ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

THREE LAYERS OF OPENNESS IN DESIGN: EXAMINING THE OPEN PARADIGM IN DESIGN RESEARCH

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ABSTRACT
This article examines the open paradigm in design research and introduces a new conceptualization for 'open design' and a three-layer framework to demonstrate the degrees of openness in design practices. The conceptualization comprises all stages in the design process, ranging from need-finding to the openness of the design documents and the data gathered during the design process, and the commercialization of the end-product. The aspects of the product and the process merge in this framework, intertwining the aspects of technical, legal and commercial openness. Finally, the article proposes a research agenda for open design. The article builds on an extensive literature review about studies on 'open' in design: open-source software, open hardware, and participatory methods in design, such as co-design and participatory design, and user-engagement methods such as crowdsourcing and co-creation.

Keywords: collective intelligence, crowdsourcing, open design, open innovation, participatory design

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1 INTRODUCTION

The shift from closed to open paradigms in new product development is seen as an emergence of new forms of production, innovation, and design (Chesbrough, 2006a; 2011; von Hippel, 2005; Benkler, 2002). Innovation processes are shifting from open source software to open source hardware design. Emulating open source software, design information for open source hardware is shared publicly to enhance the development of physical products, machines, and systems (Raasch et al., 2009). Similarly, the rise of the "maker culture" enhances product tinkering (Anderson, 2012), while the DIY-movement embraces "the open" in design (Bouchez, 2012). Users participate in design via crowdsourcing and co-creation on platforms such as OpenIdeo and Quirky and by joining proliferating open innovation challenges (Jeppesen and Lakhani, 2010). At the back-end of the design process, customers are invited to participate in mass-customization and personalization (Salvador et al. 2009) to personalize products.
The open paradigm has received scholarly attention as open source software (von Hippel and von Krogh, 2003) and as open source hardware (van der Beek, 2012). Moreover, user-engagement in the design process has been studied as user-centric innovation (von Hippel, 2005), participatory design (Schuler and Namioka, 1993), co-design (Sanders and Stappers, 2008), and as customer co-creation and crowdsourcing (Aitamurto et al., 2011; Piller et al., 2011). However, the "open" landscape in design lacks a unified, agreed-upon definition for open design practices. This is partially due to the gap in approaches to design. Studies of innovation and new product development are focused on user-centric approaches and customer engagement in several stages of the design process, whereas current definitions of open design are focused on openness of technical design information and largely exclude, in particular, the early stages of the design process. The open design definitions also lack the commercial aspects of openness. Thus, the existing definitions are too narrow to holistically comprise the shift from a closed paradigm to an open paradigm in design. Moreover, the lack of clarity and consistency in definitions is hindering the development of open design as a design approach. To fully advance the research on methods and practices, a more comprehensive perception of openness in the design process is needed.
This paper develops an overarching definition for open design and a three-layered framework for design practices. The definition covers the design process from initial problem definition through to commercialization and licensing of the design. Thus, the definition takes *openness of process* into account, not only openness of product. The paper is structured as follows. First we give an overview of the existing literature and definitions of open design practices and related work in co-creation, participatory design,crowdsourcing, and open innovation. Then we introduce the new definition for open design. The paper concludes with a research agenda for open design.

2 BACKGROUND

Open products

Several terms, including *open content*, *open source content*, and *open knowledge*, are used to refer to content such as images or text files shared under a license which grants users the right to modify and re-use that content (Caswell et al., 2008; Nov and Kuk, 2008; Awazu and Desouza, 2004). Well-known examples include Wikipedia and the Creative Commons licensing project. In this paper, we use the term *open content* to refer to any text or media files that are shared under an open license.
Free and open source software (FOSS) is software distributed under either a "free software" or an "open source" license. It gives users the right to run, study, modify, and redistribute the software source code as they wish. FOSS can therefore be considered a specific type of open content. While there are some philosophical differences between the "free" and "open source" movements, the terms "open source software", "Free/libre and open source software" and "FOSS" are often used interchangeably in the literature (e.g., Giza, 2009; Lakhani and Wolf, 2003; von Hippel and von Krogh, 2003). We will use FOSS as an inclusive description.
FOSS has been successful in the software industry. An increasing number of researchers and practitioners have suggested that the success of FOSS could be replicated in other industries (e.g. Hope, 2004; Lerner and Tirole, 2004). Vallance et al. (2001) suggested the term *open design* to describe the sharing of design information such as schematics, CNC files, and documentation. This terminology has been used by others (Koch, 2010; Raasch et al., 2009), while in the technical literature

the terms *open hardware* and *open source hardware* are often used to describe this sharing of design information. For example, Metta et al. (2008) use both terms while describing the development of an "open" robotics platform. While *hardware* is sometimes understood to refer specifically to electronic components, the open source hardware definition is intended to cover all "tangible artifacts – machines, devices, or other physical things" (OSHWA, 2012). "Design," however, can mean a process, the documentation of that process, or its end product. Therefore, we propose that the definition of open design used by Vallance et al. (2001) is too restrictive to describe the full design process, and use the term "open source hardware" (OSH) to refer to shared information related to physical artifacts.

The majority of the literature on open products attempts to explain the processes associated with their creation. FOSS production, for example, has been treated as an example of "user-centered" or "user-driven" innovation (von Hippel, 2005), compared to "collective invention" processes (Osterloh and Rota, 2003), and modeled from the perspectives of a range of economic theories (e.g. Myatt and Wallace, 2002; Bitzer et al., 2007). However, the current conceptualization of openness as used in FOSS, OSH, and open content definitions refers only to the license under which the end product is distributed. While it is true that these licenses often facilitate an "open" process of voluntary, distributed collaboration, such a process is neither necessary nor sufficient to qualify a project as open under the current definition. While this process is discussed in the literature, it is not clearly defined. The aim of this paper is therefore to develop a definition for open design that takes account of the entire design process, rather than just the means of distributing the final product. The following section describes theories and definitions related to open processes that can provide guidance in developing a new, comprehensive definition of "open design".

Open processes

Co-creation refers to a collaborative action between employees and the external participants (the "crowd") (Piller et al., 2011). In co-created processes, the experts and amateurs—the company and the customers—work together, with two-way interactions between both groups, and peer-to-peer communication among customers (Prahalad and Ramaswamy, 2000). This results in a co-created experience, as noted in studies of online customer and brand communities (Cova and Pace, 2006). These participatory mechanisms address the consumers' growing demand for personalized experiences. Such collaborative modes of design can be autonomous, and can be started by individuals without a coordinated organization. Loose groups can then form. This collaboration can be classified as commons-based peer production (Benkler, 2002). These modes also occur in collaboration with organizations, which can initiate and manage them, and set up innovation challenges and other methods to engage the crowd.

Crowdsourcing can be defined as a problem solving system in which a crowd is enlisted to help solve a problem defined by a system owner (Afuah and Tucci, 2012). It is increasingly used in a variety of capacities. For instance, it is used in creative work, such as T-shirt design (Brabham, 2010) and distributed human intelligence micro-tasking, such as Amazon's Mechanical Turk. It is also used for developing companies' new product ideas (Howard et al., 2012; Poetz and Schreier, 2011). Finally, it is used for crowdfunding projects and new products on platforms such as KickStarter (Kappel, 2009). The problem is typically clearly defined, and it can range from a small fraction of a larger problem (typically called a "micro-task") to the full design of a product. Online innovation challenges are used by organizations as a crowdsourcing technique to gather ideas and solutions from "the crowd". Companies use either innovation intermediaries, such as InnoCentive (Jeppesen and Lakhani, 2010), NineSigma, or OpenIdeo (Lakhani et al., 2012) to discover solutions via innovation challenges, or they use their own platforms to harvest ideas from crowds (di Gangi and Wasko, 2009). These innovation challenges function not only as a source of new products or improvements for existing products, but also as need-finding tools to identify users' needs in diverse cultural, geographical, and socio-economic contexts.

Participatory design (PD) is an approach where non-designers are included in the design process, on the basis that they are experts concerning their own needs and lives. By including end-users and other stakeholders, designers can ensure that the solutions developed meet actual needs of people (Schuler and Namioka, 1993). It is believed that the active participation of people who understand the practices and environments in which new products and new services will be used makes it more likely that new solutions will be accepted and sustained by the intended users (Robertson and Simonsen, 2012).

Ideally, participants should therefore take part in the entire process, including need finding, idea generation, prototyping, and testing. The designer should facilitate the process, rather than dictating the product or service development (Arce, 2004).

PD has evolved from being mainly about development of Information and Communications Technology to comprising a wide array of fields such as space design, product development, industrial design, architecture, and service design (Sanders et al., 2010). Although PD practitioners belong to various academic disciplines, they share certain views: (1) design ideas arise in collaboration with participants from various backgrounds; (2) designers should spend time with users in their own environments rather than focus on tests in laboratories; and (3) decisions should be made democratically with the participants rather than by the designers alone (Sanoff, 2007). According to Sanders and Stappers (2008), *co-design* is an updated term for PD. However, *participatory design* is also frequently used in current literature (see, e.g., *Design Issues* special edition on PD, 2012). In this paper, we therefore use the terms participatory design and co-design synonymously.

User participation is central to the development of current trends in *user-centered design* and *user-driven innovation* (Robertson and Simonsen, 2012). At the core of user-driven innovation are "lead-users," organizations or individuals who already face the needs that will dominate the market in the future (von Hippel, 2005). They will benefit from obtaining a solution to those needs and can thus serve as need-forecasting groups. Since lead-users often attempt to meet their own needs, they can also provide valuable design ideas and concepts (von Hippel, 2005). Lead-user innovation has common elements with co-design since the recipients of design are included in the design process. However, as noted by Sanders (2006), the lead-user approach is fundamentally different from PD, because it builds on the assumption that only specific types of users can add value to the development process through their participation. Lead-users represent elite experts, and thus lead-user innovation does not capture the needs and dreams of the majority of people.

Open innovation is defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2006b, p. 2). Organizations increasingly employ open innovation as a strategic tool to increase the flow of knowledge to and from the organization, and to increase R&D productivity. Simultaneously, organizations seek to discover new ways to commercialize innovations within and beyond their own boundaries. By applying the open innovation strategy, the company can move toward an open business model (also called a *platform business model*), in which the value and revenue are co-created with collaborators (Chesbrough, 2011). An open innovation process includes three core processes: an outside-in process, an inside-out process, and a coupled process. In the outside-in process, firms enhance their knowledge base by tapping the wisdom of their suppliers, customers, and other related actors. This inbound open innovation leverages the discoveries of others, and organizations become less dependent on their internal R&D (Chesbrough, 2006b). Open innovation also engages an inside-out process which externalizes innovation processes to bring ideas to market faster. A company can do this by licensing its own intellectual property, as well as by reaching new markets through spin-offs and partnerships, thus increasing overall revenue while at the same time saving R&D resources (Chesbrough, 2006b). In these cases, companies use partners to find new markets and business models for their technologies (Lichtenthaler, 2008). The third ideal type in the open innovation process is a coupled process, in which companies create alliances, partnerships, and joint ventures, thus co-creating value for both parties. In these cases, companies combine the outside-in and inside-out processes, commercializing innovations with partners and sharing complementary resources, for instance by deploying open Application Programming Interfaces (APIs) (Aitamurto and Lewis, 2012). Co-creation and crowdsourcing can be used as tools in deploying open innovation strategies, as is done with open innovation challenges. Organizations can also apply participatory design and co-design approaches to deploy the open innovation principles in practice.

3 THREE LAYERS OF OPEN DESIGN

In this section the definition of open design is rearticulated to better address developments in the open paradigm and to update the design research paradigm accordingly. The new definition goes as follows: The open design process provides public access to participation in the design process and to the product resulting from that process, as well as the data created in the design process, whether that is technical details or other data and content gathered or generated during the process. The redefined concept of open design includes all the stages in the design process, from need-finding to ideation, as

well as the production process, intertwining the aspects of technical, legal, and commercial openness, as illustrated in Figure 1. *Openness* refers to a publicly accessible possibility to participate in the design process, thus inviting both non-designers and designers to participate. As a result, the boundaries between experts and non-experts become porous. Instead of inviting only the lead-users to be part of the design process, open design practices invite everyone to participate, regardless of their qualifications, skills, or professional position. Open design is also differentiated from traditional PD practices in that the process is inherently open to the public and is not only for invited participants.
Moreover, open design also includes later stages in design, such as the commercialization of the product, and the publishing of content produced during the design process, such as blueprints and other technical details. Thus, the new definition of open design comprises open source hardware, open source software, open design processes, open commercialization, and open content. It expands on those introduced previously in the literature, from openness of the product only, to the openness of both the process and the product.

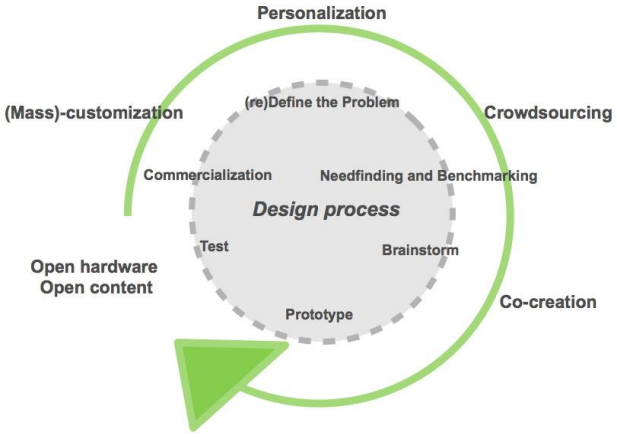

Figure 1. Open design practices and design process.

Open design principles are applied by using open design practices, as illustrated in Figure 1, and openness can be manifested in several stages of the design process. For instance, only the need-finding process might be open, or only the source-code might be publicly available. The design process is illustrated as a cycle to emphasize the recurring stages, such as testing, in the process. Moreover, the degree of openness can also vary in the design process. Openness is operationalized by deploying participatory methods, such as crowdsourcing or co-creation. For instance, to design a more functional refrigerator, the tasks could include videos of people loading and unloading a refrigerator, or pointing out the problems and advantages of current refrigerators in pictures. Alternatively, designers might post their initial concepts on online platforms such as Quirky for comments, and thus co-create their designs with users. See Table 1 for description of other possible open design practices.
To further demonstrate the practices of open design, we expand the typology of Piller et al. (2011), which in its original form describes collaboration between a company and a customer. In the developed framework, open design practices are deployed to do the following: 1) listen into; 2) interact and create with; and 3) share with other co-designers and the crowd. These three layers describe both autonomous design processes and customer–company collaboration. At least one of these three layers of open design practices can occur in an open design process.

Layer 1 – "Listen into"

In the first layer, a designer gathers information about the design task by observing behavior in offline and online communities. Customer needs can be observed, for instance, on online design communities (e.g., 99Design and Jovoto) and customer co-creation communities (e.g., Nokia Ideas Project, OpenIdeo, and Lugnet). The methodology can include netnography (Kozinets, 2002) or empathic design (Leonard-Barton and Rayport, 1997). This mode differs from traditional customer surveys and research reports in that the designer senses the customers' needs by using information gathered from open online communities rather than by using more traditional, closed methods. Needs can also be explored through sharing ideas for new solutions. There are several online platforms that allow people to share ideas for products (and thereby indirectly express needs experienced by themselves or others).

Quirky.com, for example, allows anyone to submit design ideas. Companies can follow such sites strategically to monitor reoccurring themes, needs, and gaps in the solutions offered on the market today, thus sensing the markets.

Layer 2 – "Interact and create with"

In the second mode, the designer ceases to be an observer and becomes a participant–observer, a role which includes interaction and co-creation with the users and co-designers. Participants take an active role as co-creators. The designer interacts with the crowd to gain feedback. This feedback includes money in the form of *crowdfunding*. Crowdfunding functions as a means of need-finding: if the crowd funds the design, the funders likely desire the design. Co-designers publish early concepts and develop ideas on sites such as OpenIDEO. The second mode is also expressed in design challenges, in which co-designers share ideas in public and invite feedback. The stage of these designs varies from early ideas to highly developed prototypes. For instance, Wells Fargo asks for customer feedback on prototypes through its Wells Fargo Labs. These designs are early prototypes or newly launched services. Thus, these online platforms function as live focus groups (von Krogh et al. 2000) for designers to observe and interact with users. In this mode, the users can also tinker with the products by personalizing them and mass-customizing them. When interacting with the users and other co-designers, the designer is applying PD practices while including as many stakeholders as possible in the design process.

OpenIDEO is an initiative that seeks the benefits of interacting and creating with the general public when designing for social innovation. Design challenges are posted on the site openideo.org. The crowd is invited to share stories, inspirations and need-finding insights. In the next phase, employees at IDEO generate concept ideas together with the crowd building upon each other's ideas. Based on the crowd's feedback, IDEO selects the best ideas together with the challenge sponsor. The short-listed ideas are then further refined, iterated, and prototyped together with the crowd. The crowd rates the concepts based on some key criteria before IDEO and the challenge sponsor selects the winning concept. The product realization might be done by IDEO or the challenge sponsor alone, or together with selected community members.

Layer 3 – "Share with"

In this layer, the technical details about the design are shared in public, whether they are source code or hardware details. Openness is employed by publishing the open source code and/or hardware information. The data gathered during the design process can also be published as publicly available data (on open data, see Kuk and Davies 2011). The open content can also include supply chain information, evaluation of environmental impact, such as carbon footprint and such. The principles of open innovation (Chesbrough, 2006b) can be used in the commercialization of the design by enhancing the flows of innovation to the company and from the company. Openness can be also deployed via open APIs, which enable the use of the end-product (if technological) through smooth technological integration. And it can also be used in early stages in design, by applying crowdsourcing and co-creation in problem-definition, need-finding, and detailed design. In the second mode, the focus is on active co-building and interacting, whereas in the third layer the focus is on publishing the data on the process and the product.

New technologies like 3D printers and accessible software is transforming how design is being done. In January 2013, Nokia became the first major manufacturer to give consumers access to its 3D design files so they can create their own versions of products. The company released digital files allowing users to alter and 3D print their own shells for the Lumia 820 smartphone. Consumers are thereby enabled not only to contribute with ideas an input but to also access blueprints and technology to personalize and further develop products on their own. This does, however, requires access to a 3D printer. RepRap (short for *replicating rapid prototyper*) is an initiative to develop a low cost 3D printer. The printer prints objects in plastic and can also print its own components. It can make a replication of itself and function as a self-replicating manufacturing machine - although electronic components must be purchased separately. The printer is controlled by an open source desktop software. All of the 3D designs produced by the project are released under a free software license, the GNU General Public License (reprap.org).

The benefits of applying open design practices

Open design practices hold the potential to contribute to the design process in several ways. When solutions are crowdsourced and co-created, more solutions for the design challenge will be presented than in a closed process. This variety of options can help a designer find the optimum solution, saving time and money, and the input of users and co-designers can improve the end-result. Some research indicates that problem-solvers outside the specific knowledge area of the problem (e.g., physics, chemistry, mechanical engineering) can, through crowdsourcing, help devise novel solutions (e.g., Jeppesen and Lakhani, 2010). For example, in a study of crowdsourcing in new product development, the non-expert users created solutions, which had more novelty value and customer benefit than those created by experts, according to the evaluation panel (professional engineers and designers). The solutions were, admittedly, somewhat lower in terms of feasibility (Poetz and Schreier, 2011). In this study, the evaluation panel was blind to the source of the ideas (professionals vs. users). These findings refer to the notion of collective intelligence, which is based on the idea that knowledge is most accurate when it consists of inputs from a distributed population (Levy, 1997).

Table 1. Openness in design process.

Design phase	**Methods**
Need-finding	Crowdsourcing needs, e.g., in online communities through interactions with end-users Ethnographic methods, empathic design
Ideation and concept generation	Publicly open brainstorming Crowdsourcing and co-creating concepts Crowdsourcing evaluations and discussions of ideas Co-creation of concepts by users and with users Testing problem-definition with the users
Detailed design	Crowdsourcing designs Co-creating prototypes with customers, users and online participants and testing prototypes with them
Manufacturing	Mass-customization and personalization of designs
Distribution	Open licensing of content, code, design specifications, etc. (e.g., by using Creative Commons licenses, FOSS licenses, OSH licenses)
Testing	Crowdsourcing feedback from users Opening prototypes for testing Co-creating redesigns/improvements of prototypes
Commercialization	Applying the principles of open innovation, e.g., in licensing, open APIs, marketing

Furthermore, participation in the design process can result in an effect known as the "pride of authorship," which has been noted in studies of user participation in new product development (Preece 2002). This can, in turn, lead to a stronger willingness to pay for the end-product, and a stronger feeling of ownership, as noted in co-creation studies (Aitamurto, 2013).

A commonly claimed advantage of the open approach in FOSS is "Linus's Law," which states that "given enough eyeballs, all bugs are shallow" (Raymond, 1999). In other words, with a large enough community of users and developers, any software problems will be identified and solved quickly. This goes against common wisdom in software development and other fields, which states that larger groups are less likely to achieve their goals (e.g. Brooks, 1975). An empirical study conducted by Schweik et al. (2008) investigated over 100,000 FOSS projects and found a correlation between the number of developers involved in a project and the likelihood of a project's success. This result strengthens the argument for Linus's Law.

The more open the design process is, the more design fits the notion of a public good that is accessible for the crowd to participate in and to use, tinker with, and build on the outcomes it produces. Thus, open design can be seen as a democratizing force in society. However, openness raises important concerns about divisions of labor and the abuse of amateurs in terms of the cost of expert designers (Keen, 2007; Terranova, 2004). These concerns follow larger societal developments, which appear in several fields, such as journalism (see Kreiss et al., 2011) and the music industry (Baym and Burnett,

2009). Openness is a double-edged sword, which can advance society while at the same time tearing existing structures apart.

The rearticulated definition of open design allows design researchers and co-designers to perceive the design process in a holistic manner, and include participants outside an organization. Open design has unrestricted participation as its ultimate goal; however, technology access and a lack of programming skills, for example, can limit people's opportunities for participating in and influencing the design process. PD does not necessarily have to be fully "open," as only invited/included participants may be given the opportunity to participate. However, open design inherently requires participatory approaches, when participation is perceived as engagement, and open design practices can be employed as tools for PD. Furthermore, even though the design process is partially, or fully open, it does not mean that everybody will wish to participate, nor is there a guarantee of quality. Thus, systems for unhampered, open participation have to be designed (just as with any product) with user friendliness and ease of access in mind to encourage users.

4 RESEARCH AGENDA FOR OPEN DESIGN

The framework for open design developed in this paper examines a variety of methods for employing open practices in the design process. The goal of this framework is to create a systematic and holistic approach to open design practices and to intertwine the aspects of participatory design and co-design. To examine the implications of open design practices, further research is needed. This paper concludes by suggesting research questions to examine further the phenomenon of "open" in design research.

Firstly, the impact of openness both in product and in process on quality of design has to be studied further. Experiments need to be created in which the impact of openness on design features, such as novelty, desirability and feasibility can be measured. Furthermore, also the relationship between openness in process and in product has to be studied further. Empirical research can show what are the best practices to intertwine the openness in process to openness of product, and what is the optimal balance in the openness.

Second, as the previous research indicates, participation in the design process can impact the participants' ownership of the end-product and willingness to pay for the design. This relationship needs to be studied further by measuring the impact of participation on users' desire for the product, controlling for the degree of participation. Moreover, the strength of participation likely varies based on the initiator of the design process (company, group, individual). These differences will be examined in future research.

Secondly, opening access to knowledge (in an open data manner) that is created during the open design process is becoming more common. Research has yet to address how the data commons, which is produced in the design process, can be useful, for whom it can be useful, and in which formats it should be published.

Third, the aspects of openness need to be examined within participatory design practices. The question of how to apply online practices and wider openness to participatory design remains widely unstudied. It is particularly crucial to pose these questions in the context of developing countries, in which the inclusion of stakeholders into design process with low-end technologies such as mobile phones can lead into a wider empowerment of end-users in suppressed and unprivileged societies. Acknowledging both the cultural and political dimensions of design holds the potential to increase transparency in design and manufacturing process, and thus to democratize innovation and mitigate the power asymmetries in innovation.

Finally, the open paradigm is celebrated as a democratizing force in design, following the discourse in other realms in society. However, the research has yet to address questions concerning the impact of open practices on the division of labor. A critical approach to the implications of the concept of "open" is needed to address the following research questions: How will the expansion of "the designer crowd" impact the craftsmanship of professional designers and their job prospects? Is "open" equivalent to "free," and what does "free" mean here? For whom is the object in question "free," and might "free"—or open—mean abuse for some?

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