

# ARTIFACTUAL AGENCY IN OPEN DESIGN

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## Abstract

*We readily use artifacts in theorizing and accounting for epistemic work. Yet the agency characteristics of artifacts and notably their relations to their creators (the subjects) are less understood as agency is more socially privileged than artifactually focused. Rather than understanding the ways artifacts are appropriated as utility objects, we examine the ebb and flow of agency to account for how the subjects implement, express, and document performativity through artifacts. Using an archival analytical approach, we examine design activities and artifacts on Thingiverse – an online platform for open design. Our findings suggest design derivation is driven by four types of artifactual agency manifested within the context of subject-artifact relationships. First, agency-in-situ concerns the creation of artifacts as instances resulting from a self-reflexive process in response to situational demands and contexts. Second, agency-in-use concerns the use of artifacts to signal a designer's specialism (ability, skill) and to induce further redesign and learning. Third, agency-in-practice concerns the use of artifacts as a collective effort which addresses the needs of a specific user group. Lastly, agency-in-flux concerns a co-integration of agencies that are harmoniously yet dynamically assembled in propagating and accumulating design knowledge across different contexts of use. The four types contribute to the assemblage of performativity in design. Each time when an artifactual agency is enacted, new design ideas, materials and techniques are created and added to the commons.*

**Keywords:** Agency, digital artifacts, open design, performativity, reflexives

# 1 INTRODUCTION

In the era of the ‘Internet of Things’, we create digital artifacts such as digital images and artwork for individual and social consumption. With an increase in digital artifacts in online repositories such as Google Warehouse and Thingiverse, it is possible to obtain a digital equivalent of a physical design object and to reproduce it through personal fabrication. Yet despite the availability of digital artifacts, their significance remains largely abstract and underexploited in the commercial world (Lipson and Kurman 2012). Although a parallel has been drawn with open source software development, there are stark contrasts (Raasch et al. 2009). A notable difference is that successful open source software projects are driven by a group of developers collaboratively writing code and producing IT artifacts. Whereas in open design instead of collectively making a uniform product there is a collection of physical outputs. Weighing towards tinkering with digital artifacts as opposed to collectively designing a uniform product, each output is unique and personalized to reflect individual tastes and needs. This contrasts with the focus of traditional design on making a commercially viable product or a finished object which is subject to various controls in terms of design criteria including forms, functions and fits (e.g. Dumas and Mintzberg 1991); and managerial and market considerations including costs, brand identity and competition (e.g. Gorb and Dumas 1987). The sharing of design data (CAD and other 3D source files, including instructions and/or any other relevant design information) enables the process to be tailored to individual needs, leading to multiple expressions of a design idea. What constitutes practice of online design communities when digital artifacts take the centre stage is less understood. This paper seeks to examine the performativity of digital artifacts in open design from a practice lens in the setting of an online design community.

The practice-based literature rarely distinguishes artifacts from objects, as they both share the same ontological status. Contrasting to physical objects, digital artifacts carry an imbued level of agency attributed to the human subjects (Kallinikos 2009). For example, a designer (the subject) creates a technical drawing (a digital artifact) as a means to gather feedback. Inevitably once the digital artifact is ‘contained’ or ‘expressed’ through printing on paper, it loses its editability (Kallinikos et al. 2010, Leonardi 2010). For a non-designer, for example, a product manager will interpret the technical drawing on paper as a set of constraints and conditions for the manufacturing/production process. Any alteration to the design can be expensive to manufacturing and harder to achieve without additional input from the designer. If the designer makes the source file publicly available in ‘.stl’ format (STereoLithography file), other designers can copy, distribute and notably edit the design. This perpetuates design, in that some designers may reuse a component or whole of a digital artifact and others may reconstitute design to fit a different context of use.

The relationships between humans and artifacts are associated with the way an artifact is generally conceptualised as a composite of ‘arte’ and ‘factum’ (D’Adderio 2010). The ‘arte’ entails the use of knowledge from science and art, the skill and craft to engineer and express in the process of making an artifact whereas ‘factum’ is the thing being made at the end of the process. Once a digital artifact is moved from its design context of use to a physical domain, the social aspect of the ‘*factum*’ takes over and allows other non-designers to appropriate the artifact materially and socially in a physical and often non-design contexts of use (Doolin and McLeod 2012; Suchman 2007). Despite that the ‘*factum*’ of an artifact (the object) still carries the endowed characteristics and expression of its creator, it may serve to either regulate or constrain practice intentionally and unintentionally. With the material constraints, social practice endeavours to make the impoverished artifact to retain its partial function as boundary-negotiating artifacts (Lee 2007). We use the term artifactual agency to emphasize that humans create artifacts to implement, express, and document performativity and that being digital, the intra-artifactual characteristics are subjugated to the discretion of and modification by the subjects. This contrasts with a prior conceptualisation of performative artifacts which are primarily social in aligning “multiple, and discontinuous social worlds” (e.g. Suchman et al. 2002, p. 175).

In privileging social over artifactual, this inadvertently relegates the artifacts to a peripheral position both in theory (D'Adderio 2010) and in practice (Sapsed and Salter 2004). The performativity of digital artifacts dovetails from the practice view of the interrelationship between humans and artifacts. With each design derivation, a new subject-artifact pairing is enacted with the creation and addition of new design resources to the commons. A physical instantiation is a mere instance of many possible ways of expressing of a design idea. Multiple expressions enact diverse assemblages, and each contributes to the performativity of design in a unique way. So long as the subjects have direct control and access to the source file, the digital artifacts will remain performative.

We use an online 3D printing hobbyist community to illustrate how artifactual agency residing in the subject-artifact pairing can enhance performativity and become conducive not only to reuse but also to reconstitution and propagation of new design knowledge. We study various ways designers express, implement and document performativity through artifacts and the ways artifacts are created and linked across different design genres. We identify four types of artifactual agency, which make open design active and evolving. In the following sections, first - we contrast artifacts with objects to underline their respective imbued level of agency; second - we introduce the research setting; third, using an archival analytical approach we examine the types of agency manifested through multiple subject-artifact pairings; and lastly, we discuss the findings in relation to theoretical contribution.

### 1.1 Agency in objects and artifacts

In practice theory, practice as a process ontology holds that only processes are real, other entities including objects and artifacts are not (Sawyer 2009). Specifically with constructivists, structures including contexts do not have active causal powers (e.g. Peter et al. 2013) as contexts are ephemerally constituted by action. This has several implications for how research in artifacts is undertaken. Two specific concerns which influence the ways we use artifacts in theorizing practice are further examined in this paper.

First, the emphasis on mutual constitution has privileged action over context (Mutch 2010), in that artifacts and objects share a similar fate as ephemeral entities which are subject to social, economic and/or market actions. For example, objects have been studied in relation to social performances including epistemic and collaborative works (Miettinen and Virkkunen 2005; Nicolini et al. 2012). Also in organizational studies, many scholars have been theorizing the life of objects in relation to markets and consumption as a commodity and/or an object of utility (Appadurai 1986; Engeström and Blackler 2005). The research in artifacts emphasizes actions over objects on how objects are being used and appropriated in social terms. This includes the use of physical artifacts as an affective event to evoke positive emotions and attitudes towards an organization (e.g. Rafaeli and Vilnai-Yavetz 2004). In the theory of organizational routines, object-like artifacts are treated as transitional objects to practice (e.g. Pentland and Feldman, 2008). Social practice carries the agency of change with the appropriation of object-like artifacts in reconfiguring and reorganizing work arrangement (Brown and Duguid 2000; Turner and Rindova 2012). In the actor-network theory, agency is attributed equally to both human and non-human agents, and engrossed in patterns of association. The material aspect of the focal objects remains largely unchanged as an 'immutable mobile' (Law and Singleton 2005).

Second, the rejection of methodological individualism by practice theory has privileged human agency without explicitly rejecting that individuals differ in knowledge and reflexivity. Human agency often used as a collective term portrays human agents as a homogenized collective. In critical realism, actors and objects exist and yet occupy different strata (Harre and Bhaskar 2001). Theories which sanction the view of object-in-use position objects in relation to actor-user as a reflexive agent, specifically multilayered concepts including structuration theory (Giddens 1984;), and critical realism (Archer 2003). In her morphogenetic approach, Archer (2010) argues the reaction of each actor to cultural and sociological contexts is determined by four specific modes of reflexivity relating to the levels of internal conversations that each actor undertakes. Autonomous reflexives converse with themselves and are strategic in pursuing social projects that lead to structural elaboration or change.

Communicative reflexives' internal conversations need to be confirmed and completed by their close friends and families. Meta-reflexives evaluate their previous inner dialogues against normative rationality and actions. Whereas fractured reflexives are unable to engage in purposeful conversation which leads to disorientation and personal distress. Autonomous reflexives are agents of change, and that the actions of communicative and meta reflexives are affected by their social affiliates. In a study of relating modes of reflexives to IT artifacts, it is found that the intransitive agency of the IT artifacts are retained when the subjects behave more of an autonomous reflexive than communicative and/or meta-reflexives, in that the performative aspect of the subject-artifact relationship is more pronounced than the social implications of how IT artifacts are used as an object in relation to practice (de Vaujany 2008). Reflexivity imbues a certain level of agency situated within the relationship between the autonomous agents (the subjects) and the IT artifacts. This distinction between artifacts and objects by the imbued level of agency has been made more explicit in the design research.

The subjects (the designers, i.e. software developers and HCI specialists) undertake four key stages of design consisting of: concept, model, method and instantiation. The design and development of an IT artifact often involves the use and creation of other artifacts including 'theory ingrained' and 'guided emergent' artifacts (Sein et al. 2011). Yet with unanticipated eventualities especially when an IT artifact is implemented and put into use, the end-users may treat it as an object of resistance (e.g. Rivard and Lapointe 2012). This is particularly true, when the end-users have no direct control of the intra-artifactual characteristics of an artifact. The object-like artifact signifies a mismatch between a structure of wants of the actor-users and a structure of lacks of an artifact turned to an object. Knorr Cetina (1997) conceptualises the sociality with objects as one, which *"entails reflexivity: it occurs when the self as a structure of wanting is looping its desire through the object and back...conversely, the articulation of the object is looped through the subject: as a structure of lacks, of the questions it poses or the things that it needs to become materially defined, the object receives the kind of extension that the subject determines"*. Without the means or the ability to alter and change the impoverished artifactual agency, the actor-users resort to change their routines in accommodating the inflexibility that comes with the object-like artifact (Leonardi 2011). Yet this crossing-over with the loss of agency and the ways agency can be restored are somewhat unexplored in other contexts, especially the role of artifacts and the nature of agency in relation to epistemic work are somewhat blurred by the interchangeability between artifacts and objects (Nicolini et al. 2012).

In the social constructivist perspective, artifacts are amalgamated into a sociomaterial ensemble, in that agency subsumes artifacts as part of a collective. Orlikowski in her account of technology as artifacts asserts that "technologies are artifacts whose operations and outcomes are neither fixed nor given a priori, but always temporally emergent through interaction with human in practice" (Feldman & Orlikowski, 2011, p. 1246). This instance of mutual constitution has been termed as elisionism by Margaret Archer (1995, p. 60). She argues "because transcending the dualism between individual and society consisted in replacing it by an instance upon their mutual constitution". The mutual constitution privileges action over context as the elisionist theories consider the process as real but the structures, patterns and entities as ephemeral and non-existence (Sawyer 2007). The intransitive aspect of agency inadvertently relegates artifacts to a peripheral position as a transient by-product of action. With critical realism artifacts exist as inscribed objects, which occupy a different strata from the human agents (Mutch, 2010), and mutual constitution temporally unfolds as a sequence of events of interaction between action and context over time, and artifacts form part of the context. The contrasts in the ontological assumptions and the degree of separability between the elisionist and the critical realist's approach locate artifacts as either core or peripheral to the practice theory. Because of the intransitivity of agency as portrayed in the elisionist approach, artifacts are used interchangeably with objects. With the critical realist's approach, whether an artifact bears more object-like characteristics is contingent upon the types of reflexives. In this paper, we illustrate through theorizing and advancing the concept of artifactual agency as an emergent relational property between creators (the subjects) and their artifacts, underpinning the structure of wants and lacks; a subject creates an artifact to quench her lacks, and the artifact is created to meet the wants of the subject.

## 2 RESEARCH METHODS

### 2.1 Research Setting

We carried out an archival study of an online platform for open design called Thingiverse (<http://www.thingiverse.com/>). Thingiverse is used by the online 3D printing communities as a place where user-designers can share designs and create derivatives. It has the facilities to archive and also to document design activity in such a way that users can trace back by following acknowledgement of prior design/artifact and understand the social history of a particular collection of design. Open communities provide an excellent setting for studying artifactual agency for several reasons. First, it provides an online repository of design artifacts and activities. When designers upload the design data including design schematics, other background information is also provided, which aims to encourage 3D printing and further redesign. Second, it provides a rich test-bed to observe on-going design activities and interactions among designers and users, specifically the multithreaded conversations centred on design artifacts and 3D printing. The on-going and traceable archival logs of artifacts, design activities and conversations provide a captive view of the social life of artifacts. The platform allows users to communicate and exchange design ideas. The design information shared through user interaction provides valuable insights into the ways designers use prior artifact to create new or variants of design. It also allows us to examine how artifacts evolve and what drives designers to contribute actively and continuously to the platform. We observed collaboration among designers that results in creative outputs including: mash-ups (objects acquiring multiple functions), innovative use of personal fabrication tools and techniques (using 3D printing technology and/or laser cutters), exploration and application of material properties, and notably untethered design activities allowing users to innovate without being confined to the manufacturing/production and monetary (target-oriented) constraints of a commercial setting.

### 2.2 Data Collection

Between February and November 2012, we examined and observed over 800 design artifacts ('things' on Thingiverse) in different contexts of use relating to nine design genres. The ethnography was largely asynchronous (e.g. Johnson and Humprey 2012); we used archives to support our observations by following changes added to designs featured on the website. Two researchers coded the observations independently, and compared their analysis on a weekly basis to achieve at least 90% of agreement. Table 1 provides a summary based on a generalized classification of 668 artifacts. Artifacts can belong to a family of the same design genre or crossover to a different design genre depending upon its subject-artifact pairing. We wrote a Python script to scrape all the data on Thingiverse. This resulted in an identification of 1217 tree-like structures.

Genres	Description
Ornaments	Artifacts that represent a character from a book/movie/cartoon/game or fiction. These carry a symbolic meaning (cultural, historical or political) and can be a mythical figure, animal or a toy. They are generally created for fun, games, entertainment, humour and/or are collectables. (N = 163)
Objects of Art	Artistic creations - sculptures or jewellery, which are expressed in an evocative and creative fashion. These often experimenting with curves and surfaces and push cases they are just simple objects of beauty (N = 51)
Objects of Utility	Artifacts of daily living which constitutes some sort of use value. These are generally designed/created to solve a problem or fulfil a need, for example tools or gadgets that make our lives easier (N = 54)
Mash-ups	These are recombined Thingiverse objects/parts to reveal some sort of symbolic meaning. They are rarely objects with any utility value, on the contrary, they are often a result of one's imagination to express strong opinion about a character or a person with cultural, historical, political or fictional significance. N = 4
Geometrical Figures	Archimedean Solids, Catalan Solids, Platonic Solids, Hoberman Spheres etc. These generally have educational use/value to represent a complex geometry in real tangible form. N = 6

Makerbot Parts and Firmware	Self-replicating machinery parts are endlessly being developed and improved by the MakerBot community. These constitute a large part of what collaborative design is about on Thingiverse, and are often characterized with highly iterative nature. Contributors have vested interest in improving the process of 3D printing equipment & process and the development of those parts enables them to do so. N = 330
Techniques	Application of specific fabrication techniques to test material strength, reveal novel ways of improving designs and/or creating opportunities of designing objects/part that wouldn't otherwise be achievable through any other means (such as flexible joints etc.). These may also include techniques for improving the efficiency of 3D printing as a process (ex.: tool that simplifies the process of combining multiple STLs into a single file for larger volume 3D printing). N = 12
Engineering concepts	Artefacts which represent an engineering principle and demonstrate the way it works, for example kinetic or mechanical parts. Often the idea is used to demonstrate the principle for educational purpose and/or aesthetic value, or become part of a bigger part utilizing its function. N = 33
Libraries	These are either sets/collections (e.g., font modules, emoticons, game characters etc) or parts of bigger projects (e.g., Clockwork Library), in which case Thingiverse is used for cataloguing all parts of a bigger project as separate objects (similar to github). N = 15

*Table 1. Design genres in Thingiverse (N = 668 artifacts)*

### 2.3 Data analysis

In order to establish the relationships between artifacts and their designers, we started with a random sample of 140 artifacts across different design genres to ascertain the underlying motives against any background information provided by the designers. Our initial effort concentrated on the relations between artifacts and designers. This formed the basis of our first-order analysis primarily to capture how designers used artifacts to express, implement and document performativity of 3D design and printing (see Table 2). We then applied the empirical and theoretical constructs to a larger dataset of 668 artifacts across the 20 largest family trees spanning across nine design genres. The aims were two-fold. First, it was to subject the first-order analysis to further testing with a new dataset. This was to ensure that our first order analysis was exclusive and exhaustive. Second, with the social history of design and derivations, we examined the emergent properties of artifactual agency within and between different family trees, hence instead of a random sample of artifacts, the study of family trees allowed us to examine the ebb and flow of agency manifested in multiple subject-artifact pairings.

## 3 FINDINGS

The common motives for uploading, designing, and creating ‘things’ underpin performativity in open design, which is primarily driven by hobbyists’ interests in pushing the capabilities of the fabrication process, material, tools and technique to the limit, the sharing of skills in 3D design and personal fabrication, and seeking to expose various aspects of printing a 3D object through improving the process design in 3D printing. The performativity of digital artifacts has to be understood within each subject-artifact pairing. In this case, the subjects include designers, fabbers and hackers creating artifacts in digital forms and physical instantiations.

Table 2 provides illustrative examples of empirical and theoretical observations, and constructs based on multiple subject-artifact pairings. There are nine unique ways that the subject uses artifact to document, implement, and express performativity. First, when the subject uploads design files to Thingiverse, it often comes with learning instruction including extensive uses of multiple media to document performativity relating to the 3D printing and design. The focus is more on learning about the process of 3D printing rather than creating a unitary output, in that, each output is an instance of a physical instantiation of a design. This is related to our second observation. Designers understand 3D printing is about expressing individuality rather than printing a uniform product as can be found in the commodity market. Hence, they often provide other users and/or designers with sufficient affordance, such that parameters of design and printing can be easily re-configured to encourage reuse. The

instruction is deliberately made explicit and is proceduralized. When any instruction is unclear, users can post questions directly to the designers for support. The subject uses artifact and its associated printing process to encourage reuse in the ways a particular design can be tinkered to fit to a specific context of use and personal requirements. Third, the subject uses artifacts to express performativity in solving a problem from our daily living. Instead of using verbose instruction, the physical instantiation of a simple design documents performativity itself. Yet the level of details varies. Detailed instruction is often provided especially when the design involves a new technique, or when a design problem is being solved, and also when the designer reveals a novel way of reconstituting design. Because of the significance and novelty to the community, detailed narratives about the artifact are given to implement as well as document performativity. The aims are manifold including: to convey the relevance and importance of the design knowledge to a specific user group; and to facilitate an increase in performativity with newer design in different contexts of use.

Amidst all the files uploaded onto Thingiverse, a small percentage of them are sets and/or collections of files (e.g. font modules, emoticons, game characters) or parts of bigger projects (e.g. clockwork, screw libraries). These form the design elements that can be appropriated further by designers. In effect, the online platform serves as a public repository, which constitutes an archival record (similar to the general purpose of a git-hub in open source software), and provides a documentary trace of design history. Lastly, performativity in artifact is often expressed against the contextual and personal circumstances in which a particular design is conceived and the unique way a design is instantiated. This is particularly the case when it comes to using design to solve a problem in daily living. The expression comprises the use of personal story, the evocativeness of design, and the underlying cultural meaning and significance to convey the contextual and the causal conditions of why and how a specific artifact is made.

Empirical Observation	Theoretical Observation	Theoretical Construct
<p><i>"How do you replace a sliding door handle that broke at 2pm today!"</i></p> <p><i>"A bottle opener for people who don't have any coins"</i></p> <p><i>"This case is perfect for using your iPhone when it's hailing, or when it's too sunny to see your screen properly, or when onlookers are trying to peek at your screen"</i></p> <p><i>"Don't want to pay the ridiculous prices for an electric toothbrush or the replacement heads? This accessory is the answer!"</i></p>	Through the use of design for solving a daily problem	Express
<p><i>"Here is a video documenting the process <a href="https://youtu.be/9MdUsIWFFTo">youtu.be/9MdUsIWFFTo</a>"</i></p> <p><i>"This script relies on both the MCAD involute_gear library and on my own clockwork library. Current repository for the latest version of the clockwork library: <a href="https://thingiverse.com/thing:81551">thingiverse.com/thing:81551</a>. Print one of each STL file, or fiddle with the script, check your work with assembled(), and then generate a new STL for each part with laidOutToPrint(), and print those. The current configuration requires two shafts to slip the sleeved gears over, outer diameter 2mm with a clearance of half a millimeter either side, so M3 might work, depending on the print tolerances"</i></p>	Learning with detailed instructions, and an extensive use of media	Document
<p><i>"You can edit the file using your favorite text editor (notepad, vi, emacs, pico) to change the height, width, and length of the box"</i></p> <p><i>"This was designed along the same lines as the screwless cube gears: <a href="https://thingiverse.com/thing:10483">thingiverse.com/thing:10483</a>, and in fact uses the exact same center block (though the pins are slightly shorter)"</i></p> <p><i>"Mirko van Landschoot initially made this, but I ( <a href="https://thingiverse.com/Erik">thingiverse.com/Erik</a> ) recreated it in OpenSCAD so I could completely control how much the text should be embossed."</i></p>	Direct reuse	Implement, document
<p><i>"I extended TBusser's OpenSCAD bitmap font module to support drawing the fonts on circles and cylinders. It centers the text along the Y axis, and fits it to the radius you specify (longer text requires larger radius)"</i></p> <p><i>"I took everything that I liked from other designs and got rid of that horrid threaded rod approach.. The frame is built from Misumi rails and is extremely rigid. the x, y, and z axis are simple and easy to assemble and they are all rock solid"</i></p>	New design through extensive changes	Implement, express, document

<p><i>"Instead of using magnets, this uses my pin connector library. I also redesigned IWorkInPixels's ring body to be slimmer than the original"</i></p> <p><i>"The basic Hermite interpolation calculation has actually been lurking for a while, but now it's put to good usage. With this, there is now a lerp (linear interpolation), berp (bezier interpolation), and herp (hermite interpolation) in the library"</i></p>	Design knowledge, e.g. academic journals	Document
<p><i>"By using manufacturing techniques like this it is possible to make all product features in a single production step and in one material"</i></p> <p><i>"This is an attempt to standardize rod spacing on mendel style 3D printers that are adopting a vertical orientation for the X axis smooth rods. Some examples include RepRap 1x2, Mixtape Mendel, Emaker Huxley, and a rumored Prusa variant from Russia. The standard will be informal. Those wishing to design conforming bots, X carriage designs, X axis assemblies, etc. can use this as a starting point"</i></p>	Solving a design problem through contest and competition	Implement, document
<p><i>"My girlfriend challenged me to make a hand soap dispenser that is cooler than anything we could buy at Crate &amp; Barrel (or similar stores). The result, after a number of design iterations, is this bottle which now inhabits our bathroom"</i></p> <p><i>Something that is useful, not another idiotic i-widget that is something useless to snap onto an iphone"</i></p>	Sharing of personal encounters	Express
<p><i>"I thought the Pocket Coin-op would look nicer with some tapered edges. Are you full of jealousy seeing all these dualstrusion parts popping up everywhere? Well now you can stick it to the man with a three colour bottle opener!"</i></p> <p><i>"Use it to show your nerdy significant other that your love can't be expressed in a mere 3 dimensions."</i></p>	Evocative of design	Express
<p><i>"This is a printed spindle holder. It's more than strong enough and still uses only a little plastic filament. It's designed to accommodate the Bits From Bytes filament spindles. It's not the cheapest source, but it's really nice for various accents"</i></p> <p><i>"I presented the Mighty Bottle Opener as the pocket equivalent to Starno's Coin-Op. It wasn't. It isn't. I just wasn't able to find a reliable way to protect the plastic. I went back to the drawing board, and have come back with a beefier "church key" design"</i></p>	Novelty involves personal specialism	Implement, document

Table 2. *Performativity in Open Design*

Among all the multiple subject-artifact pairings, users that only consume design also interact with designers through discussion forums. Although these users do not design, some of them can still contribute to performativity by sharing their successes and insights into ways of tweaking a particular printing procedure. These exchanges among users take place in the comment section, and provide other designers with invaluable insights (in terms of users' want and the lack of prior artifact) into creating a newer design as illustrated in the Pliers example later on.

With the ways artifacts were used by designers, artifactual agency was manifested in four specific ways. First, agency-in-situ was a self-reflexive process. Artifacts were created as instances in situations when designers attempted to solve a design problem; and in the use of design to redress a daily living problem. Second, agency-in-use concerned the use of artifacts to signal a designer's specialism. Third, agency-in-practice concerned the use of artifacts as a collective effort towards the needs of a specific user group. Lastly, agency-in-flux concerned a co-integration of agencies which were dynamically assembled to propagate and accumulate design knowledge across different contexts of use. Below are four examples to further illustrate how artifactual agency works in tandem and helps explain performativity in open design manifested in multiple subject-artifact pairings.

**Example 1. Moineau Soap Dispenser** (Thing ID: 16775; User-designer: emmett; Object type: Objects of Utility)

The artifact in this example is a soap dispenser. Two types of agency are observed: agency-in-situ and agency-in-practice. Agency-in-situ is evoked when the designer was presented with a challenge attributed to the dissatisfaction of existing soap dispensers in the commodity market. The artifact was a by-product of the lack of existing products that answer those needs and the designer's want to design a better and more functional product.



*My girlfriend challenged me to make a hand soap dispenser that is cooler than anything we could buy at Crate & Barrel (or similar stores). The result, after a number of design iterations, is this bottle which now inhabits our bathroom*

This quote indicates the challenge (the lack), the designer's effort (ability) to 3D print the soap dispenser (artifact) to quench the couple's need (the want). Agency-in-situ as an emergent property to situational demand induces the needed performativity of using design to reduce waste.

*This dispenser is designed to reduce waste in a number of ways. First, it is easily refillable, and so can be used for many years. Second, as the pump is turned, liquid soap spills from the spout back into a hole in the bottle, thus recycling any drips. Third, this design makes it easy to get as much or as little soap as you want, while commercial soap pumps often dispense more soap than necessary with a single squeeze*

The designer went through engineering journals including design history related to old and new developments of cavity pumps. He came across a technique invented by René Moineau in 1930. Given the technique was no longer subject to patent protection, he made use of this historical invention rather than reinventing the wheel. In effect, agency-in-practice was brought into the mix in the design of artifact by bringing the performativity of Moineau pump alive.

*The crank drives a progressing cavity\*, or Moineau, pump which was invented by René Moineau in 1930 and first described in his doctoral dissertation. His idea helped him found a company that is still around today, selling these very pumps: [pcm-pump.com/pump-manufacturer/history.html](http://pcm-pump.com/pump-manufacturer/history.html).*

**Example 2. Empire State Recorder (instrument) - Thing ID: 12904; User-designer: Cymon; Object type: Utility/Ornament**

In this example we observe agency-in-use and agency-in-flux. Agency-in-use is evoked against the intent and the specific way that the designer (cymon) used someone else's design to signal his specialist area of interest (the windway of a recorder) and his hacking ability as a competent 3D fabber. He chose to hack a printable Empire State Building model, which had little functional value other than ornamental. He showed how by incorporating his invention into the design of the Empire State building, he achieved a functional design with personalization and aesthetic appeals. By using someone's design as the exterior for his invention, he openly invited others to try to house it in other exteriors, enticing others to join his specialist area of interest.

*Theoretically the windway of the recorder is the important part. The exterior could be shaped like anything you want. Even the Empire State Building (by Hoeken [thingiverse.com/thing:625](http://thingiverse.com/thing:625) )*

The functions of the wind way were an important part of the designer's specialism. The merging of two designs in serving a dual purpose - an ornament and a recorder evokes agency-in-flux.

*As if making music wasn't beautiful enough, now this recorder can sit on your shelf as an objet d'arte. 3D printing allows designs to go beyond functional to decorative*

Agency-in-flux portrayed the ability of the designer in enhancing utility values to our everyday lives through meeting needs of several user groups. The designer spoke about his design objectives were making 3D printing fun, useful and interesting by introducing performativity to an ornament, giving his design a quirky composition. The co-integration of ornamental and music making functions effectively signalled his specialism to others, in that by enhancing the functions while making the form of the design fit to the environment.

*For the New Museum Challenge: What is the design a derivative of? How does it improve on or challenge existing design conventions? How does it utilize the unique ability of 3D printing to personalize and improve on the world around us?*

**Example 3. 47t herringbone gear for Greg's Wade / Hack-a-Day logo skull mash-up**

Thing ID: 18758; User-designer: NM-Buzzard; Object type: MakerBot Parts & Firmware

In this composition we observe agency in practice and agency in flux. The original design of the skull was an ornament (a badge) with symbolic meaning to the 3D printing community and designed for the

Hack-A-Day event. It was transferred and incorporated into a functional part - a herringbone gear for Greg's Wade replicator. This transition added an element of visual appeal and carried the symbolic meaning of the original badge to a functional MakerBot part, which constituted agency-in-practice. It allowed this symbolic meaning of the community that it belonged to, to become embellished in the MakerBot equipments, indirectly reinforcing the values of the community as a whole. This attracted other members of the community to print the gear with the skull and allowed the badge to be taken out of its temporal and contextual use and embedded into a functional part, which would be used and seen more and for longer, upholding functional values and identity of the group:

*Derived from triffid-hunter's herringbone gears .scad thingiverse.com/thing:10707, and The Hack a Day badge thingiverse.com/thing:1562... a one-off mash-up*

This interesting combination between an ornament with symbolic meaning and a functional MakerBot part enabled the transference of the ornament into a different context, constituting agency-in-flux. The user (NM-Buzzard) shared the design and invited others to carry on tinkering by exposing the need for refinement:

*As I am not completely satisfied with the skull faces, I will probably do some more edits and re-print with .35 nozzle and finer layer height*

NM-Buzzard was also introducing an element of fun conveyed in a subtle and slightly humoristic message through the words below - the community was implicitly aware of 'skulls' and also 'herringbone gears'. He recognised and personified the symbolic meaning of the badge identifying its cultural significance as a badge of honour and uses this to increase the aesthetic value of the herringbone gear.

*Cause I like herringbone gears. And skulls*

#### Example 4. **High Quality Pliers made ready for ReplicatorG**

Thing ID: 11816; User-designer: danman; Object type: Objects of Utility

This example constituted agency-in-use and agency-in-situ.

The original pliers (thing ID:11332) were designed for educational purposes and were of high quality. This revealed an agency in use, exposing the skill and ability (the title of the object: High Quality Pliers), and serving an educational purpose of 3D printing.

*This a pair of snap together pliers that I designed as a demonstration part to teach other students how to use the university's 3D printer*

Although the design was well received, a few users expressed their wishes including wanting a bigger rather than a small pliers. Another designer (danman) took the constructive feedback from the users, and redesigned the original design to create the High Quality Pliers which were a direct copy of the original design with the clear purpose of refining it by smoothing out any design problems that were found, acknowledging the ingenuity of the original design:

*Combines both snap together sides of the awesome high quality pliers from russrobot. The two sides of the pliers have been rotated, combined into one model, and enlarged 30X for easy opening and printing in ReplicatorG*

The quote shows directly what the problems were and how they were resolved, pre-empting the reasons behind the need for this design and making it fit to our agency-in-situ pattern: new design has to become printable on ReplicatorG (need), original pliers were too small and in different planes (proof of no alternative), hence the pliers were enlarged, rotated and combined in one model (result).

## 4 DISCUSSION

In exploring the ways each designer (the subject) uses digital artifacts to document, express and implement performativity, our current framework argues artifactual agency is an emergent property

residing within a subject-artifact pairing. Each design derivation is an enactment of a new pairing with enhanced performativity, and facilitates propagation of design from one to another context of use. Some of the pairings are more circumscribed to a situational context, and a specific design area and interest. Others collectively tie to a specific user group and collaboratively contribute to the commons of 3D printing. Not all of the subjects in our study have the ability to alter design. Those who do often make digital data available with an intention to encourage others to reuse, tinker, and re-constitute design. Sometime a physical manifest is sufficient to express and document performativity, and in other instances, detailed instruction is provided specifically when the functions and the underlying novelty of the design are not obvious. The contextual information of why an existing artifact has been designed in a particular way provides other designers with a better understanding within the structure of wants and lacks. In the example of pliers, the original designer created the design for pedagogical reason, which served the purpose of illustrating 3D printing. The design was purposely to be printed as a small object, which was meant to be economically viable as it used fewer resources to print. He never intended to make the pliers in a full scale version. Yet other users wanted to print a larger version so that the pliers could have more utility than a pedagogical object. This lack prompted the designer Danman to modify the design as he had the ability to modify the design to satisfy the wants of a specific user group.

Performativity in digital artifacts is not just about sharing and replicating but allowing the design to be furthered and enhanced. Prior artifacts set the context for the next design. Yet rather than constraining future design, the illustrative examples show how competent designers use digital artifacts to signal their abilities by transporting a prior design in one context, and reconstituting it in a different context. This ability to move and reconstitute design through design derivation makes performativity in open design dynamically generative as new meaning, techniques and novel ways of reconstituting design are introduced. This dovetails from the maintenance view of artifacts to performatively producing practice (Butler, 1993, 2010) and routines (e.g. Pentland & Feldman, 2008).

Our study dovetails from prior research by not distinguishing between human and material agency, in that artifactual agency resides within the subject-artifact pairings. This provides a different theoretical lens to understand performativity in digital artifacts from individual pursuit of design (agency-in-situ and agency-in-use) to a collective effort in promulgating and accumulating design knowledge (through agency-in-practice and agency-in-flux). The performativity view of artifactual agency is always enabling. Artifactual agency challenges the boundary view of practice, specifically in view of the limits of boundary objects in non-routinized tasks when the condition of methods of standardization is not met. Without conceptualizing artifact as an impervious object in attempting to cross boundaries, digital artifacts with the subject-artifact pairing are more readily to change and cross between different functional contexts of use. It allows designers to engage in the sense making aspect of practice, focusing attention and interactional resources. This follows from Wenger's view of the significance and the role of the subject-artifact pairing in connecting and crossing boundaries, in that, "it is often a good idea to have artifacts and people travel together. Accompanied artifacts stand a better chance of bridging practices" (Wenger, 1998, pp. 111-112). Our starting position in theorizing the role of artifact is matter rather than material. This strikes an accord with agential realism where matter is not a material thing, but an enactment involving the act of doing, in that "discursive practices are specific material (re)configurings of the world through which the determination of boundaries, properties, and meanings is differentially enacted" (Barad, 2007, p.148). The agential account brings the focus back to the agential relationship between subjects and artifacts as they partly constitute the design apparatuses. The creation and/or the use of digital artifacts in open design is an agential cut by materialising design ideas into physical expressions, and vice versa. This process allows subjects and digital artifacts coexist and intract. Digital artifacts provide a placeholder for meaning and mattering through the ways intractivity takes place. Multiple subject-artifact pairings are linked and provide the social history of digital artifacts in which agency-in-flux and agency-in-practice perpetuates design.

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