that there is no closed structural relationship between technologies, strategies and distribution policies. Given these considerations we offer the following second proposition:

> P2: 3-D printing technology allows for the development of different distribution strategies: direct e-commerce, alliances with organized distribution, and new types of retail channels such as open design shops.

The characteristics of 3-D printing technology allow for the production of different categories of products in limited quantities and, above all, without any technological or complementarity of consumption among them. In 3-D printing firms there is extreme heterogeneity in the types of goods produced and sold. Fashion accessories, jewels, toys, shoes, musical instruments, lamps, and interior design products can all be found in 3-D printing companies' product portfolios. In fact, the major problems connected with this technology are due to the different exploitable materials. The absence of links and technological complementarity with potential products, together with the absence of production scale and volume economies, require skills to manage a wide and heterogeneous product portfolio. Profitability is achieved through sales of a high number of product lines in low volumes (Kekre and Srinivasan 1990; Amit and Zott 2001; Osterwalder and Pigneur 2010). This characteristic is typically found in "open innovation" and "open business" models, where creating new solutions and products comes from more than just sharing technological, aesthetic, or category links among products (Sanderson and Uzumeri 1995). Breaking these links reduces the brand power of these products, and as some products such as accessories, interior design products, and jewellery are typically brand-driven purchases, in the case of 3-D printing the signaling value of the brand is replaced by the signaling power of customization. In turn the brand value of 3-D printing is supported by association with the creative process and its community links through crowdsourcing. Moreover the seeking for a "by product category" specialized creativity tends to dramatically increase the network wideness and the number of constituting knots.

> P3: The open business model induces 3-D design companies to achieve a profitable product portfolio through providing a wide variety of customized and low-volume products with no technological complementarities, in which the management of the community prevails over the management of the brand.

Technology does not have intrinsic value (Teece 2010). In other words, obtaining a dynamic competitive advantage and turning it into a profitable venture requires competence (Hamel and Prahalad 1990), the mastery of dynamic capabilities (Teece et al. 1997; Eisenhardt and Martin 2000), and the ability to transform resources into value for the client. In open innovation models, given their greater dynamism, capabilities are not limited to physical capital but mainly arise from careful management of relational ties and the firm's knowledge (Chesbrough 2006).

Apart from the operation of 3-D printing machines, the main activities that are central to the successful management of 3-D printing organizations are: (i) the management of creative networks and crowdsourcing; (ii) the management and selection of projects, taking care of their visibility and sales promotion; and (iii) the management of market and/or distribution channels. These activities are an example of the "double-sided" business models (Osterwalder and Pigneur 2010), that is, platforms that connect content providers with their users. From this viewpoint, the development of open-source communities enables a social interaction that may help the development of the technology, and may also create new knowledge and new ideas. In the case of Fab Labs, they are physical platforms – design shops – that are open to users for the self-production and prototyping of their own artifacts. On account of the key capabilities required of these models we suggest a fourth proposition:

> P4: 3-D printing ventures require dynamic capabilities related to network and market management, and project selection.

Conclusions

The development of 3-D printing in modern industrial and manufacturing economies is promoting new competitive mechanisms based on different business models. In particular, a new competitive arena is emerging in services connected with design and creativity. In the current structure of 3-D printing businesses, which features stable and well-supported relationships between large-scale manufacturers, incumbent designers and design consulting firms (Capaldo 2007; Dell'Era and Verganti 2010), a new scenario appears to be emerging that features new ventures (including newcomer designers) whose competitive advantage depends on external networks that leverage open, distributed creativity.

In this scenario, 3-D printing enterprises are trend accelerators of a new approach to business where incumbent players and new entrepreneurs seek to develop open business models such as marketplaces and open design shops that are centered on community and design crowdsourcing. The distribution models that are found in these contexts often surpass the traditional vertical relationships between producers and distributors. Our empirical analysis in this paper suggests that 3-D printing technology allows both new design ventures and established prototyping companies to develop different distribution strategies. Direct e-commerce, alliances with established distributors, and specialized retail channels such as open design shops turn collaborations between producers, distributors and customers into business competition.

This process involves having access (Rifkin 2000) to an organized and open system of productive resources. Inside this expanding context, products do not need to have technological complementarities or branding relationships. With 3-D printers – given certain material limitations – companies produce lamps, shoes, accessories, or toys, without any type of category ties and complementarities. The absence of merchandise categories prompts a reconsideration of the traditional boundaries between companies and actors within the value chain.

Given its focus on limited evidence from the 3-D printing industry, our analysis cannot be used to comprehensively identify the features of a new industry, but in this paper we have identified certain trends that we have argued are important in design-based ventures specifically in 3-D printing. Our propositions then provide cues for future research that should aim to develop a deeper understanding of how the diffusion of open models are affecting the design value chain, and how product manufacturers may engage designers in the development of impactful business processes.

Acknowledgments We wish to thank the Professors of Stanford University, Westminster University and the University of Torino and in particular Prof. Martin Steinert and Prof. Luca Console for their advice and support. We are also grateful to Rebecca Pera for facilitating the business case development and Mauro Giraudo for assisting us with our content analysis. Financial support from the PRIN fund "Diffusion of technologies" is also gratefully acknowledged. Any mistakes or omissions remain the sole responsibility of the authors.

Appendix

Table 1 List of articles used to define the practice cases and develop content analysis

Magazine	Date	Title	Practice cases cited
Business week	June 29, 2012	Crowd-sourced in the U.S.A.	Quirky
The Economist	April 21st 2012	The third industrial revolution	Quirky
The Economist (Blog)	April 21st 2012	The gentleman manufacturer	Quirky
Wired	09.11.12	A Startup That Turns the Ideas Filling Your Head Into Products Filling Shelves	Quirky
The Economist	Jun 9th 2005	How to make (almost) anything	Fab-Lab
Wired	September 2005	The Dream Factory	Fab-lab
Business week	May 01, 2005	Desktop Factories	Fab-lab
The Economist	Apr 21st 2012	Solid print	i.materialise
The Economist	Dec 10th 2011	The shape of things to come	i.materialise
Wired	October 13, 2010	Spime Watch: Materialise	i.materialise
Wired	02.16.11	The Secret World of Printing Concept Cars in 3-D	i.materialise

Table 2 List of articles analyzed through content analysis

Magazine	Date	Article title	Emergent issues
Business week	26 April 2012	3-D Printers: Make Whatever you want	- Manufacturers and companies that are users of 3-D technology - The functional logics of 3-D technology - Main sector involved in the use of 3D printing
Business week	09 May 2012	Bre Pettis: 3D Printing's First Celebrity	- Producers of 3D printing technology - Contexts of application
Business week	03 May 2012	How About Them Gams: 3 D Printing Custom Legs	- Integration between design and prototyping - Potentials for customization
The Economist	10 February 2011	The printed world	- Manufacturers and companies that are users of 3-D technology - The functional logics of 3-D technology - Prototyping companies using 3-D technology
The Economist	21 April 2012	The third Industrial Revolution/Solid Print	- Manufacturing scenarios - Facts and figures about 3D printing technology - The functional logics of 3-D technology - Manufacturers and companies that are users of 3-D technology
Wired	05 September 2011	An Industrial revolution in Digital Age	- The functional logics of 3-D technology - Sector mainly involved in 3D printing use - Manufacturers and companies that are users of 3-D technology
Make	February 2010 Vol. 21	Your Desktop Factory - 3D Manufacturing at home	- The functional logics of 3-D technology - Producers of 3d printing technology

Table 3 Selected blogs with 3-D technology used in content analysis

Blog	Topic/Title	Posts/Comments
The Economist	The Third Industrial Revolution	364
Business week	3D Printers: Make Whatever You Want	8
Wired	Cube indoors and outdoors	33

Table 4 Content analysis dictionary

Business model building block	Reference dictionary	Contest qualification dictionary
Customer value proposition	Custom*	User* designer*
	Relation*	Collaborat* Participat*

Table 4 (continued)

Business model building block	Reference dictionary	Contest qualification dictionary
Key resource	People	Crowd* User*
	Techno*	3-D printing
	Product*	Finite* Customize*
	Channel*	E-commerce Shop*
Key process	Manufact*	Digital*
	Interact	Network* Select*

*The content analysis includes the number of sufixis for the same root-words

Table 5 Construct table and score

Theoretical construct	Dictionary	Sentences selected by CATA	Score
Customer value proposition	Collaborative	Quirky is engaged in the **collaborative** design field: It creates links and conversations between a global influencer community (people able to give feedback to help the design process), the experts of the design team and the inventor (Quirky)	High correspondence
Value proposition	Design	**Designers** will be on-site to accept original product ideas from the public (Quirky). I .materialise gives designers an opportunity to showcase their talent and sell their products from a worldwide distribution network. Potential buyers can access unique products realized on demand	Medium correspondence
Key source	People	“For this **process** to work, you need to find the right people, ask the right questions and appeal to the right market,” says Jeremy Brown, CEO of sense Worldwide, a consultancy that has helped Nike and Procter & Gamble set up co-creation initiatives (Quirky)People made the staff, by the end of this year it’s planned they are going to be 80 (Quirky)	Medium correspondence
Key process	Develop*	Fab-lab San Diego’s program was **developed i**n response to a need to inspire students while engaging them in learning about next generation technologies	Low correspondence
Key process	Technology	The flexibility given by the type of **technology p**revails over “minimum quantity” as just one single piece can be produced (i.materialise)	High correspondence
Key process	3D printing	I.materialise is an **online 3D printing service**, based in Belgium	Medium correspondence

References

Ahuja, G. (2000). Collaboration networks, structural holes and innovation: a longitudinal study. *Administrative Science Quarterly, 45*, 425–455.

Amit, R., & Zott, C. (2001). Value creation in E-business. *Strategic Management Journal, 22*(6–7), 493–520.

Baum, J. A. C., & Oliver, C. (1991). Institutional linkages and organizational mortality. *Administrative Science Quarterly, 31*, 187–218.

Baum, J. A. C., Calabrese, T., & Silverman, B. S. (2000). Don't go it alone: alliance network composition and startups' performance in Canadian biotechnology. *Strategic Management Journal, 21*, 267–294.

Berman, B. (2012). 3-D printing: the third industrial revolution. *Business Horizons, 55*(2), 155–162.

Bianchini, M., & Maffei, S. (2012). Could design leadership be personal? Forecasting new forms of "Indie Capitalism". *Design Management Journal, 7*(1), 6–17.

Bruce, M., & Bessant, J. (2002). *Design in business - Strategic innovation through design*. London: Pearson Education.

Bruce, M., & Jevnaker, B. H. (1998). *Management of design alliances. Sustaining competitive advantage*. Chichester: John Wiley & Sons.

Capaldo, A. (2007). Network structure and innovation: the leveraging of a dual network as a distinctive relational capability. *Strategic Management Journal, 28*(5), 585–608.

Carley, K. M. (1997). Extracting team mental models through textual analysis. *Journal of Organizational Behavior, 18*, 533–558.

Cautela, C., & Zurlo, F. (2011). Managing the five tensions of the design process. *Design Management Review, 22*(3), 6–14.

Chesbrough, H. (2006). *Open business models: How to thrive in the new innovation landscape*. Boston: Harvard Business School Press.

Dell'Era, C., & Verganti, R. (2010). Collaborative strategies in design-intensive industries: knowledge diversity and innovation. *Long Range Planning, 43*(1), 123–141.

Dumas, A., & Mintzberg, H. (1989). Managing design designing management. *Design Management Journal, 1*(1), 37–43.

Edmondson, A. C., Bohmer, R. M., & Pisano, G. P. (2001). Disrupted routines: team learning and new technology implementation in hospitals. *Administrative Science Quarterly, 46*, 685–716.

Eisenhardt, K. M. (1989a). Making fast strategic decisions in high-velocity environments. *Academy of Management Journal, 32*, 543–576.

Eisenhardt, K. M. (1989b). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they? *Strategic Management Journal, 21*(10–11), 1105–1121.

Fab Lab Airedale (2013). Available http://www.centreofmanufacturingexcellence.com/fab-lab/.

Fab Lab Manchester (2013). Available http://www.fablabmanchester.org/about-us/fab-foundation.

Finocchiaro, C. W. (2013). Personal factory or catalyst for piracy? The hype, hysteria, and hard realities of consumer 3-d printing. *Cardozo Arts & Entertainment Law Journal, 31*, 473–569.

Friedman, T. & Mandelbaum M. (2011). That used to be us: how America fell behind in the world it invented and how we can come back. New York: Farras, Straus and Giroux.

Galunic, D. C., & Eisenhardt, K. M. (2001). Architectural innovation and modular corporate forms. *Academy of Management Journal, 44*, 1229–1249.

Gobble, M. (2013). The rise of the user-manufacturer. *Research Technology Management, 56*(3), 64–66.

Hagedoorn, J., & Schakenraad, J. (1994). The effect of strategic technology alliances on company performance. *Strategic Management Journal, 15*(4), 291–309.

Hamel, G., & Prahalad, C. K. (1990). The core competence of the corporation. *Harvard Business Review, 68*(3), 79–87.

Hargadon, A. B., & Douglas, J. Y. (2001). When innovations meet institutions: Edison and the design of the electric light. *Administrative Science Quarterly, 46*, 476–501.

Hargadon, A. B., & Sutton, R. I. (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly, 42*, 716–749.

i.materialise (2013). Available from http://i.materialise.com/about.

Johnson, M. W., Christensen, C. M., & Kagermann, H. (2008). Reinventing your business model. *Harvard Business Review, 86*, 57–68.

Kekre, S., & Srinivasan, K. (1990). Broader product line: a necessity to achieve success? *Management Science, 36*(10), 1216–1231.

Kotler, P., & Rath, A. (1984). Design: A powerful but neglected strategic tool. In M. Bruce & R. Cooper (Eds.), *Marketing and design management* (pp. 204–214). London: Thomson.

Lorenz, C. (1986). *Design & design management som konkurrensmedel (the design dimension)*. Kristianstad: Svenska Dagbladets Förlags AB.

Micelli, S. (2011). *Futuro Artigiano, l'innovazione nelle mani degli Italiani*. Venezia: Marsilio.

Mintzberg, H. (1979). An emerging strategy of "direct" research. *Administrative Science Quarterly, 24*, 582–589.

Mintzberg, H., & Waters, J. A. (1982). Tracking strategy in an entrepreneurial firm. *Academy of Management Journal, 25*, 465–499.

Morris, R. (1994). Computerized content analysis in management research: a demonstration of advantages & limitations. *Journal of Management, 20*, 903–931.

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation*. Chichester: John Wiley & Sons.

Parade.com (2010). *What's your big idea*? Available from http://www.parade.com/news/2010/10/24-whats-your-big-idea.htm.

Petrović, V., Gonzalez, J. V. H., Ferrando, O. J., Gordillo, J. D., Puchades, J. R. B., & Grinan, L. P. (2011). Additive layered manufacturing: sectors of industrial applications shown through case studies. *International Journal of Production Research, 49*(4), 1061–1079.

Pettigrew, A. (1988). Longitudinal field research on change: Theory and practice. Paper presented at the *National Science Foundation Conference on Longitudinal Research Methods in Organizations,* Austin.

Porter, M. E. (1980). *Competitive strategy*. New York: The Free Press.

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Inter-organizational collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly, 41*, 116–145.

Ravasi, D., & Lojacono, G. (2005). Managing design and designers for strategic renewal. *Long Range Planning, 38*(1), 51–77.

Rifkin, J. (2000). *The Age of access. The new politics of culture vs. commerce*. Available from http://lizard.artun.ee/~raivo/imke/additional%20reading/E2002_043_rifkin.pdf.

Sachs, E., Cima, M. J., & Cornie, J. (1990). Three dimensional printing: rapid tooling and prototypes directly from a CAD model. *CIRPAnnals, 39*(1), 204–210.

Sanderson, S., & Uzumeri, M. (1995). Managing product families: the case of the Sony Walkman. *Research Policy, 24*(5), 761–782.

Sch n, D. A. (1984). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Sennett, R. (2009). *The craftsman*. London: Penguin.

Shan, W., Walker, G., & Kogut, B. (1994). Interfirm cooperation and startup innovation in the biotechnology industry. *Strategic Management Journal, 15*(5), 387–394.

Short, J. C., Broberg, J. C., Cogliser, C. C., & Brigham, K. (2010). Construct validation using computer-aided text analysis (CATA): an illustration using entrepreneurial orientation. *Organizational Research Methods, 13*, 320–347.

Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal, 50*, 20–24.

Stevenson, R. L. (2001). In praise of dumb clerks: Computer-assisted content analysis. In M. D. West (Ed.), *Theory, method and practice in computer content analysis* (pp. 3–12). Portsmouth: Greenwood.

Stuart, T. E. (2000). Inter-organizational alliances and the performance of firms: a study of growth and innovation rates in high-technology industry. *Strategic Management Journal, 21*(8), 791–811.

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning, 43*, 172–194.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533.

The Economist (2012, 21 April). *The Third Industrial Revolution. The digitisation of manufacturing will transform the way goods are made and change the politics of jobs too*. (http://www.economist.com/node/21553017).

Tumblr (2012). *Today's entrepreneur: Collaborative product development*. Available from http://todaysentrepreneur.tumblr.com/post/37767035973/collaborative-product-development.

Verganti, R. (2003). Design as brokering of languages. The role of designers in the innovation strategy of Italian firms. *Design Management Journal, 14*(3), 34–42.

Verganti, R. (2006). Innovating through design. *Harvard Business Review, 84*(12), 114–122.

Verganti, R. (2008). Design, meanings, and radical innovation: a meta-model and a research agenda. *Journal of Production and Innovation Management, 25*(5), 436–456.

Verganti, R. (2009). *Design-driven innovation*. Boston: Harvard Business Press.

Walsh, V. (1996). Design, innovation and the boundaries of the firm. *Research Policy, 25*, 509–529.

Weber, R. P. (1990). *Basic content analysis* (2nd ed.). Newbury Park: Sage Publication.

Yair, K., Tomes, A., & Press, M. (1999). Design through making: crafts knowledge as facilitator to collaborative new product development. *Design Studies, 20*(6), 495–515.

Yin, R. K. (2008). *Case study research: Design and methods* (Vol. 5). London: Sage.