Building Material

Exploring Playfulness of 3D Printers

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Abstract

This article explores the practice of 3D printers from a playful perspective. Using the Ultimaker Original as a case study, it addresses the question of whether the practice of open source software and hardware in 3D printing is inherently playful and how the user affects and is affected by its playability. After examining the materiality of open source development and hacking processes in the Ultimaker Original, I will argue how playfulness of 3D printing stimulates hacking the 3D printer. From a broader perspective, the playful practice of 3D printing can be seen as part of a general development towards the ludification of culture.

Keywords

Play, Playability, Playful Media, 3D Printing, Open Source Software, Open Source Hardware, Ludification, Hacking, Ludic culture

Introduction

In his recently published manifesto, game scholar Eric Zimmerman argues ‘the 21st century will be defined by games’ (2013). He states ‘when information is put at play, game-like experiences replace linear media. Media and culture in the Ludic Century is increasingly systemic, modular, customizable, and participatory. Games embody all of these characteristics in a very direct sense’ (Ibidem). Although I do not disagree with Zimmerman, perhaps a more nuanced approach is desirable. ‘Game-like experiences’ relate in a direct sense to playing computer games, and involve skills and knowledge related to games. As Katie Salen and Zimmerman himself have argued, there are multiple layers of playful expressions, game play, ludic activities and being playful (2004, p. 304). Where game play is the most rigid structure, ludic activities are less formal and being playful is a much broader category of play. Many game scholars agree that digital technologies seem to advance a culture of play (Raessens 2006, Montola et al. 2009, Deterding et al. 2011). And some scholars argue, there is a 'ludic turn in media theory' (Raessens 2012). In this article I propose to analyse cultural practices from a play perspective instead of a game perspective, which opens up an entire spectrum of media objects for game research. One such a recent phenomenon is the development of consumer 3D printers.

3D printing as technology is not a new technology – it has been around in professional industries for decades. However, in popular discourse there is rhetoric that 3D printing offers 'the promise of control over the physical world' (Lipson and Kurman 2013). Any object can be made digitally, and printed physically. '3D printing gives regular people powerful new tools of design and production' (Ibidem). This rhetoric of newness is something that is often seen in digital technology (Kücklich 2004, Lister et al. 2009, Schäfer 2011). The problem with the rhetoric of progress is that it stays on a macro-level, and does not account for the dynamic process on the micro-level between user and design. Scholars like Patrick Hood-Daniel, James Floyd Kelly and Brian Evans write about the design process and how a 3D printer works but remain descriptive in their literature.

3D printing for consumers is an idea that has been in development since 2004 by Adrian Bowyer and a select group of enthusiasts in the RepRap Project (RepRap 2013a). One of those people was Erik de Bruijn, who together with Siert Wijnia and Martijn Elserman invented the Ultimaker, an 'open source, large build platform derivative of the RepRap project' (RepRap 2013a). Companies like RepRap and Ultimaker supply do-it-yourself (DIY) kits for users to build their own 3D printer. When looking into the production of these consumer 3D printers, I found that companies like Ultimaker have a large community of users that 'hack' the software and hardware in these printers, and in turn help to innovate this technology. There seems to be certain playfulness in the practice of building and hacking a 3D printer. In addition to functionality and usability, playfulness is becoming an important aspect of the user experience (Arrasvuori et al. 2011, p. 1). As Marc Hassenzahl argues, emotional responses to a device or product depend on the interaction between perception, emotional responses in various situations, and the subjective nature of the experience (2003, p. 33),

This article deals with the notion of playfulness of the 3D printer Ultimaker Original. It addresses the question of whether the practice of open source software and hardware in 3D printing is inherently playful and how the user affects and is affected by its playability. Play perspective allows me to review the playfulness in the building and appropriation of DIY 3D printers, and their focus on open source software and hardware practices. This perspective of play serves as a hermeneutical tool to analyze hacking as a playful practice. Also, it permits me to investigate the ontologically playful nature of media phenomena like 3D printers. Game scholar Julian Kücklich argues that users experience freedom in media practices when submitting by the rules, which relates to the experience of pleasure of being in- and out of control (2004). According to Joost Raessens (2012) and Douglas Mark Rushkoff (2012) this dynamic constitutes four levels of playability, which can be understood as four stages of a player's interactivity. These four stages allow for different emotional experiences of playfulness, which is materialised in the playful experience (PLEX) framework (Arrasvuori 2011). Together these views on the notion of play and playability will form lenses to which this article investigates hacking the Ultimaker Original as a playful practice, and its playful affordances.

Having studied the practice of the Ultimaker intensively for two months and visiting the Ultimaker company in Geldermalsen (Holland) to learn more about open source hardware and software processes in 3D printing, I will use it as my main case study. Also, I have reviewed a selection of academic literature and media texts on 3D printing. To investigate the playfulness in the practice of 3D printing, I will first analyze the relationship between the user and the design process in open source software (OSS) and open source hardware (OSHW) in the Ultimaker. Furthermore, by comparing the modularity of OSS and OSWH processes with LEGO bricks, I will frame 3D printing as a ludic activity. Lastly, to argue for hacking as a playful media practice I will explore the relationship between different levels of playability and hacking practices.

3D Printing is Lego for Grownups

Tea. Earl Grey. Hot.

Popular discourses speculate about the meaning and future use of 3D printing. Every time an innovation is sold to the public, there seems to be an analogy with Star Trek. This time it is the Start Trek Replicator. "Tea. Earl Grey. Hot" a favorite drink from Captain Jean-Luc Picard, played by Patrick Stewart, is 'printed' by the replicator. This example is mentioned regularly as a future that we are moving towards (Carlson 2012, CNN 2012, De Wereld Draait Door 2012). The American company Makerbot has named their 3D printers 'Replicator' (Pettis 2012a). In *Fabricated: The New World of 3D Printing* (2013), robotics scholar Hod Lipson and technology blogger Melba Kurman provide the reader enough food for thought on the possibilities of 3D printing. Starting their book with a glimpse into the future through science fiction, the authors argue how 3D printing gives us control over the physical world.

Lipson and Kurman emphasise the instrumental materiality of 3D printing. Through examples in education, fashion industry, cuisine and science they argue that 3D printing will 'close the gulf that divides the virtual and physical worlds' (2013, p. 14). According to them, the convergence between physical and virtual worlds will happen in phases:

> "First we will gain control over the shape of physical things. Then we will gain new levels of control over their composition, the material they're made of. Finally, we will

> gain control over the behaviour of physical things." (Ibidem)

In this quote 'control over physical' means making all objects from the physical world that were hard to replicate before 3D printing. Through the translation of shapes and materials into binary language it is possible to print designs with holes, curves and inside chambers with different blends of previously incompatible materials. The authors claim 3D printing technology allows for a new materiality. Digital virtual is the space where laws of nature like gravity do not apply and virtual objects are easily distributed and remixed. In the digital physical, the laws of nature are translated into code, are remixed, distributed and then translated back again into a new physicality (Lipson and Kurman 2013, p. 13-7). By stating this, the authors imply that there is a digital/physical dichotomy, and argue 3D printing can resolve this gap.

Utopian discourses like these are blind sighting for what is really going on, and raise the need for a critical evaluation of the actual material aspects in 3D printing. Although 3D printing makes digital 3D models into physical objects, the authors seem to claim that a new physical reality shall emerge. This modernist belief in progress is something that clings to technological developments. Many scholars have criticized a recurring rhetoric of progress in technological developments like 3D printing (Kücklich 2004, Lister et al. 2009, Schäfer 2011). As I will show later on, materiality of 3D printing lies in the process of open source software and hardware. Seemingly, the materiality is not in the stuff that comes out, but the processes around 3D printing.

Open source tinkering

Open source innovation kick started development in 3D printing for consumers. It all started with RepRap. RepRap is a 'low cost open source rapid prototyping system that is capable of producing its own parts and can therefore be replicated easily.' (RepRap 2013). Fueling the machine and its development, there is a large group of hackers who create and share ideas on the RepRap Wiki. Other rapid prototyping systems, or 3D printers like Ultimaker or Makerbot, are based on RepRap developments (Makerbot 2012, RepRap 2013b). It is important to note that this development is based on open source ideology. Open source software (OSS) is based on the value that software is freely released. 'Free', in this context, means free for the public to distribute, modify and use. Or as information scholar Steven Weber argues, 'when you hear the term free software, think "free speech" not "free beer"'(2004 p. 5)[1].

The Open Source Initiative (OSI) has defined the core of free software in the Open Source Definition. OSS is based on open distribution, available for everyone and modifiable (Weber 2004, p. 5). Officially, for software to be called open source it has to meet the requirements defined by the OSI[2]. OSS is opposite from software that is closed, not open for distribution and protected for commercial reasons. At first impression OSS may not seem commercially interesting in terms of intellectual property or copyright. However, OSS has proven to be very successful at stimulating innovation and development (Weber 2004, von Hippel 2005). This is something that we see in the development from high cost, to low cost 3D printers:

> "[T]he cheapest commercial machine would cost you about €30,000. And it isn't even designed so that it can make itself. So what the RepRap team are doing is to develop and to give away the designs for a much cheaper machine with the novel capability of being able to self-copy (material costs are about €350)." (RepRap 2013b)

1. The term Free Software was coined by software freedom activist Richard Matthew Stallman, founder of the GNU project. GNU project's objective is to give freedom and control to computer users and their devices, by collectively developing and sharing software that is based on the rights for users to: Freely run the software, copy and distribute, study and modify the software (http://www.gnu.org/gnu/manifesto.html.en).
2. Extra information legal issues regarding the licencing in open source software and hardware, see the article 'Towards Open Source Hardware' by John R. Ackermann (2009).

Open source innovation like the RepRap Project has helped to develop ‘lessons that show that users can create, produce, diffuse, provide user field support for, update, and use complex products by and for themselves in the context of user innovation communities’ (von Hippel 2005, p. 14). This group of programmers fosters the use, sharing and remodeling of software and advocate to contribute improvements. So, OSS is modular, digital and easily changeable due to its open distribution and availability. However, what is interesting in 3D printing, is also the openness in sharing designs and knowledge about hardware.

The open source equivalent to hardware is called open source hardware (OSHW). OSHW works on the same principles as OSS. However, they are not a new phenomenon. DIY electronics have been around since tinkering with the radio. Fittingly, Tucson Amateur Packet Radio (TAPR) gives a commonly used definition of OSHW on their website:

> “Open Hardware is a thing – a physical artifact, either electrical or mechanical – whose design information is available to, and usable by, the public in a way that allows anyone to make, modify, distribute, and use that thing. In this preface, design information is called “documentation” and things created from it are called ‘products’.” (TAPR 2013)

Even though OSHW borrows most of its definition from OSS, the open design and sharing of blueprints for hardware differs from the nature of open source software. Software, because of its digital nature, cannot be patented. It can only be kept private. Hardware, on the other hand, is tangible and accompanied with legal issues like patents and intellectual property (Ackermann 2009). While OSS and OSHW are different on an instrumental level, they are interrelated. In some sense OSHW is the physical form of OSS. They are part of the same family where voluntary participation and actions like making, modifying, and distributing are central.

3D printing and LEGO

Experimental production is motivated by curiosity in knowing, pleasure in tinkering, learning about the ins and outs of a machine, and fueled by ideologies like the belief that this work can benefit society. In open source development von Hippel highlights fun, intellectual stimulation, creative experience, greater knowledge and acknowledgement as important factors (2005, p. 60-61). In 3D printers, autonomy, informal learning, relatedness and meaningful experience can be seen as important motivations for participating in development (de Bruijn 2011, p. 20-3). It is the curiosity to know how technology works, and the desire to break open the machine. Participants in the RepRap movement have argued 'it's good fun as well as a learning experience' (quoted from de Bruijn, p. 22). Although fun and informal learning seem to be important motivation, there also seems to be a belief in the broader societal significance in creating and building 3D printers. It is fueled from the intrinsic motivation that availability of 3D printers will have a big impact on society. 'The thought of helping to make 3D printing far more accessable [sic.] to most households and third world countries in the hopefully not-too-distant future' (Ibidem, p. 23). Experimental production of technology like 3D printers is an informal way of building, or tinkering.

While the ideological motivations of availability and access are also important to consider, I want to zoom into the way pleasure and informal learning can fuel open source innovation. Michel Resnick and Eric Rosenbaum describe tinkering as a specific approach to making and development. 'The tinkering approach is characterized by a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities' (2013, p. 164). Resnick and Rosenbaum explore the possibilities of tinkering in education for young students, and have worked together with the LEGO group to use LEGO Mindstorms in projects. Just like von Hippel, Resnick and Rosenbaum argue for playful ways to collaborate and gain knowledge about technology.

Pleasure in tinkering seems to play an important role in the development of 3D printing. In some ways, 3D printing is like LEGO for grownups[3]. The physicality of OSHW invites tinkering, playing with the machine. This resembles LEGO bricks, where the user can build, rebuild and share new inventions and ideas. Open source is flexible and can be used for different goals. The user can look into the software and hardware design, because of its open nature. Participation is voluntary, and the earlier successes of open source development are inviting. The interest in 3D printing seems to be more about the technology and how it works. The intrinsic motivations of the participant, and the playful building bricks are creating deeper knowledge and understanding of the technology in 3D printers. But to learn the extent of how the playful nature of the machine stimulates tinkering, I will take the reader deeper into the process of building a 3D printer.

Playful Process in Building 3D Printers

How-to-tinker

After seeing the playfulness in open source, lets take a closer look into the process of tinkering for the user. One of the problems in critically examining the newness of 3D printing is the descriptive nature of academic literature on the subject. When reviewing some books on 3D printers, a lot of them are about building a 3D printer, how to choose one, or how to use one. In *Printing in Plastic: Build Your Own 3D Printer* (2011) authors Patrick Hood-Daniel and James Floyd Kelly explain in detail how to build your own 3D printer. The authors take the reader step by step through the process of cutting the material and assembling it, assembling the motor and motor mount, the thermoplastic extruder, filament drive, mounting electronics, fixing the wiring like connecting power to the motherboard and motor, and finally installing the software (Hood-

3. LEGO products are constantly designed, targeted and sold to adult players as well. Some LEGO products are even used in the contexts and sites of serious play such as idea agencies and the like, see the book Toy Box Leadership. Leadership Lessons from the Toys You Loved as a Child, by Ron Hunter Jr. and Michael E. Waddell (2008).

Daniel and Floyd Kelly 2012. In *Practical 3D Printers* (2012) Brian Evans also describes how a 3D printer operates. The printer control application brings in the 3D model and sends it to a slicer application. Then, the printer control communicates with the firmware (specialized code), which runs on the electronics platform. The firmware controls electronics hardware to send the 3D objects according to the instructions received from the printer control and send data (temperature, positioning and other information) back to the control application (2012, p. 29). When building a 3D printer, the user learns into detail how the different parts make up the machine, how they operate and communicate with each other.

Because experiences is subjective in nature, it is impossible ‘to design an experience, but it is possible to design *for* an experience’ (Schifferstein and Hekkert 2008, Arrasvuori et al. 2011) In order to find out how the design affords playful experiences in building a 3D printer, lets try to break open the black box. In order to do this, we will need to examine its affordance, design and appropriation. According to Schäfer, all three aspects are intertwined: ‘appropriation is related to affordance, because the material characteristics and the design choices affect the act of appropriation. Design and the specific material qualities form the basis for use and appropriation’ (2011, p. 20).

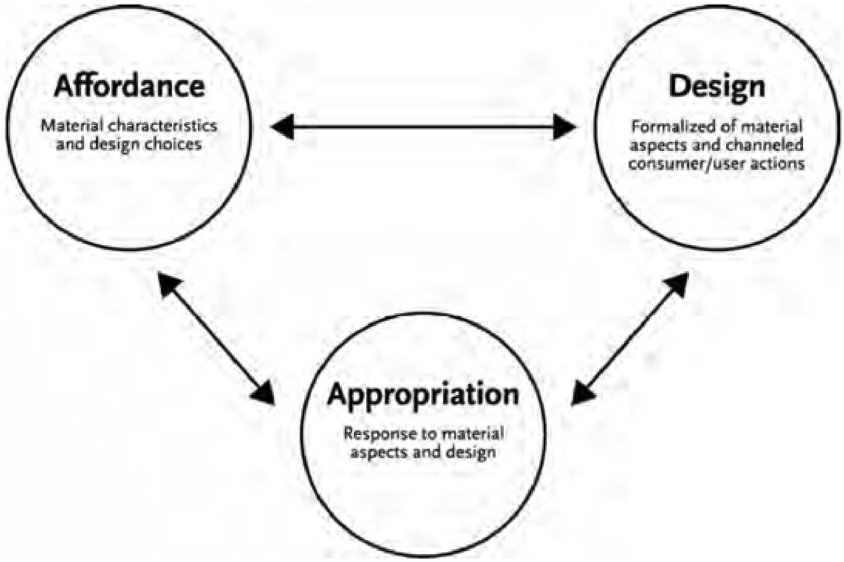

Figure 1: The interdependency of affordance, design and appropriation (Schäfer 2011, p. 20)

Firstly, looking at the affordance of 3D printing is describing its specificity. Here we are looking at the material aspects of the object, and the stuff that it is made of. Consider, for instance, the design of a couch and how it is made sit on. 'Affordance describes two characteristics, the material aspects, or the specificity of an object or a technology, and the affordance imposed on it through the design' (Schäfer 2011, p. 19). Secondly, when examining the design the need for 'evaluation of the specific features of materials used for a designated object, and an evaluation of the user's appropriation to be incorporated into a next level of development' (Ibidem, p. 19) arises. Lastly, by looking at the appropriation of 3D printing, this allows us to see the integration of 3D printing in everyday use, and how the users are adapting and transforming its original design. What is so interesting in the design aspects here is that the modularity of OSS and OSHW allow for a multitude of modifications. Users adapt and modify both software and hardware to fit their wishes and needs. Schäfer also argues the process of design is influenced by the maker's own social context and political mindset (Schäfer 2011, p. 19). In this case, the open source ideology of sharing design, no commercial ownership and giving back to the community plays an important role.

Some scholars argue playfulness is an important part of product design, and state there has been a shift from 'functional experiences (i.e., perceived usability and usefulness), to emotional experiences, the pleasures of using a product' (Arrasvuori et al. 2011, p. 2). In their research, Arrasvuori et al. differentiate emotional experiences into several categories. The playful experience (PLEX) framework consists of 22 types of emotional manifestations: captivation, challenge, competition, completion, control, cruelty, discovery, eroticism, exploration, expression, fantasy, fellowship, humor, nurture, relaxation, sensation, simulation, submission, subversion, suffering, sympathy, and thrill (Ibidem, p. 2). These different types of emotion serve as an important indication of the different types experiences the user goes through. For instance the thrill in discovering how the system of building a 3D printer works, the pleasure in experiencing the first 3D printed object, made by the printer that was assembled by the user his/hers own hands. Also, the frustration when a mistake means the device has to be de-assembled again. But these emotional states are important in learning how the machine works, and create pleasure in building a 3D printer.

The emphasis on the descriptive working of the technology diminishes the playful aspects of the tinkering process. Fortunately, in these 'how-to' books there are important clues that can show us how users interact with the rules of 3D printing. They show materiality in the practice of 3D printing and how design is made to evoke emotional experience. As mentioned before, an important motivation of putting together and developing a 3D printer is the pleasurable experience of knowing how the device works and learning new knowledge. Although the concept of emotion is complex and problematic, some scholars have attempted to develop frameworks for measuring and analysing emotional experience (Desmet 2005, Norman 2005, Arrasvuori et al. 2011). 'Using a product with a particular product character in a particular situation has certain emotional and behavioral *consequences'* (Hassenzahl 2003, p. 33).

Hassenzahl emphasizes how the subjective nature of experience is a culmination of its interaction with the perception of the device, and the emotional response to the product, create the user's subjective emotional experience. 'People construct the apparent product character based on the particular combination of product features and their personal standards and expectations' (Hassenzahl 2003, p. 33). The level of playability of the 3D printer depends on the expectations and tinkering experience of the user and the affordance of the product. A user, or player who wants to learn how a 3D printer works and use it, is able to work his way through the instructions, and following the rules. However, the playful design seduces the user to discover, and perhaps try to alter the 3D printer by reshaping the open source design.

Tinkering with hardware

The material design of the Ultimaker is plywood. This design has two specificities that draw the user into modifying a 3D printer. First, plywood in its bold form invites the user to be creative. You can change the color and finish if you like, or just keep it as it is. Secondly, the user has to put all the pieces of the Ultimaker together. The materials that are used to build the frame of the printer invite the user to modify the printer by changing the appearance, modifying from the inside creates deeper knowledge on how the device works. The affordance of plywood invites the playful experience of expression, where the user can be creative and use the 3D printer as a blank canvas. And it is also a form of relaxation, an easy modification that can be done without specific technical knowledge.

The only parts that come ready made are the electronics. The electronics include many parts that work together to build a 3D printer (Evans 2012, p. 30). Mostly, and as it is in the Ultimaker, a user doesn't have a lot of choice which electronics come with the printer. Ultimaker uses open source RepRap based electronics that has up to 5 stepper drivers. These steppers are used to drive the x-,y-,z- axes and the extruder. Although the electronics comes ready made, the user still has to hook it up to the printer itself. The user uses, or appropriates the 3D printer by actually assembling and de-assembling it. This way, tinkering with a 3D printer is actually part of its everyday use. In this process, the user can choose to either play the rules of the game, or break them and create something new that changes the shape or functionality of the 3D printer. Depending on the level of knowledge, the user can take control of his device and remodel the design, and some of the affordances. Later on I will dig into some examples of users whose modifications turned into innovations in the Ultimaker.

The big advantage when building a 3D printer, or in the case of the Ultimaker assembling it, is that the user really gets to know what kind of device they are dealing with. The user is not only building or assembling his or her own 3D printer, but also gaining knowledge about *how* this device works from the inside out. The affordance and design of OSHW invite the user to play. In 3D printing 'play is a style of engaging with the world, a process of testing the boundaries and experimenting with new possibilities' (Resnick and Rosenbaum 2013, p. 163). The user explores the underlying system of 3D printers by taking one piece, inspecting it and putting it together with other pieces, which in turn allows for the discovery of a new functionality. There is a constant feedback loop of captivation, exploration, discovery, challenge and completion.

Tinkering with software

As Resnick and Rosenbaum stress, a user can also tinker with software. They see 'tinkering as a style of making things, regardless of whether the things are physical or virtual' (2013, p. 166). Open source software in particular invites the user to try out different programs, or even create new ones. In the Ultimaker, there are different examples where users appropriate different types of software to fit their needs. A 3D printer has different types of software that work together to control the printer.

Control boards need firmware loaded on its microcontroller to make electronics come to life. Firmware is responsible for interpreting G-code commands sent to the electronics from the printer (Evans 2012, p. 35). Ultimaker firmware can run on Sprinter, but more commonly used is Marlin, which is based on Sprinter (Ultimaker 2013b). Each firmware has its own features, and the open source design from Ultimaker allows for different types of firmware to be installed, giving the user more freedom to choose a program or develop one of their own. These choices create a sense of ownership over the device, which invites the user to play with the system of the printer.

There is a separate application called a slicer to generate the path for the printer extruder, which takes a solid 3D model and slices it into layers suitable for 3D printing. This process makes the code that tells the 3D printer where to move the extruder, when to extrude plastic, and how muck to extrude. These commands are called G-code, and are sent from the printer control software to the firmware on the electronics. The electronics are responsible for interpreting these codes to control the printer motors and heaters. The most widely known slicing engine was Skeinforge, developed by a user in The RepRap Project (Evans 2012). Different companies use different engines, with all of their own algorithms. A downside of Skeinforge is the time it takes to translate 3D model into slices (Mazzotta 2013). Right now Ultimaker uses Cura, which has its own slicing engine and is a lot faster then Skeinforce.

The printer control application is the user interface. The host software, also named printer interface or printer control, is where the whole tool chain comes together (Evans 2012). From this application the printer connects and communicates to its firmware; moves the three different axes; reads and sets temperature for the hot end and the print bed; launches the slicer application and prints the 3D models. Ultimaker currently runs on Cura. Interestingly, the engine is developed by Ultimaker user David Braam as a better and faster alternative for Skeinforge. The Cura Engine is open source C++, and the console application is open source Python. It has been made as a better and faster alternative to the old Skeinforge engine[4]. Although

4. Cura was a solution for the usability of ReplicatorG. ReplicatorG is a printer control originally developed by 3D printing company Makerbot. ‘Where Skeinforge was the

Cura is fully preconfigured to work on the Ultimaker, you can also use it for RepRap printers.

The open source design of the Ultimaker invites the user to modify and tinker with the software. And the modification done by David Braam, originally an Ultimaker user, is a prime example how tinkering can lead to innovation within the 3D printing community. Braam developed Cura in his spare time to improve the functionality and user interaction (Benchoff 2013). In an interview with Braam, he states Cura is a lot more playable. You can 'play around with your 3D model, turn it around, play around with settings' (Mazzotta 2013). Sharing his open source program with the community, the program quickly became the new standard for the Ultimaker printer control. This example illustrates how the playful design of the Ultimaker and its open source affordance allows users to appropriate their device. Hacking the software of the 3D printer is a high level of playability that revolutionizes the game by changing the rules. Of course specific knowledge and programming skills are needed, but it illustrates how the playful experience of informal tinkering is an important factor in innovation within the community.

In short, because of the openness in affordance and the design, a user is invited to play with their 3D printer. The feedback loop in assembling the printer allows for multiple playful experiences, which vary on the basis of knowledge, skill, environment, and personal interest of the user. The modularity of the Ultimaker is like playing with LEGO, where the user learns how to build use and appropriate their printer. The tinkering affordance of the Ultimaker created space for developers like David Braam to create an application like Cura. The really interesting part about the open source system of the Ultimaker is that the design and affordance allow modifications on both the physical and the digital level, expanding modularity not only on a software level, but also on a hardware level. As such, the ontology of the 3D printer can be seen as playful. Its modularity

slicing engine that was widely adopted in the early days of the RepRap project, ReplicatorG, and the popularity of the MakerBot printers made this application synonymous with 3D printing' (Evans 2012, p. 43).

invites the user to play just like with LEGO bricks: tinker, experiment, and appropriate your 3D printer any way you like.

Playful Printer, Playful Practice

Playfulness of 3D printing

The modularity and open source development in 3D printing are playful. But 3D printing is also a playful practice. Kücklich argues that a perspective from game studies is especially fruitful to analyze media phenomena, because of its flexible nature and ability to both preserve and criticize their own theoretical framework (2004). When looking at 3D printing from a play perspective, it is necessary to further define it. When we are talking about play, Katie Salen and Eric Zimmerman argue ‘play is free movement within a more rigid structure’ (2004, p. 304). When looking into the way play manifests itself, the authors group three types of play; game play, ludic activities and being playful (Ibidem, p. 303).

The practice of 3D printing is a ludic activity. Ludic, meaning ‘*of or related to play’* can be play activities that not only form games, but also non-game behavior we call playing’ (Ibidem). Being playful ‘refers not only to typical play activities, but also to the idea of being in a playful state of mind’. Here the authors are referring to ordinary activities (Salen and Zimmerman 2004, p. 303). Tinkering with a 3D printer can be seen as a ludic activity. It is intentional and informal play, but still has some formal rules like the earlier discussed tool chain. In order to work properly, electronics need firmware to operate. Interestingly, as mentioned earlier, the modularity of open source has a playful nature. As shown before, models like open source are inherently playful.

Just as the open source system is both digital and virtual, the boundaries between play and non-play seem to fade. Media phenomena like 3D printing account for multiple transgressions of the boundary between play and reality (Kücklich 2004, p. 14). For instance, our mobile phones give us access to the Internet, carrying potential play with us everywhere we go. He argues there is 'ambiguity between openness and closure' (Ibidem). Media practices are ludic, and transgress the playful boundary between digital and everyday life. Moreover, as Kücklich argues, old dichotomies of virtual and real world, or open and closed do not apply (2004). Here he is referring to augmented reality, where play is still mediated by the mobile device.

In 3D printing, the aspect of play is mediated both digitally (software) and physically (hardware). The user is actively involved in the physical creation of a user's 3D printer. Like LEGO, the user gets a kit, which the user has to assemble his/herself. Instructions are given with tutorials that are also accessible via the Ultimaker website (2013a). The hybridity of both the physical and the digital aspect pose the need for a higher consciousness of the playfulness in open and closed spaces. 3D printing transgresses openness/closure of play and non-play and rethinks the blurred space of media practices,

Because of its affordance, the open source system is interchangeable. According to Rushkoff '"open source" development can be seen as infinite games' (2012, p. 248). He argues for a distinction between finite and infinite games and draws his argument based on the theory of James P. Carse:

> "The rules are changed when the players of an infinite game agree that the play is imperiled by a finite outcome – that is, by the victory of some players and the defeat of others. The rules of an infinite game are changed to prevent anyone from winning the game and to bring as many persons as possible into play (Carse quoted in Rushkoff 2012, p. 248).

Like Carse, Rushkoff makes a distinction between games as finite, or infinite games. Whereas the rules of a finite game have winners and losers, an infinite game is changed to prevent anyone from winning.

In the infinite play of open source, the rules of the game – as defined by OSI – are, availability, open distribution and open for modification. Interestingly, in 2012 Makerbot CEO Bre Pettis announced that the hardware of their latest 3D printer, Replicator 2, is not open source (Cnet 2012). Makerbot decided to go against the code of conduct, and not release the software and designs for their latest printer. This caused a real uproar in the OSHW community and lead to a few intense discussions on the Makerbot forum about ethics and intellectual property (Pettis 2012a, Brown 2012, Giseburt 2012). The real pain was caused by the commercialization of a product that once belonged to open source play. Even though the first Makerbot designs are inspired on RepRap, Makerbot decided to change the rules of the game and use closed code and hardware on their latest model. Which, in the eyes of the open source community, is spoiling the game. From a neo-liberal perspective, they can be seen as a winner. However, from a hacker perspective, the company of Makerbot is cheating. And as such, Makerbot is prevented from winning. The open source system can be seen as an infinite game, where there is a constant oscillation between the digital and physical materiality.

Hacking as a playful media practice

So, when looking at 3D printing from a play perspective, 3D printing is informal, ludic and infinite. The practice of hacking can be seen a mode of media consumption. 'Hacking as play has been seen as inseparable from the demands (in terms of expertise and time) of programming' (Lister et al. 2009, p. 291). Early home computing for the producers and users meant programming. To run most programs a basic knowledge of code was required. Just as in early home computers, 3D printers require technical skill on both the hardware and software side. The user has to know or learn the 'language' of 3D printing. How does the printer control 'talk' to the G-code in the firmware? What software is best suitable for my needs, and if there isn't any, can I build it? Of course, there are many different types of users.

As we have seen in the notion of play from Salen and Zimmerman, play can exist in both ludic activities and ordinary activities. So what is the scope of playful interaction between the players and

3D printing? Although it was Huizinga (1951) who first theorized different types of players, Raessens (2012) and Rushkoff (2012) have both argued these different levels account for different levels of playability in media practices. The practice of 3D printing can have four different levels of playability; the regular user, the cheater, the modder or programmer. First, there is the user who accepts the fact that the 'rules of a game are absolutely binding and allow no doubt' (Huizinga 1955, p. 11). This would be the type of user that would just be interested in the technology and how the user can play the game. In the Ultimaker, this is the user who 'just' assembles the printer. However, open source ideology allows and maybe even entices the user to start fooling around with the process. The cheater who "pretends to be playing the game" (Ibidem) operates at the second level. This player – for example the one who uses cheat codes in computer games – is aware of the explicit and implicit rules of the game and tries to deploy them (against the rules) to his own gain. Users who make use of the available open source applications for the Ultimaker, but do not share their new ideas with the community, can be seen as cheaters. This can be an explanation of the harsh response of the 3D printer community on Makerbot's decision to patent their products. At the third level we have the spoilsport, or the modder, "the player who trespasses against the rules or ignores them" (Ibidem). This is the user that modifies the game if the system affords it. OSS and OSHW afford for an entire reconstruction of the design and functionality of the 3D printer. Painting the Ultimaker can be seen as a form of light 'modding'. Finally, there is the 'outlaw, the revolutionary' (Ibidem, p. 12). Users like David Braam have modified the everyday use of the 3D printer by creating a new printer control, which revolutionized the speed and functionality of the Ultimaker.

In the Ultimaker, the rules of the game stimulate the player to experiment and bend the rules. Download other software, play with settings, and if possible, try to improve your model to your liking. Hacking the 3D printer becomes a level of playability and part of the media practice. Not everybody will redesign their Ultimaker to make it fit their needs. Regular players people just like to print 3D objects. However, the more skilled a user is, the more freedom in the system they experience. Playful practices such a building the Ultimaker 'teach players to think in an active way about complex phenomena … as dynamic, evolving systems' (Turkle 1995, p. 70). The player gains new experiences and affiliations, and preperation for new learning, something that literacy scholar James Paul Gee calls 'active learning' (2005, p. 24). The next level is, how can I improve my machine, and this is where hacking as a practice comes to life. As Rushkoff argues, the degree 'to which playability is introduced to a closed system, reflects the extent to which its participants can set their own rules' (2012, p. 249). The modder and programmers are exempting practices of hacking. The more the user hacks, develops or modifies, the more knowledge over the technology the user gains.

It is clear that the playfulness of 3D printing lies more in its technology and practice, than the act of printing. And as we see in the Ultimaker, hacking as a playful practice contributes largely to this development. Looking at the regular player, the objective is just to print cool objects. The tinkering involved is just putting the Ultimaker together, and when it works, it works. '[P]lay itself usually consists of learning those rules of the game world, as well as the interface' (Rushkoff 2012, p. 251). But as Kücklich argues, the pleasure in playability for the user is the 'individual who upholds the rules simply for the sake of the pleasure she derives from submitting to them' (2004, p. 33). Being able to print anything you like depends on submitting to the rules of the interface. But interestingly, the rules of playing with the Ultimaker are almost teasing to bend the rules and appropriate the machine to your liking, either physical or digital. This itch can be traced back to the 'intimate relationship between pleasure and control' (Ibidem). In the open source system, a player gets rewarded for their hacks and modifications. Hacking as a playful practice ultimately leads to more control within this system.

Oscillation of in- and out of control

According to Rushkoff the level of playability reflect autonomy and agency of the player (2012). But in the open source system, breaking the rules is an unwritten rule. So I think we should make the distinction here between individual agency and autonomy and systemic agency. Ultimaker has a close relationship with its modders and programmers. The company rewards hackers with the opportunity to develop their hacks to products and stimulates users to build new stuff, like LEGO. On their website, the company advocates the freedom to hack your 3D printer any way you like, either the hardware, software, electronics or material (Ultimaker 2013a). Increasing agency comes in different forms; personal pleasure; a deeper knowledge of the technology and working for bettering the community. As Kücklich argues, the pleasure of control exists on multiple levels, on an individual and systemic level (2004, p. 36).

Let's zoom into an example of an individual level: the Ulticontroller, created by Bernhard Kubicek in 2011 for Ultimaker Original. In 2012 he wrote his personal experience down in a 'tale of how a mere playful hardware hack developed into a product' (Kubicek 2012, p. 1). Bernhard Kubicek bought the Ultimaker Original and put it together in 2011. Ultimaker allows users to use different types of firmware on their 3D printers. Kubicek describes how he modified the firmware Sprinter to run on the Ultimaker Original, and 'made this configuration available to other people in the growing Ultimaker community' (2012, p. 1). He worked together with people from this community to increase the usability and to spread his hack. Because of the technical affordance of Sprinter to support SD cards, he developed the idea to print directly from an SD card in the Ultimaker. This means a user can print without the use of a computer and the software (Ibidem). He developed his first prototype, and writes:

> "The choice of how it should do what it should do were done by me: a guy who chooses mind over body, who is more concerned about his coffee machine than about his clothes. A guy who prefers building things to having a vibrant social live. Me, who dislikes apple, and loves Linux. Me, wanting to dominate the machine, knowing exactly what I want. Me, the typical hardware hacker, most likely your brother in arms. My satisfaction depends on how fast I can control the machine"(Ibidem, p. 2)

This quote illustrates pleasure of being in control (of the machine). On a personal level, Kubicek's pleasure comes from governing his own machine and a better understanding and deeper knowledge of the rules that govern the OSS and OSHW system.

In the example from Kubicek, we can see that the user has gained more autonomy. But the moment commercial interests are involved the oscillation of being in- and out-of control is visible. When other users and eventually Ultimaker got interested in the Ulticontroller, and organized a hackathon to tinker with the first prototype of the Ulticontroller. The biggest problem was that his hack wasn't aesthetically attractive, and needed more development:

> "It was like he spoke a different language when he argumented. He wanted one button and an encoder, ideally combined. […] For them [Ultimaker], the panel would be a nice add on to selling more printers. For me it was a nice hack" (Kubicek 2012, p. 3).

After the hackathon, Kubicek handed control over to Ultimaker, who developed the second prototype. For the hack to become a product that Ultimaker could sell, Kubicek had to hand over control of the device. According to himself, he was too involved emotionally; 'If somebody pointed out how I could improve my panel, it most often felt like a personal insult'. Here the loss of control is unpleasant at first, however later on the loss of control is pleasurable again.

Improvements on the prototype proved to be a success: 'the brain could not figure out, why it is so much better now than any of my designs attempts. I liked the shape. Honestly, I never thought about that' (Kubicek 2012, p. 4). Eventually, Kubicek learned more about industrial design principles, and gained a deeper knowledge on developing workable prototypes for the 3D printing community. Furthermore, on the Ultimaker store, they give full credit to Kubicek and link to his personal story (Ultimaker 2013c). As Kücklich argues, 'the loss of control is often experienced as enjoyable – if it alternates with the experience of being in control' (2004, p. 38). It is because of this oscillation of being in- and out of control on an individual level, that hacking – as a practice – seems to give more control to the user.

Kücklich argues 'the media practices that have emerged with new media technology draw attention to the fact that users are not content with the level of control they are granted by the producers of this technology' (2004, p. 36). He is referring to 'illegal' download activities and 'ripping' of CD's and DVD's. From the constructivist micro approach, the practice of hacking gives more control to users because of the dynamic relationship of affordance, design and appropriation. Redesigning the system, or changing the rules increases 'the notion of pleasure the user experiences (Kücklich 2004, Raessens 2012, Rushkoff 2012). Further research can go deeper into the relationship of control and agency on the systemic level.

So, from a play perspective 3D printing is an informal, infinite play in both hacking as a practice, and the nature of 3D printing. In this type of play, the rules are to break the rules. Just like LEGO, 3D printing is made out of building bricks that can be built, broken down, rearranged and put back together in a new form. There are multiple levels of playability, where the modder and programmer have the highest control on an individual level. There are still commercial interests that have agency on a systemic level, so further research may look into the dynamic relationship between the individual and systemic relationship of control.

Conclusion: Learning to Play by the Rules

As I have argued in this article, for now, 3D printing is more about the development of its hardware and software, than about the stuff that comes out when you hit print. This development is made possible by the collective effort of enthusiastic hackers. Where hackers used to be political activists in claiming the 'open space' of the Internet (Barlow 1996), now they are integrated in neo-liberal activities and invited in hackathons and forums to share ideas and knowledge. According to Henry Jenkins, this active involvement of media culture has begun to alter the character of new media. He recognizes the crossing of grassroots movement and corporate media through the concept of *Convergence Culture*: Media-savvy consumers turn into participants and are creating their own knowledge communities (Jenkins 2006). This influences the use of playful media. In this light hacking becomes a playful media practice. On a meso-level, companies like Ultimaker seem to stimulate such an environment, however more research needs to be done about their business relationship and the dynamic between user and producer.

According to Schäfer, material aspects have to be considered when analysing the use, change, and modification of technology like 3D printing. He argues that 'affordance describes two characteristics, the material aspects, or the specificity of an object or a technology, and the affordance imposed on it through the design' (2011,p. 19). Analysing the black box of the 3D printer shows its playfulness on a physical and digital level. The modularity of both software and hardware, and its open source design invites modification. As Rushkoff argues, open source can be seen as infinite (2012). Participants and nonparticipants work together im- or explicitly. I have argued from a play perspective; the hybridity of physical/digital hacking in open source environments stretches playful activities into a playful nature.

In their discussion on playful media, Montola et al. postulate the function of pervasive play in teaching media literacy skills. They argue it is a 'societal response to the need for advanced media literacy' (2009, p. 276). This is in agreement with Resnick and Rosenbaum, who see hacking 'as a valid and valuable style of working, characterized by a playful, exploratory, iterative style of engaging with a problem or project' (2013, p. 164). This article has been an effort in showing how hacking as a practice teaches vital skills and knowledge of the 3D printer and its open source design. Open source software and hardware design break the 3D printer up into modules. The modularity of 3D printing is like playing with LEGO. LEGO bricks can be put together, broken apart, shuffled and appropriated in different ways. In this process, the user gains more knowledge on its technology. From a wider perspective, the hacking the 3D printer can be seen as part of a general development towards the ludification of culture.

Seeing media phenomena through the lens of play opens up new perspectives on the relationship between user and producer. In this article, I have considered playability as a capability that can occur on four levels; the player that accepts the rules; the cheater who chooses to follow or break the rules; the modder who creates new situations within the game's framework; or the programmer who either fundamentally alters the game, or designs a completely new one (Raessens 2012, Rushkoff 2012). When looking at the development of 3D printing, the modder and programmer are the players who gain a higher notion of control over the machine. The modder changes software, like what type of firmware is being used, or installs an open source upgrade to fit his/her needs. The programmer takes it to the next level, and creates OSS like David Braam, designing a new printer control that fundamentally changes the way the 3D printer is used. Hacking as a practice gives the user more control on an individual level.

It becomes apparent that 'playability is dependent on the dialectic of being in control and out of control' Kücklich 2004, p. 38). From a constructivist approach, hacking the Ultimaker, the user gains a higher level of control over the machine, deeper knowledge and autonomy. Bernhard Kubicek upgraded the usability of the Ultimaker by adding a controller, making the computer obsolete during printing. This micro-level of playability is related to the notion of control over the machine. From a meso-level, hackers, producers and 3D printing technology are actors in a complex process. Further research from a play perspective in the dynamic network of actors and actants may shed more light on conditions in which ludo-capitalistic, cultural and technological factors are playfully shaped, and shaping.

Acknowledgements

I would like to thank Joost Raessens for his support and guidance throughout these last few months. It has been a pleasure working with you and hope this is not the last of this fruitful collaboration. Also, I would like to thank Kevin Willemsen for proofreading this article. Lastly, I would like to thank the peer reviewing board for their time.

Bibliography

"About." *RepRap*. 2013b. Accessed 28 February, 2014 http://reprap.org/wiki/About.

Ackermann, J.R. "Towards Open Source Hardware." In *Dayton Law Review* 34(2009) 183-222, 2009.

"Admin." *Reprap*. 2013a. Accessed 28 February, 2014. http://reprap.org/wiki/Admin.

Arrasvuori, J, Boberg, M., Holopainen, J., Korhonen, H., Lucero, A. and Montola, M. "Applying the PLEX Framework in Designing for Playfulness." In *Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces (DPPI '11)*. ACM, New York, NY, USA.

Benchoff, B. "An Interview With David of Ultimaker." *Hackaday.com*. 20 June, 2013. http://hackaday.com/2013/06/20/an-interview-with-david-of-ulitimaker/.

Brown, R. "Pulling Back From Open Source Hardware Makerbot Angers Some Adherents." *Cnet.com*. 27 September, 2012. http://www.cnet.com/news/pulling-back-from-open-source-hardware-makerbot-angers-some-adherents/.

Bruijn, E., de. "On the Viability of the Open Source Development model for the Design of Physical Objects: Lessons Learned From the RepRap Project." Tilburg University, The Netherlands, 2010. Accessed 28 February, 2014. http://thesis.erikdebruijn.nl/master/MScThesis-ErikDeBruijn-2010.pdf.

Carlson, N. "Ready To Download Your Next Pair Of Shoes? How 3D Printing Is Turning Bits Into Atoms." *Business Insider*, November 26,

2012. Accessed 28 February, 2014. http://www.businessinsider.com/3d-printing-is-turning-bits-into-atoms-2012-11#ixzz2ubqBo0dM.

"CNN Explains: 3-D Printing." [n.d.]. Video clip. Accessed 13 April, 2014, *Youtube*. http://www.youtube.com/watch?v=e0rYO5YI7kA.

Desmet, P. "Measuring Emotion: Development and Application of an Instrument to Measure Emotional Responses to Products." In *Funology: From Usability to Enjoyment*, edited by M.A. Blythe, K. Overbeeke, A.F. Monk, and P.C. Wright, pp. 111-124. Norwell, MA: Kluwer Academic Publishers, 2003.

Deterding, S., Dixon, D., Khaled, R. and Nacke, L. "From Game Design Elements To Gamefulness: Defining 'Gamification'." In *Mindtrek Proceedings 2011,* pp. 9-15. ACM Press: Tampere.

"De Wereld Draait Door." 14 February, 2011. Video clip. Accessed 13 April, 2014, *De Wereld Draait Door*. http://dewerelddraaitdoor.vara.nl/media/20067.

"Discover: History of MakerBot." *Makerbot.* 28 November, 2012. Video clip. Accessed 13 April, 2014, *Youtube*. http://www.youtube.com/watch?v=UpHjax7rqEE#t=57.

Evans, B. *Practical 3D Printing*. New York, NY: Springer Science+Business Media. 2012.

Gee, J. P. *What Video Games Have to Teach Us of Learning & Literacy*. New York, NY: Palgrave Macmillan, 2007.

Giseburt, R. "Makerbots Mixed Messages About Open Source Their Future." *Makezine.com*. September 22, 2012. http://makezine.com/2012/09/22/makerbots-mixed-messages-about-opensource-their-future/.

Hassenzahl, M. "The Thing and I: Understanding the Relationship Between User and Product." In *Funology: From Usability to*

Enjoyment, edited by M.A. Blythe, K. Overbeeke, A.F. Monk, and P.C. Wright, pp. 31-42. Norwell, MA: Kluwer Academic Publishers, 2003.

Hood-Daniel, P. and Floyd Kelly, J. *Printing in Plastic*. New York: Springer Science+Business Media, 2011.

Hippel, E., von. *Democratizing Innovation*. Cambridge, MA: The MIT Press, 2005.

Huizinga, J. *Homo Ludens. A Study of the Play-Element of Culture*. Boston: The Beacon Press, 1955.

Hunter, R., Jr. and Waddell, M. E. *Toy Box Leadership. Leadership Lessons from the Toys You Loved as a Child.* Nashville, TN: Thomas Nelson, 2008.

"How To Upload New Firmware To The Motherboard." *Ultimaker*. 2013b. Accessed 28 February, 2014 http://wiki.ultimaker.com/How_to_upload_new_firmware_to_the_motherboard.

Jenkins, H. *Convergence Culture: Where Old and New Media Collide*. New York, NY: University Press, 2006.

Kubicek, B. "Why Hardware Hackers Should Investigate Design, or, the Tale of the UltiPanel." *Kariert.org*, 20 May, 2012. http://kariert.org/design/hackersdesign.pdf.

Kücklich, J. "Play and Playability as Key Concepts in New Media Studies." *Dublin City University*. Dublin, 2004.

Lipson, H. and Kurman, M. *Fabricated: The New World of 3D Printing*. Indianapolis: John Wiley and Sons, 2013.

Lister, M., Dovey, J., Giddings, S., Grant, I. and Kelly, K. *New*

Media: a Critical Introduction. Second ed., London: Routledge, 2009.

Mazzotta, A. "3D Printing Adventure – David Braam – Cura Developer – Netherlands." [n.d.]. Video clip. Accessed 13 April, 2014, *Youtube*. http://www.youtube.com/watch?v=yMAIsGV-OuA#t=543.

Montola, M., Stenros, K. and Waern, A. *Pervasive Games: Theory and Design*. Burlington, MA: Morgan Kaufman, 2009.

Norman, D. A. *Emotional Design: Why Do We Love (or Hate) Everyday Things*. New York, NY: Basic Books, 2005.

Pettis, B. "Fixing Misinformation With Information." *Makerbot.com*, September 20, 2012a. Accessed 13 April, 2014. http://www.makerbot.com/blog/2012/09/20/fixing-misinformation-with-information/.

Pettis, B. "Lets Try That Again." *Makerbot.com*, September 24, 2012b. Accessed 13 April, 2014. http://www.makerbot.com/blog/2012/09/24/lets-try-that-again/.

Raessens, J. "Playful Identities, or the Ludification of Culture." In *Games and Culture* no. 1.1. (2006): 52-57.

Raessens, J. *Homo Ludens 2.0.: The Ludic Turn in Media Theory*. Utrecht: Utrecht University, 2012.

Resnick, M. and Rosenbaum, E. "Designing for Tinkerability". In *Design, Make, Play: Growing the Next Generation of Stem Innovators*. Edited by M. Honey and D.E. Kanter, pp. 163-181. New York, NY: Routledge, 2013. Accessed 28 February, 2014. http://web.media.mit.edu/~mres/papers/designing-for-tinkerability.pdf.

Rushkoff, D. "Monopoly Moneys. The Media Environment of

Corporatism and The Player's Way Out." PhD diss., Utrecht University, 2012.

Salen, K. and Zimmerman, E. "Chapter 22: Defining Play." In *Rules of Play: Game Design Fundamentals*. pp. 302-311. Cambridge: The MIT Press, 2004.

Schäfer, M.T. *Bastard Culture! How User Participation Transforms Cultural Production*. Amsterdam: Amsterdam University Press.

Schifferstein, H. N. J., Hekkert, P. *Product Experience*. San Diego, CA: Elsevier, 2008.

Tucson Amateur Packet Radio. "Publications: Open Hardware License." 2013. Accessed 28 October, 2013. http://www.tapr.org/ohl.html.

Turkle, S. *Life on the Screen: Identity in the Age of the Internet*. London: Phoenix, 1995.

"Ultimaker specs and features." *Ultimaker*. 2013a. Accessed 28 February, 2014. http://wiki.ultimaker.com/Ultimaker_specs_and_features.

Weber, S. *The Success of Open Source*. Cambridge, MA: Harvard University Press, 2004.

Zimmerman, E. "Manifesto: The 21st Century Will Be Defined By Games." *Kokatu*. 2013. Accessed 28 February, 2014. http://kotaku.com/manifesto-the-21st-century-will-be-defined-by-games-1275355204.