Doing is Believing: How Material Practices Shape the Future in 3D Printing

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Abstract. Recent years have witnessed the emergence of 3D printing framed as a revolutionary and transformative technology. The development of consumer 3D printers, as well as the emergence of FabLabs has fueled a wave of expectations and (over) enthusiasm around the technology. Expectations around 3D printing address not only what the technology may deliver (economic growth, solution to societal challenges, radical innovation) but also how the social arrangements around the technology offer new possibilities. This is a narrative where innovation occurs because of curiosity, 'tinkering' and enjoyment in an open, collaborative and distributed way. This narrative corresponds to specific imaginaries and shared visions of technology development that are able to shape technological paths. This chapter studies the material practices in which these visions of 3D printing are embedded. We explore and compare how three companies actively shape and anticipate the future of 3D printing by embedding and mobilizing expectations in specific material practices. These are guided by a combination of logics that move between open-source and techno-economic. We show that these two different logics are accommodated within the same practices, and are aimed at fulfilling parts of a similar vision. The analysis provides preliminary indications of how logics of innovation evolve and shape anticipation in the case of an emerging technological field.

Keywords. 3D printing, sociology of expectations, anticipation, anticipatory practices.

Introduction

In recent years the growth of the consumer or desktop 3D printer has been explosive– analysts estimate a growth of 346% between 2008 and 2011 (Wohlers, 2014). To the date, there are no concrete estimates of how many consumer 3D printers are 'out there', since many of these machines are self-produced by makers and 3D printing enthusiasts. As an indication, on 12 January 2015, 3D Hubs, a service of online 3D printing based in the Netherlands announced that they had connected the 10,000th 3D printer to their worldwide network of printers (3D Hubs, 2015). This was only about a year and a half after the company started its service, now turned into a large network of interconnected 3D printers across more than 140 countries. This is only one sign of the explosive growth in the number and types of available machines, with hundreds of small 3D

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printing companies founded via crowdsourcing sites and large companies entering the 3D printing business.

As the number of machines has grown, so have the expectations. The 3D printer became the new favorite of the media, being associated to grand promises and visions about prosperity and disruptive innovation. It is presented as the technology that will enable the Third Industrial Revolution creating a wave of disruptive innovation, local production and the end of scarcity (Anderson, 2012; Rifkin, 2011). However, the expectations about a future where 'anybody–who owns a 3D printer–can make almost anything' go far beyond the current possibilities enabled by the technology and only exist in the imaginaries of those who engage with it. In fact, the increasing attention the field has received has also been accused of overpromising and hype (Bass, 2013).

In this chapter, we investigate the material practices deployed by a set of actors in the 3D printing field in order to anticipate particular futures for the technology. By material practices we refer to practices that are not *explicitly* anticipatory, as for instance foresight would be, but rather practices of designing, organizing, sensemaking and financing of technology, which are usually not considered as anticipatory in the first place. Rather, these practices, which are part of innovation processes, contribute to shape the future of 3D printing–or particular aspects of it including, for example, the development of software, hardware, standards, forms of transaction–by referring to, voicing, mobilizing or challenging expectations, either through discourse or embedded in material developments (prototypes, reports, standards, etc.). We furthermore show how these practices are guided by two different but complementary logics that move between techno-economic and collective experimentation regimes. As our guiding research question we ask: *which material practices shape expectations about 3D printing, and which logics guide these practices?*

The chapter develops as follows. The section one introduces the historical context of the development of 3DP, in particular related to the RepRap project, FabLabs and maker communities. Section two presents the framework; our methodology is set out in section three. The fourth, empirical section analyzes three actors and the material anticipatory practices these actors engage in to promote their visions about 3D printing, and the logics that guide them. Section five reflects and discusses the relation between the variety of practices and the logics that guide them.

1. Background

3D printing, as we know it today, is a derivative of a 20 year old industrial technology called Rapid Prototyping or Additive Manufacturing (AM). As the name suggests, it is a technology that produces 3D structures layer by layer, in contrast to subtractive manufacturing techniques. A variety of materials can be used, ranging from plastics to ceramics and metal. In its origin, 3D printing was used for the production of prototypes for industry and now is more and more moving into the production of everyday, yet 'customized' and unique, objects (Berman, 2012). For many years 3D printing machines occupied a niche market until the concept of the 'consumer 3D printer' emerged with the RepRap project.[2] For this reason, we suggest to distinguish between

[2] Although the RepRap Project is the most visible, there were earlier attempts to develop a consumer 3D printer: Fab@Home (Available at: http://www.fabathome.org/) and Desktop Factory (a company acquired by 3D Systems in 2009).

the industrial and the consumer realms of 3D printing (Hague and Reeves, 2013). In the remainder of the chapter we will investigate practices associated to 3D printing (3DP) that is, consumer-oriented technologies.

The RepRap project, initiated by Adrian Bowyer in 2004 was aimed at producing an open source 3D printer that would in the long run be able to reproduce itself–hence the RepRap 'Replicating Rapid Prototype' name (Bowyer, 2014). The development of this project has been described in detail elsewhere (Söderberg, 2013; Söderberg, 2014; West and Kuk, 2014; de Bruijn, 2010). What is important is that the RepRap project, by being framed and developed as an open-hardware project, spurred collaborative and open innovation across a community of hackers and makers that resulted in a desktop size 3D printing accessible at a much lower cost than the existing industrial 3D printing machines. As a consequence, it opened a complete new market beyond the industrial prototyping applications. Today, most of the machines that fall into the category of consumer 3D printers derive from the RepRap Project. Understanding this context is essential to characterize the way the future is portrayed by 3D printing actors today.

The 'open source' aspect of the RepRap machine was central to Bowyer's vision. All the design instructions and files, as well as the accounts of the process of construction were shared online via the RepRap wiki and blog, and anybody could get involved in the project and develop their own RepRaps. These requirements were directly in line with the vision of 'wealth without money' that Bowyer saw for the machine. Following this logic open source 'was the only sensible thing to do' (Bowyer, 2007) since the final aim of the RepRap project was to spread the technology all over the world and displace existing manufacturing paradigms, democratizing and distributing production (Söderberg, 2014).

In the course of this project, a growing community of 3D printer enthusiasts and makers was formed, connected through the RepRap site, who developed various noncommercial and commercial machines. The earliest and most well known of these open source startups was Makerbot. This company spun off from the RepRap project in 2009 and quickly became the market leader of desktop 3D printers. They created a website called Thingiverse, an online community for sharing user generated content and designs compatible with open source hardware, and which later became the major hub for 3D designs. Makerbot sold open source assemble kits for 3D printers that helped to spread the RepRap concept across various communities (West and Kuk, 2014).

In its early stages, Makerbot was aimed at making information and the technology flow as much as possible by making it accessible to a broader community of makers and hobbyists, who could also improve the machine. Thus, keeping the software and the design open source was important. This created a tradeoff since it required highly skilled users and long-time investment to make the machines work properly (Söderberg, 2013). This was not a problem for the makers, who enjoyed tinkering and suggesting improvements, but it was at odds with the intention to expand it to a broader public. In this context, Makerbot started to acquire a more and more proprietary (closed source) strategy, also as a means to differentiate itself from other RepRap based companies (West and Kuk, 2014). This process culminated in 2013, when the large multinational Stratasys acquired Makerbot (Sharma, 2013). This was the result of a process where both the machines, and the sharing platform Thingiverse became more and more proprietary, creating an adverse reaction from a large part of the 3D printing community. This acquisition was a disappointment for the community that supported Makerbot, not only as consumers but actively building the technology and its

ecosystem, who saw their openness as central to the commercial success of Makerbot and not as a competitive disadvantage (Dickel et al., 2014)

While this is the specific story of Makerbot, it is important understanding how the expectations about the technology have unfolded. It shows the general tension in the field between ideas of democratizing innovation versus economic logics. As the technology has become more popular, actors have changed their strategies, moving away from their original ethos. Nevertheless, the basic promise of the 3D printer–and its limitations–remains almost the same since the 2004's RepRap manifesto: in the long run, the technology will enable anybody to make almost anything. In practice, it is possible to print simple available designs but actually developing own prints requires non-trivial design skills.

There is a second component that adds to the promises of 3D printing which is the emergence of shared workshops for digital fabrication, particularly FabLabs. Around the same time the RepRap project was initiated, Neil Gershenfeld at the Center of Bits and Atoms in the MIT started his FabLab initiative. Fablabs are workshop spaces that provide the possibility to 'make almost anything', and which quickly spread across the world. While a FabLab includes various fabrication machines, the 3DP became quickly the 'crown jewel' of the FabLab (Lhoste and Barbier, submitted) although it was never part of the official chart of machines.[3] However, the 'magic' of the 3DP and the effect it had on those who saw it made it an emblematic component of FabLabs (Troxler, 2014; Walter- Herrmann and Büching, 2014).

These two developments are intrinsically anticipatory. The RepRap project has been called 'a roadmap to the transcending of the existing market society' (Söderberg, 2014) while FabLabs have been defined as a roadmap to 'digital fabrication' (Gershenfeld, 2015). By framing these initiatives as 'roadmap' it is made explicit that the construction of communities around workspaces and sharing practices is paving the road for specific futures. These two projects are not framed as something for today, but as the road to a different techno-economic context. In this future, the digital merges with the material, atoms and bits are indistinguishable enabling anybody to make anything, anytime, anywhereb (Söderberg and Daoud, 2011).

2. Framework: anticipatory practices and logics

This chapter explores the material practices that embody expectations about 3D printing, and how these are used to further mobilize these expectations. We want to investigate how the context in which actors are embedded affects the expectations that are produced, and how the way they are produced matters for their performativity. We argue that these expectations are performative because they affect, change and guide social processes occurring in innovation fields.

For new and emerging technologies, promises, visions and expectations play an important role in guiding activities in contexts of high uncertainty (Rip, 2012; Borup et al., 2006). Anticipation is a process where the present is transformed, intervened in and ultimately governed in the name of the future (Adams et al., 2009; Anderson, 2010).

[3] According to the FabLab foundation, to qualify as a FabLab there are certain requirements of tools and processes. There is a list of critical machines and materials that should be found in every FabLab in order to make their operation reproducible across the world. This list of machines did not include a 3D printer in the beginning.

An important part of the process of anticipation is the mobilization of expectations and visions in order to legitimize, guide and coordinate particular futures. In this chapter we describe a process of anticipation happening in 3D printing, and the anticipatory practices through which it takes place. We focus particularly on the relation between visions, expectations and these specific practices that give shape to the 'futures' of the technology.

We begin by clarifying the differences and relations between these three categories. In general, *expectations* are statements about future conditions or developments that imply assumptions about how likely these are supposed to be. With a focus on expectations related to science and technology, technological expectations have also been defined as 'real time representations of future technological situations and capabilities' (Borup et al., 2006), with collective expectations being those that are collectively shared by a community (Konrad, 2006). Besides *expectations* which may be confined to particular technological developments or future states, *visions* refer to more or less coherent packages of potential future states. Visions usually imply more normative connotations, while not necessarily assessments of likelihood or plausibility. Usually visions are related to a series of expectations; for example, the *vision* of distributed manufacturing associated to 3D printing is accompanied by *expectations* about the roles certain actors should play, the kinds of requirements that should be fulfilled by the technology, among others (van Lente, 1993; Parandian et al., 2012). Visions and expectations are part of a process of *anticipation*, in which visions, expectations and other forms of knowing the future, are mobilized to change the present in the name of the future, through specific material practices (Anderson, 2007).

Expectations are produced by a range of *anticipatory practices*, invested, formalized and deployed for knowing and acting upon futures (Anderson, 2010). These anticipatory practices encompass a wide range of activites, from explicit forms of anticipation, such as foresight, to every day practices of innovation actors such as filing patents, scientific publications, conferences, grant applications, among others. We consider these practices anticipatory if they refer to, mobilize and/or shape expectations about the technology, either as part of discourse or embedded in material developments such as prototypes, press releases, legal standards, software tools etc. This approach highlights that expectations are 'conducted in material settings' (Kearnes, 2013; Brown and Michael, 2003) and that they are not just the result of explicit tools but instead a component of many innovation practices. By doing so, this perspective stresses the relation between the context, expectations and the way they are produced. Different practices produce different types of expectations, content wise, and implicitly with regard to the possibilities (and requirements) for action which are created for actors in the field. Therefore, we suppose that the performativity of these practices differs.

We can think of this relation at the actor level: innovation actors deploy expectations for specific purposes, such as mobilizing resources or coordination. At the same time, there is active shaping and use of these expectations by actors, with effects that go beyond the original purpose (Konrad and Alvial Palavicino, forthcoming). This reflexive relation is embedded in material practices, as we will show in the remainder of this chapter.

These material practices are quite diverse, and it is interesting to understand what leads a certain actor to engage into a particular set of practices and how these practices are coherently arranged. We would argue that the type of practice an actor deploys relates to the conditions in which these actors are embedded. To understand these conditions we use the concept of *logics*, which broadly refers to a set of rules, or

grammar that enables and discourages certain practices and their combinations (Glynos and Howarth, 2007). It refers to the guiding principle that brings these practices together in order to act in relation to a future. By introducing logics, we want to highlight two aspects. First, the ways of acting upon the future are not given but need to be constantly reenacted (Anderson, 2010). Second, the constant reenactment of practices also leads to spaces for contestation and innovation, which may introduce new practices and enable evolution and change.

How to think about the logics that guide innovation processes? It has been argued that current innovation regimes move between two modes, or two logics: the *regime of economic techno-scientific promises* and the *regime of socio-politics of collective experimentation* (Felt and Wynne, 2007). These two regimes characterize two types of innovation: on the one hand there is a linear and centralized model of innovation; and on the other a distributed, collective and open one. In practice, most innovation processes are located somewhere in between these two regimes. We will take these two regimes as a starting point to study the logics of anticipation in 3D printing.

We propose that there are two logics that guide anticipation in the field of 3DP: an *open-source logic* and a *techno-economic logic*. These two logics can be considered as 'ideal types', in the sense that they do not represent exact instantiations of social phenomena but idealizations of them (Weber, 1988:190).[4] The selection of these logics as a starting point for the analysis relates to the background history of the field and the distinction between regimes of innovation introduced earlier. While further characterization has to be empirically grounded, we will argue that processes in 3D printing situate somewhere between these two logics. We will shortly describe each of them.

2.1. Open source logic

This first logic relates to what we have referred to before as regimes of collective experimentation. As mentioned earlier, the RepRap project originated in communities engaged with open source hardware and software. To understand the cultural significance of the open source software, Christopher Kelty introduced the concept of 'recursive publics' (2008), by which he means that the development of open source (in his case, software) is related to a set of practices in which technical and legal developments are used to discuss the future possibilities of a technology. Recursive Publics is then the term given to these communities, defined as,

> 'a public that is vitally concerned with the material and practical maintenance and modification of the technical, legal, practical and conceptual means of its own existence as a public; it is collective independent of other forms of constituted power and is capable of speaking to existing forms of power through the production of actually existing alternatives (Kelty, 2008:3).

These recursive publics are brought together by a logic in which power is challenged and contested mainly through the construction of technical alternatives, rather than by rhetoric or social means. This is clearly the case for the RepRap project, in which the vision of 'wealth without money' is expected to challenge capitalism not by social revolution but by the use of technology (Bowyer, 2007).

[4] This understanding of ideal types follows the analytical conception of ideal types by Max Weber. This does not exclude that these ideal types, in particular the open source logic, are perceived as a normative ideal by actors in the field.

Actors do not only share collective expectations about the technology, but also use the technology itself as a means to think, speak, tinker and actively anticipate futures. Futures are not just imagined, they are actively created. The geek public discusses, shapes and enacts their visions of the future less by rhetoric and more through material practices. For geeks, the aim is to do rather than to discuss; 'ideologies' are mediated by the socio-material practices that sustain them (Kelty, 2008).

Starting from this notion, we define an *open source logic*, which refers to the possibility of opening spaces for change and discussion enabled by technical and legal developments. The materialities emerging from these practices are recursive: they are explicitly and intentionally subjected to constant change.

2.2. Techno-economic logic

The second logic that we find in 3DP is related to the regime of economics of techno-scientific promises, and we will call it a *techno-economic logic*. Today, 3DP has become much more than a 'geek' technology, moving into the broader consumer sector[5] which is guided by dominant economic logics.

One of the characteristics of this economic logic is that new technologies are associated to promises and expectations constructed in relation to a problem to be solved (for example, a societal challenge) and their possibilities to contribute to economic growth (Joly, 2010). New technologies, such as nanotechnology and synthetic biology, are presented and legitimized as if they could solve many, if not all problems faced by society without fundamentally changing the conditions that lead to these problems.

These promises refer to narratives of breakthrough, progress and urgency, in which the possibilities of a technology are balanced out against its threats and risks. Specifically, the practices that develop under this logic are aimed at the quantification and specification of futures (such as forecast, scenarios or Delphi) in order to legitimize specific paths and methods of intervention, governance and control. Overpromising is also a feature of this logic. In this dynamic of promises and concerns, new technologies also need to be controlled and regulated (Fordyce, 2015; Record et al., 2015). A techno-economic logic enables practices in which the future is referred to with a sense of urgency and competition, and in which the aim is to intervene as early as possible in order to achieve a promise while avoiding potential risks.

We argue that the anticipations found in 3DP move between these two logics, open source and techno-economic. Similarly, the maker movement moves between four self-definitions: bourgeois pass time, innovation in education and technology, new renaissance reconciling liberal arts with science and engineering in a contemporary and playful way, and the new industrial revolution. But in practice the movement swifts between the first two definitions, while the latter two are just rhetorical means, romantic or rebellious (Maxigas and Troxler, 2014). However, rhetorical as they may be, these ideas guide and articulate some of the anticipatory practices in which actors in the field engage. Practices move between these two different logics, which makes the articulations about the future of 3DP a complex mixture of visions and expectations.

[5] Large companies such as Stratasys and 3D Systems have expanded their operations into the consumer domain.

3. Research questions and research approach

As we have introduced earlier, the purpose of this chapter is to enrich the discussion about anticipation in 3DP by looking at the material practices through which the future is anticipated. To do so, our main research question is: *How are expectations about 3DP embedded in material practices and what logics guide them*? Specifically, we want to study material practices and their relation to the future (as being informed by expectations, but also being aimed at shaping expectations) and the logics that guide these practices. Last, we want to reflect on how diverse practices, related to different logics, contribute to shape the field of 3DP.

To analyze these questions, we took a case study approach. These cases are built around 3D printing companies based in The Netherlands. Methodologically, we draw on 23 semi structured interviews (company CEOs, technology consultants, researchers), participants observation (attending two conferences and one trade show) and digital ethnography (Coleman, 2010) in selected 3D printing media sites, the crowdsourcing site Kickstarter, blogs and relevant social media.

While the actors presented in these cases only represent a fraction of the 3DP field, our analysis shows how diverse material practices and logics can be. We particularly focused on practices that are not explicitly anticipatory (as it would be the case of foresight) but rather material practices that have an anticipatory component. We analyze three companies that represent a wide range of positions, from open source to closed business models: Ultimaker, 3D Hubs and Printr. Two of these three companies are well known globally. Ultimaker is one of the oldest and leading companies in consumer 3D printers worldwide, and 3D Hubs is a recently developed platform that has had enormous success, being present in around 150 countries. These two companies are recognized for their contributions to innovation in consumer 3D printing.

Based on this data, we identified key practices in which these companies engage and their relation to visions and expectations. For identifying an anticipatory practice we searched for cases in which claims about the future (visions and expectations) were used to give meaning and to frame the practice, and in which the practice is meant to have an effect on the conceptions about the future of 3DP for a certain community of actors. For each anticipatory practice, we focused on the associated expectations, on the means by which it is constructed, and its effects in related communities. We classified these practices with respect to their guiding logic, be it open source, techno-economic or a combination of both.

4. Doing is believing: anticipatory practices and logics in 3DP

In this section we describe the material practices by which a set of actors in 3DP develop and embed visions of the technology. We show how these practices speak to different logics and the contradictions that might emerge.

4.1. From RepRap to the Ultimaker: the future is about sharing

Ultimaker is a consumer 3D printing Dutch company founded in 2011, 'spun out' from the RepRap Project. It is one of the most popular companies for 3DP in Europe (3D Hubs, 2015) and well known around the world. The company itself has strong roots

within the maker and the FabLab movements. The founder of the company, Erik De Bruijn was, since 2008, part of the original core team of the RepRap project, when he started producing his own RepRap machines.[6] He met the cofounders of the company, Siert Wijnia and Martijn Elserman while being directly involved in setting up one of the first Fablabs of the Netherlands, Protospace (Utrecht). For these communities, values of tinkering, sharing via open source hardware projects and self-empowerment are important and shape their practices (Nascimento, 2014).

From his first engagement with the RepRap, De Bruijn explains how it was important for him to actively construct the meaning of the technology. This was not just about rhetoric, but work such as building your own 3D printer in cooperation with a community. In this context the company was founded, seen as part of the developments that will fulfill the promise of 3D printing. As explained by De Bruijn, this is,

> 'in a way that is I guess less morally driven, but it is actually a technology that is empowering people. (…) the companies that made it more accessible made something different than what the hackers and the tinkers made for themselves' (Interview 7, Erik de Bruijn).

This is how this company keeps the vision of 3DP alive and feasible while being pragmatic about its normative commitments.

We describe two of these anticipatory, material practices: the sharing of source files for their machines and the developing of a sharing license for 3DP. We will argue that these two practices respond mainly to open source logic.

4.1.1. Sharing the Ultimaker 2

The Ultimaker defines itself as an open source 'inspired' company[7], concerned with meeting the expectations of their 'community' of users. Being identified as open source is an important aspect in order to engage with a particular community and enable their vision of 3DP. Open source practices are essential for spreading 3D printing and encouraging open innovation.

In this context, the source files for the Ultimaker 2, the latest printer released by the company, were made available in the sharing site YouMagine and GitHub[8] six months after the release of the Ultimaker 2 in March of 2014 (Park-On, 2014). The release of these files was referred to numerous times in specialized media, blogs and forums. The files were released under a Creative commons non-commercial (CC BY-NC) license, which enables the use of the files but not to profit from them. As framed in the release site in YouMagine,

> 'It is our firm belief that sharing knowledge does not mean losing knowledge. On the contrary, we learn from each other, inspire each other and use each other's knowledge to create even better products and develop impressive innovations world-wide' (Ultimaker, 2014).

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[6] At the time he started working in the project he was a Master's student in Economics. He wrote his thesis in relation to the RepRap project that gave him a good overview of the market of 3D printing.

[7] It is out of the scope of this paper to assess if the Ultimaker is or is not really open source, but rather, what does it mean to define a company as such.

[8] GitHub is a web-based repository for publishing and sharing source code (software), but also a social networking site for programming

Ultimaker users positively received this action. However, some blogs and forums questioned the open source status of this particular practice. We looked at the discussions occurring in the YouMagine blog (Ultimaker, 2014) and in the RepRap forum (RepRap, 2014). In these forums, the open source status of this release was questioned. Some users questioned if a six-month delay for the release of the files, under a non-commercial license, could still be called open source. Strictly speaking and borrowing directly from open source software definitions, open source licenses should allow the commercial use of the files that are being shared (Open Source Hardware Association, 2014).

It was questioned if this release was motivated by business interest instead of the open source ethos (comment by bld, YouMagine blog, May 2014). Other users would argue that this indeed qualified as an open source practice, because the definition of open source had to be rethought to be useful to companies that wanted to invest in R&D, in a context of growing interest and competition among 3DP companies (comment by Dani Epstein, YouMagine blog, December 2014).

The way the 'community' discussed this particular practice speaks to questions of the future of open source moving into hardware and its relation with the global 3D printing industry. For the Ultimaker, releasing the files of the Ultimaker 2 is a way to make clear their own commitments with the way they think the industry should develop to ultimately, fulfill the 3D printing visions. For users this open source release can be seen either as a marketing practice, or as a legitimate transition to how open source hardware from a company perspective. More fundamentally, it is these 'open source hardware' practices that are questioned, rethinking how they should be embedded in an environment subjected to market demands. Thus, the specificities of what is released, when and how are relevant and help to re-define the practice itself, as well as the relation between open source and the vision of 3D printing.

4.1.2. 3DP sharing license

A second practice in which Ultimaker engages is the development of a sharing license for 3DP. In order to build and enable 3DP, Ultimaker supports the development of the site YouMagine, an 'online community for everyone who's eager to explore the world of 3D printing'.[9] This platform was built in response to the changes in Thingiverse, the original sharing site associated to Makerbot. Following Makerbot acquisition by Stratasys, Thingiverse modified its Terms of Service (ToS) to an irrevocable license of broader scope, causing some disappointment in the 3D printing community (Dickel et al., 2014). The members of the community argued that the platform was not open anymore and that it has betrayed their ethos (Moilanen et al., 2015). A number of alternatives emerged, including YouMagine. De Bruijn explains his motivation to build this platform:

> 'I'm personally on a mission to encourage people to share more, to empower others and to allow global collaboration. The technology to create things, in the hands of the many can lead us into a new age of innovation and prosperity. YouMagine could play a large role in this. (…) From before it became part of Makerbot until recently, I've been a huge advocate of Thingiverse. Me and many maker/RepRap friends believe we've helped make it happen. But now Thingiverse isn't what it used to be. There has to be a good place to share, and I intend to make YouMagine as friendly as possible and stick to our ideals' (Peels, 2014b).

[9] Available at: https://www.youmagine.com/

He emphasizes the need to enable a platform for people to share. However, these are not sharing platforms just for today. They are built and transformed in order to fulfill a specific vision of tomorrow, a vision about collaborative innovation. Currently, YouMagine works as many other online platforms[10] (such as Instructables, among others) where members, via free registration, can upload their 3D designs and share them with other members, or use the ones available. It is expected that in the future new functionalities will be enabled in the site, in order for YouMagine to become a true sharing platform.[11] It is envisioned as a site that enables and encourages collective projects from all over the world to flourish, such as the e-nabling project (Dickel et al., 2014). There are two requirements: to enable a group functionality in the site and to develop a license appropriate for these sharing projects. The community manager of YouMagine explains the logic of this license, how it relates to the Ultimaker's vision of 3DP and why none of the existing licenses fulfills this requirement. He explains how a future of sharing and innovation needs to be supported by appropriate technical and legal means, and once these are in place sharing will happen, almost naturally. This new form of sharing is central to the vision of 3D printing, up to being referred to as the 'killer app of the technology' (Interview 6, consultant, 22 October 2014).

> 'We hope we make a license that would work given what we think the future is. (…) Our goal is to make people share, this is the new thing, the killer app. Cause the whole one-guy-making-one-thing everyone else is already doing. One company locking up one design of technology everyone else is already doing it, so we are gonna do the opposite, which is don't lock anything up and let everything be available for remix. Copy-paste all the things. (…). We are not very philosophical about it but we are very goal oriented towards that. Anything not sharing it doesn't make sense for us. [Furthermore, later he adds] Our vision of the future is people sharing, and that's why we do it. We hope we kind of make a license that would work given what we think the future is' (Interview 6, consultant, 22 October 2014).

In March 2015 a beta version of the sharing license, named 3DPL was released (Peels, 2015a). The developers explicitly asked for feedback for this version from the broader community of 3DP users and enthusiasts. The license addresses issues of Intellectual Property, and encourages sharing and remixing, making explicit the rights and responsibilities of those who are part of this remixing process.

The 3DP community received the release of the license with some skepticism. Users that responded to the release questioned the need of yet another open source license, when there are other licenses available such as GNU or CC.[12] Users argue that there are already many private actors releasing their own licenses and this seems like a marketing tool (YouMagine.com, *Leigh Dodds* 6 March 2015). These users also questioned whether some specific aspects of the license would enable sharing, such as the attribution sign and the penalty system. The license proposes to add to each print a sign that enable consumers to track back the source and the history of production of the object, a form of traceability of 3D printed objects (Peels, 2015b).

These questions, concerns and criticisms were discussed during a Google Hangout session organized by YouMagine.[13] During this session it was emphasized that the difference the 3DPL license wanted to make was to enable sharing and remixing. This

[10] Gillespie (2010) shows that these online platforms fulfill different discursive roles, shaping the politics of information circulation through the Internet.

[12] One unsettled topic in the open hardware movements is if the existing 'open' licenses, such as GNU and Creative Commons are suitable for hardware and 3D printed objects (Greenbaum, 2012).

[13] Available at: https://plus.google.com/events/cntm9mtvvqjr7bok6rm9qleif2c

is something that will become more and more relevant in the future, when distributed innovation enabled by 3D printers, becomes a mainstream issue. Thus, developing this license is anticipatory, as they argue; this is the time when efforts are worth taking in shaping the technology, before it becomes mainstream and stabilized. However, for users this particular anticipation seems to be still too early.

4.1.3. Ultimaker and an open source logic

We have shown how two of the practices in which Ultimaker engages, the release of files presented as open source and the development of a sharing license for 3DP objects, are anticipatory. These two practices are informed by the visions and expectations the company has, and at the same time they are used as means to spread these expectations and actively shape the future in a particular way. This shows how these visions and expectations are materially embedded but it is the materiality and its context that is contested. We argue that these practices are guided by what we call open source logic because they speak to and try to change the current innovation regime via the development of technical and legal means, and this development is open (to community considerations) and recursive. For example, the release of the files of the Ultimaker 2 is not only relevant for the company itself, but it leads to a reflection about what open hardware means in the changing context of 3D printing.

4.2. 3D hubs and the raise of a global 3D printing community

In the last 4 years the number of consumer 3D printers available in the world has increased exponentially as well as the number of companies that produce consumer 3DP. This includes 'old RepRaps in new dresses' (Interview 6, 3DP consultant, 22-10-2014) as well as innovative machines that are bringing other types of technologies[14] to consumers. In this dynamic context, another type of company has emerged, what is often referred to as service bureaus (Reeves, 2014). These companies are online 'marketplace' platforms (websites) where consumers can order to print their 3D designs on demand. These companies (such as Shapeweays, Sculpteo or i.materialize) often have their own 'factories' with industrial 3D machines available and offer the service of delivery, as well as pre-made designs.

In the summer of 2013, two young Dutch entrepreneurs funded one of the newest and most innovative of these service bureaus. 3D Hubs, as the name indicates, is a platform, an 'online hub' that 'connects people who want to 3D print with people that own a 3D printer', anytime and anywhere in the world, promoting local production and the expansion of the use of 3DP. In order to do so, owners of 3DP sign up to offer printing services locally, which people interested in printing can access on demand and via subscription to the site. Very quickly, the website has become very successful, growing exponentially with nearly 15,000 printers listed in over 140 countries.[15]

Brian Garret and Bram de Zwart, the co-founders of 3D Hubs wanted to start a company that could really fulfill the promise of 3DP, which they defined as the local

[14] In addition to fused deposition modeling (FDM) machines, which is the most popular type of consumer 3DP, in recent years other technologies such as stereolithography (SLA) have been adapted for consumer, adding also new materials.

[15] This number of printers corresponds to June 2015. As mentioned in the introduction, by the beginning of 2015 this number was 10,000 printers. The variation shows the rapid growth of the 3D Hubs network. Up-to-date information is available at: https://www.3dhubs.com/

and distributed capacity of manufacturing. Their motivation was based on the assumption that the promise of 3DP of local and on demand production was not being fulfilled fast enough (Peels, 2014a). The head of community of 3D Hubs explains this motivation as giving access to 3D printing to a wider range of people:

> '(…)3D printing harvests a huge potential for social reformation, and decentralization of manufacturing and thus economic power, decentralizing wealth. Current manufacturing methods centralize both the wealth and the power. So I guess most in terms of accessibility and social potential 3D printing wasn't doing much a year ago [in 2013]. So, we figured, the sales were rising already, sales of desktops machines and new technology came to market very quickly, so we thought we need to give more access to it (…) (because) individuals have half a million machines on their desktop, which is the technical potential' (Interview 19, community manager, 28 November 2014).

3D Hubs frames fulfilling the vision of 3DP as an issue of access. We will describe two of the anticipatory practices 3D Hubs engages in. The first one is creating and enabling local 3D printing communities and the second, the release of Trend Reports.

4.2.1. Unlocking the Hub

According to the founders, to fulfill the promise of 3D printing, the local capacity of manufacturing needs to be 'unlocked'. Unlocking means to enable every owner of a 3DP to offer the service of local production through the 3D Hubs platform. The platform of 3D Hubs enables owners of 3D printers to open 'a hub' where they can offer a printing service. Among the 'hubs' there are individuals, maker spaces, companies, associations, etc. These hubs are created and sustained by a combination of offline and online activities.

Each of these hubs is composed by many local 3D printers. In order to enable a hub to be listed in the 3D Hubs site and opened in a specific location, there is an 'unlocking' mechanism. The Head of Community explains how this mechanism works:

> 'An early adopter, a 3D printer enthusiast, they see this rule and they are gonna ask all his (sic) friends to join, not realizing that they are building the community already. They would get 20 printers listed, (…), the marketplace as a place works, and then we unlock the community, we throw a party and there is a lot of PR, and more people come and more consumers come. This was also a growth tactic, which was also leading to the foundation of the community. And after the community is unlocked we open the position for mayorship, which is basically a volunteer who shares our vision, the things where we started and he wants to make that happen' (Interview 19, community manager, 28 January 2014).

This unlocking mechanism enables 3D Hubs to build and support and coordinate their communities, both online and offline. These communities are organized around the vision of 3DP, particularly the vision and values shared by "geek publics" of open, local and distributed production. However, their daily choices are very pragmatic and there is space for all beliefs and motives. Yet members sustain these hubs because they believe in the vision and are willing to work for it (Interview 19, community manager, 28-1-2014). The vision of 3D printing of increasing accessibility is able to accommodate divergent and diverse expectations.

This practice is central to the functioning of 3D Hubs. One of the functions of the hub is to spread their vision and specific expectations about 3DP. Some of the events that are organized in a Hub discuss recent developments in the field (including, for example, materials, procedures) and keep the hub community together. This is what the

company calls 'the network effect',[16] against which they benchmark themselves in comparison to similar companies (Shapeways, MakeXYZ, etc). This 'effect' is about being able to offer a diversity of services to one consumer based on the availability of the network, much in line with the idea of a sharing economy.

4.2.2. Releasing the trend report

In order to give an overview of their market and community, 3D Hubs releases monthly Trend Reports. These reports are produced by the operation of the network itself: with almost 15,000 3D printers, it leverages the data produced from the reviews of users and owners of 3D printers. The report is constantly updated, based on an algorithm that takes and analyzes the data from the site. It is presented as authoritative knowledge about the 3D Hub's network and consumer 3D printers in general. These free reports show the growth of the network, what is being printed, the preferred machines, geographical distribution and others. The head of community explains that these reports are for free because 'the data is basically from the community, they give it to us by joining the network, makes sense to give it back' *(*Interview 19, community manager, 28 January 2014).

These reports[17] include a ranking of the most wanted and best evaluated 3D printers (model and company) in different geographical locations, for both consumer and industrial 3D printers. To assess the quality of prints of a certain machine, 3D Hubs has created its own standard, the Marvin figure. This is the print of a model based on the character 'Marvin the Martian' by Warner brothers. When a new printer is added to the network it is asked to print a Marvin and send pictures of the result to 3D Hubs.[18] Because of the popularity of 3D Hubs among consumer 3D printers, and thus its trend reports, the Marvin has become the *de facto* standard to assess the quality of prints for an important part of the community.

The report (latest edition in April, 2015) shows that the 3D Hubs network is largely composed by desktop 3D printers, with a smaller portion of industrial machines. The report is used by many 3D printer companies for benchmarking purposes, and by experts and consultants in the field to assess the state of the technology.[19] It gets legitimacy from the fact that the data is produced by the 3D Hubs 'community' rather than individual experts. These free reports are circulated through various 3DP news sites and are quoted as authoritative sources for the state of the industry.

[16] 'Network effect' refers to an effect in economics, related to the value that one user of a service has for the value of that product for other people; the value of the product is dependent on the number of people using it, i.e. the network. The interviewee refers to this effect as 'something we did not anticipate so fast is the whole network effect of it, so the whole accessibility of 3D printing that was a pretty clear idea, people listed it and just like Airbnb. But what Airbnb doesn't have it's a network, so you don't link the different departments in any way. We can, we have like a central brain, network, and we put like assignments in all kinds of different machines so you really get the network effect' (Interview 19, community manager, 28-1-2014).

[17] Available at: https://www.3dhubs.com/trends

[18] See, for example: https://www.3dhubs.com/talk/thread/marvin

[19] These reports are quoted and analyzed in 3D printed specialized media such as 3dprintingindustry.com, 3ders.org and tctmagazine.com, among others.

At the beginning of 2015 the company also released a crowd-sourced guide to 3DP[20] based on the data generated by the reviews in their site. This report is introduced in the 3D Hubs site as:

> 'Which 3D Printer should I buy? is the most common question we at 3D Hubs are asked. We reached out to our global community of Hubs to learn from their experience and see what they thought of the 3D Printers they own. The 2015 3D Printer Guide is based on the reviews of 2,279 verified 3D Printer owners. Their collective 1623 years of 3D Printing experience coupled with 317,000 prints completed on 235 different 3D Printer models, makes this the most comprehensive guide available'.

Figure 1. Marvin Keychain by 3D Hubs (CC A-SA).[21]

The report is presented as the result of all the data gathered from the network and it reflects its depth and extension of the network. It comes to fill a void in relation to those newcomers to the technology who look for information about what printer is suitable for their needs, and it does so by leveraging the knowledge of a whole community of 3D printing enthusiasts, enforcing the collective identity of the field.

We would like to argue that these trend reports are anticipatory, in the sense that they provide innovation actors with a sense of prediction; they give a feeling of the momentum of the industry that encourage them to take certain decisions. These reports do not intend to represent the view of a set of experts, but the view of "the community" of 3D printer users. The sense of community and predictability, enabled by social media, has been discussed as 'myths' (Couldry, 2014). Second, this practice has effects that can be considered anticipatory coordination: because of the circulation of

[20] It is important to note that machines are ranked based on the score given by users to each of the printers. However, the categories in which these printers are scored (materials, print quality, community, operability, running costs, etc.) are hardly comparable. Also, the number of reviews that are used to score a printer is very variable. For example, a Builder Dual Feed machine is ranked second on the basis of 6 reviews (score 8.7) while the Ultimaker 2 is ranked 6th on the basis of 142 reviews (score 8.6) (available at: https://www.3dhubs.com/3d-printers). For this reason, the accuracy of this assessment can be easily questioned; however, it is treated as a legitimate report for actors in the field. The 3D printer guide can be found at: https://www.3dhubs.com/best-3d-printer-guide

[21] Available at: http://www.thingiverse.com/thing:215703

information about its network 3D Hubs defines relevant categories and sets standards, not only within the network but in the broader 3D printing field. This can be considered a form of infrastructural knowledge, a way of shaping innovation by proactively naming and defining emerging technologies (Pollock and Williams, 2010). While in these reports there are no explicit forecasts, these trends implicitly give an idea of the current momentum the field is going through and what is to be expected. Positive but critical interpretations of these reports are presented in the specialized media or by consultants in the field, who used them to explicitly spot trends. The report also serves to highlight and reinforce the key position of 3D Hubs in the field.

4.2.3. The logic of unlocking a network

The two practices we have highlighted in this section, unlocking communities and releasing trend reports, contribute to shaping and fulfilling the vision of 3D printing which·3D Hubs stands for: increase the accessibility of available machines and unlock its technical potential (i.e., increase usage/time) in a decentralized way. This promise is about distributed, local manufacturing accessible to the highest number of people possible, with a potential disruptive effect in society. For this reason, constituting a self-organized network, making this network visible, defining standards and engaging more users are essential steps on the path.

We suggest that the anticipatory practices in which 3D Hubs engages in are characterized by a mixed logic, both open source and techno-economic. While the network of 3D Hubs is co-constructed between the company and its users, the company determines the technical means and definitions over the network. They set standards, mechanism of transactions and the type of publics of the network. Visions and expectations of 3D printing are used as a means to bring the network together, but not necessarily to open its practices. However, each of the local hubs is to a large extent self-organized and instances of recursive and exploratory practice might happen in these local settings.

4.3. PrintR and the missing element of 3DP

PrintR is a Dutch company formed in Enschede, the Netherlands who offer an online platform for 3D printing. Their motivation is to bring 3D printing to a wider public by facilitating the process, including design and printing. There have been numerous software solutions introduced to the market to facilitate the printing process (Milkert, 2014). Their solution is composed of a series of products: Formide and FormideOS, the platform itself and the software, and The Element, a 'dongle'[22] that promises to make the process of 3D printing much easier and reliable.

This small company, as many others in 3D printing, has gone through a crowdsourcing campaign via the site Kickstarter. A crowdsourcing campaign is an online event where funding is collected for a particular technology. Crowdsourcing can be considered anticipatory because specific expectations about a product are spread in order to create enthusiasm and collect financial resources. This practice has been quite relevant as a means of funding technology startups in early stages in 3D printing, and

[22] A dongle is a small piece of hardware that attaches to a computer, TV, or other electronic device in order to enable additional functions such as copy protection, audio, video, games, data, or other services. These services are available only when the dongle is attached.

this is why we consider this particular case in detail. Some of the most successful consumer 3DP companies, such as FormLabs and Zortrax, have been founded via Kickstarter or Indiegogo campaigns. In fact, every week there is a new 3D printer or related product promoted in Kickstarter, and experts (consultants) in the field follow the developments in these websites to get an idea where the field is moving (Interview 6, consultant, 22 October 2014).

The particular crowdsourcing campaign of Printr was organized in the context of a Dutch boot camp for technology startups. This Kickstarter of 'The Element' was aimed at covering the production costs of this new product.

4.3.1. 'The Element' Kickstarter

As explained by one of the members of Printr, the motivation to go for a Kickstarter was the outreach and marketing possibilities such an exercise enables:

> 'It was our idea to start the Kickstarter and the reason for that is that with Kickstarter you have a huge reach. Specially for marketing purposes, Kickstarter is way better. Cause if we would have just opened up a preorder system is not really big or you don't get a lot of media coverage or something like that. And if you do a Kickstarter campaign that explains your idea and your product … We got a lot of people worldwide backing us now, and buying our products. So for marketing purposes it is a really good platform' (Interview 10, community manager, 26 February 2015).

A Kickstarter campaign has a standard format. An idea is presented that can be translated into products and those who support the idea–'backers' or financial supporters–receive some benefit (including, for example, getting it first, a t-shirt, or being part of the dream). As introduction there is a promotional video and a general explanation about what the project is about and its main features. The funding mechanism is based on what backers contribute. There is a list of fixed types of contributions that backers can choose from, which specifies the type of 'reward' per contribution. For example, for a contribution of 10 euros you can get a keychain, while in order to obtain the actual product it is necessary to contribute at least 75 euros. There is a timeline that describes the milestones of the project, so the backers know what to expect and when.

There is a Risk and Challenges section, FAQ and the possibility for people to ask questions, add comments or send private messages. In this sense, the Kickstarter page is not static and updates can be made to the project, there is space for interaction with backers and projects get considerable feedback for their products. This is one of the aspects of crowdsourcing that the company Printr considered most interesting but most challenging, because it requires constant attention to the questions raised. In terms of the expectations that are presented in the page, these are rather specific to what the technology has to offer. There are rarely references to grand visions, although 'The Element' is presented in the context of the big promise of 3D printing. For example, in the Q&A section, one of the points referred to is if it is open source or not. A member of the company explains why they addressed this topic explicitly:

> 'it is important because the entire 3DP community exists from open source. So started with RepRap and so people jumped into it and built over it, so almost the entire community is open source. I think especially for the really geeky-techy kind of people it is really important to have open source things in it. Also for them to build on top of it' (Interview 10, community manager, 26 February 2015).

Being somehow open source, is in this case a way to refer and relate to a specific 'geeky-techy' community and a particular way in which the community organizes through the technology ('they build on top of it'). However, they are not sure which parts would be open source, everything that runs in their servers is proprietary, and that maybe some APIs[23] and the slicer[24] will be open. The open source aspect is still a promise.

The campaign made it into the Kickstarter Staff Pick[25] and it was featured in more than thirty 3DP news sites. However, and because the goal was quite high (100,000 euros) the campaign did not succeed. The campaign was closed with contributions for 44,000 euros[26] and it succeeded in attracting lots of attention from all over the world. This attention was later taken up in a forum and a system of pre-order of 'The Element' in the Printr site.[27] Thus, while the crowdsourcing was not accomplished, the marketing effect was the desired one.

Beyond this particular instance, crowdsourcing is a relevant but not uncontested funding model for new 3DP companies. In a recent piece in the site 3DPrintIndustry.com, the author examines the challenges crowdsourcing brings for the industry (Grant, 2014a). By 2014, there were at least 200 3D printing companies that were funded through a Kickstarter campaign (Grant, 2014b). The author argues that this model that in principle is aimed at opening up the process of innovation, can lead to overpromising and exaggeration of the qualities and expectations of a certain product, to which there is no clear accountability.

Among the main criticism to this form of funding is that it raises wrong expectations in relation to product price and functionality, far lower than the market prices. For this reason, projects often do not deliver in time what was promised, but responsibilities for project delay or failure are not often clear (Grant, 2014c). Kickstarter does not take responsibility for the promises, expectations and disappointment that might arise from the projects.

> 'The creator is solely responsible for fulfilling the promises made in their project. If they're unable to satisfy the terms of this agreement, they may be subject to legal action by backers' (Kickstarter, 2015).

Thus, while the crowdsourcing model appears as a way of opening up the process of sharing expectations and funding a new technology development, it becomes also a space for overpromising which might fuel hype. This is partly because it has become a marketing tool but also because of the proliferation of crowdfunding campaigns and the lack of accountability of these. We would like to argue that the logic within these sites is less about opening up expectations but rather a techno-economic one. Expectations are presented in terms of their future benefits and gains and at the same time the risks are assessed, and backers are invited to join the project by assessing the financial value

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[23] An API or Application Programming Interface is a set of routines, protocols and tools for building software applications. APIs work as building blocks for programs other developers can use and build on. For social networking sites, APIs are used to connect between one application and other.

[24] A slicer is the program that defines how a 3D design is going to be printed, optimizing the extrusion of plastic, movement of nozzle and other functions required for this task. There are various open source slicers, the most common being the Cura Slicer.

[25] Kickstarter's Staff Picks get prime placement on the website and are promoted to the followers of Kickstarter in social media, as well as via Kickstarter email list as 'Projects We Love'.

[26] According to Kickstarter policy, the funding goal is an all-or-nothing, so if the goal is not reached no money is funds are obtained by the Project.

[27] Available at: https://formide.com/

of the proposed product. While ideas of 'open source' are referred to, they are used for legitimation instead of as a mean to open up the technology.

5. Discussion

We have shown that there are a variety of anticipatory practices in which 3D printing actors engage in. All these practices have in common that they refer to a vision of the future of 3D printing, in which the digital is meshed with the material−atoms to data. In this new configuration, anybody can make almost anything, anytime, and as a result there is redistribution of the capacity of manufacturing and ultimately wealth. All these practices speak to an imagined community of makers, users, 3DP enthusiasts or citizens.

We can consider the relation between these expectations and practices a dual one. As we have shown, expectations inform and produce material practices, that we call anticipatory, which at the same time are used to shape these expectations. The anticipatory practices described in this chapter are framed in relation to visions of 3D printing, and they are deployed with the purpose of advancing this vision. The effect of these practices is to further articulate anticipatory processes in the community the actors are embedded in. The specific type of anticipatory effect each practice has varies considerably. For example, in the case of the development of a sharing license by Ultimaker, this practice is deployed in order to concretize a particular vision of 3D printing about the role of the technology in enabling open innovation. This vision is, however, contested by the users' community of the Ultimaker: they do not see the need for the development of a sharing license, and some consider the proposed model of innovation unrealistic.

The anticipatory effect of this practice is to open up a space for discussion of different future paths of development of 3DP: one that promotes sharing and open innovation, and one that promotes individual entrepreneurship. In contrast, the specific expectations that are created and mobilized in the Kickstarter campaign of PrintR are successfully spread to a community of users, despite of the failure of the campaign itself. Its effect is on the one hand, increase the attention and expand the network of users of PrintR, but also, increase the attention to the technology in general, potentially contributing to hype–this ultimate effect being anticipatory. The difference in anticipatory effects lies partly in the type of expectations that are mobilized in each case: while the Ultimaker is explicitly normative about the role of 3DP in society, PrintR presents a set of expectations that do not challenge the collective ones, appearing as 'neutral'. In that sense, it reinforces collective expectations. Thus, the type of expectations that inform and frame a practice will influence to a certain extent its anticipatory effect. This is a recursive process in which material practices and expectations are coproduced.

These practices are shaped by the context in which the technologies develop and at the same time shape this context. They serve as a way to explore and define socio-technical arrangements for 3DP relevant for each of these actors. For example, the way 3D Hubs and the Ultimaker construct their communities relates and translates into a particular way of seeing 3DP embedded in society. In both cases, the aim is to enhance local communities, distributed innovation and empower users. However, how much these communities are engaged actively in technology development differs for each

case, and in the case of the Ultimaker there is an explicit aim to allow users to contribute to technology development.

We argue that these differences are partly explained by the different logics that guide these practices. While open source logic explicitly aims to open up the blackbox of technology and engage users in the development, a techno-economic logic pushes the development of a technology forward by providing a sense of need, urgency and competition. In most practices these two logics coexists and steer the same processes, and what we observe as a result is a combination of both. Similarly, it has been argued that technology development situates between techno-scientific and collective experimentation regimes, allowed by institutions and cultures of innovation that seek to emphasize the importance of distributed innovation by embedding it in existing structures (Felt and Wynne, 2007). What we show is that these two logics, and consequently these two regimes, are to be considered as 'ideal types', and that developments in the field move between the two. Actors see these two logics as complementary approaches to technology development in which they need to move about. We see this in the three cases: Ultimaker maintains its open source ethos, while actively using it as a way to gain a central position in the consumer market and 'evangelize' the public about the promises and possibilities of 3D printing. 3D Hubs functions based on the strength of their communities, but also in making alliances with industrial players, securing their position in the network. Last, PrintR refers to open source practices as part of a marketing strategy that enables them to enter a particular community.

While our analysis refers to a few actors in the field, we show that there is a large diversity of material practices that more or less explicitly refer to expectations and that these practices are related to central aspects of the operations of each of these companies. Thinking of the larger field, there have been explicit attempts at shaping its expectations such as the development of roadmaps,[28] but as we have shown, much of the shaping of expectations happens on the micro level, in material practices in which relevant actors engage. Further research could look at the relation between these micro practices and broader, larger practices aimed explicitly at shaping the field at large.

Last, our account goes beyond an explanation where an open source logic is only seen as a rhetorical means for the 3DP printing movement, but rather we show that this logic effectively contributes to shaping some of the practices these actors engage in. Furthermore, it helps us to understand how open source logics are embedded, adapted and contested in relation to techno-economic ones, and gives some light into the future of innovation processes.

[28] For example, there was a roadmap produced in 2009 that was aimed at defining the industry into the future (Bourell et al., 2009)

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