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Topology, typology, and dynamics of commons-based peer production: On platforms, actors, and innovation in the maker movement

Venkat Aryan[1,2,3] | Juergen Bertling[1] | Christa Liedtke[2,3]

[1]Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Oberhausen, Germany

[2]Wuppertal Institute for Climate, Environment and Energy, Wuppertal, Germany

[3]Folkwang University of the Arts, Essen, Germany

Correspondence
Venkat Aryan, Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, 46047 Oberhausen, Germany.
Email: venkat.aryan@umsicht.fraunhofer.de

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In this paper, we aim to present a comprehensive analysis on the emerging phenomenon of distributed innovation in commons-based peer production (CBPP) platforms. Starting with the exploration of the widely held belief on value-creation confined to industrial settings, we raise several questions regarding the feasibility of, and a need for, an inclusive innovation process that can tap grassroots capacity into both traditional (industrial research and development) and emerging (peer-to-peer) innovation models to yield sustainable solutions. In particular, we explore the emergence and structuration of digital innovations in the maker movement, as it presents an alternative construct of innovation wherein access to and sharing of knowledge is predominantly distributed. With innovation outcomes often freely revealed, its very structuration could pose a principal challenge to our conceptualizations of value creation and competitive advantage in the current economic model. Drawing from responses received from 200 collaborative innovation platforms, six semi-structured interviews focusing on socio-technical innovation cases, as well as four in-depth narrative interviews with maker turned entrepreneurs, we present a detailed analysis on the topology of network, typology of actors, as well as the underlying innovation ecosystem in CBPP networks in Germany. In doing so, we contribute to the conceptualization of peer-to-peer distributed innovations in collaborative platforms.

KEYWORDS
collaborative platforms, commons-based peer production (CBPP), digital innovation, digital manufacturing, distributed innovation, maker movement, open innovation platforms

1 | INTRODUCTION

The idea of commons-based peer production (CBPP) (Benkler, 2007) over the past years has evolved from being a niche individual activity to a widespread global phenomenon. As maker movements grow in number, size and participation across the world (Dougherty & Conrad, 2016), CBPP platforms are playing a heightened role as prefigurative physical spaces where knowledge, tools, artefacts, culture, and values (Ruotsalainen, Karjalainen, Child, & Heinonen, 2017) are incessantly shaped, shared, and exchanged. The drive for digitalization with recent advancements in additive manufacturing, machine learning, Internet-of-Things and so forth, is blurring existing boundaries and enabling the rise of a new networked social structure (Smith, Hielscher, Dickel, Soderberg, & van Oost, 2013). This, in combination with novel open innovation platforms, could pave way to potentially disruptive socio-technical transitions (Valenduc & Vendramin, 2017) that reduce the cost of experimentation through sharing of risks and collaborative entrepreneurship (Nambisan, Siegel, & Kenney, 2018).

Increasing productivity through technology, innovation, and entrepreneurship is often touted as the engine for economic growth (Baumol, 1996; Drucker, 1985; Porter, 1990; Schumpeter, 2006). Historically, since the onset of market economies, the dominant discourse on innovation has for the most part deemed it an activity that ought to be confined within the boundaries of a firm (Chandler, 1962; Hannan & Freeman, 1977). Now, faced with global competition, rapid technological shifts and shorter innovation cycles, in light of the negative socio-environmental impacts, has forced a rethink on the nature of innovation and therewith its (re)conceptualizations. In particular, the rise of the maker culture and the proliferation of collaborative platforms globally have enabled the opening up of the innovation process. Such collaborative platforms are said to have the potential to transform entrepreneurship by acting as intermediaries for organizing value creation (Hagiu & Altman, 2017), wherein user innovation communities are able to produce bottom-up, grassroots innovative solutions to address local needs and challenges (Smith, Fressoli, & Thomas, 2014). Several progressive practices and collaborative models (Kostakis, Niaros, & Giotitsas, 2014) within these emerging structures now appear to have the potential to shape new markets (Baldwin & von Hippel, 2011; Rifkin, 2016), revive localized manufacturing and production (Anderson, 2012; Rifkin, 2016), and achieve wider sustainable transformations (Liedtke, Baedeker, Hasselkuß, Rohn, & Grinewitschus, 2015).

Although maker culture is historically associated with DIY (do-it-yourself) activities, it is now increasingly growing into a DIWO (do-it-with-others) movement (Maravilhas & Martins, 2017) that could be equated to “communities of innovation” (Dahlander & Gann, 2010). With democratized access to professional-grade tools; groups of designers, artists, activists, and inventors collaborate in a range of projects that could be classified as grassroots explorations or innovations (Troxler, 2010). As such, the maker culture has now expanded beyond its traditional artisanal origins to a movement, wherein technically sophisticated physical products are fabricated with the aid of digital and rapid prototyping tools. Further evidence of grassroots innovation is now noticeable in sophisticated fields such as nanotechnology and synthetic biology (Kera, 2014), biotechnology (Landrain, Meyer, Perez, & Sussan, 2013), and medical diagnostics (Walsh, Kong, Murthy, & Carr, 2017).

According to some proponents such novel forms of participation could fundamentally transform the construct of work (Fukuyama, 2000) and propel structures of “combinatorial innovation” that leverages traits of distributed innovation to create products and services in which the innovation/application boundary is constantly in-the-making (Yoo, Boland, Lyytinen, & Majchrzak, 2012). Heightened claims also include a path to a “third industrial revolution” (Rifkin, 2016) and post-growth or de-growth economic paradigms (Paech, 2016). Yet, several studies show that not all users within collaborative platforms innovate or diffuse their innovations to the extent that could be considered as a socially optimal output (de Jong, von Hippel, Gault, Kuusisto, & Raasch, 2015; Stock, Oliveira, & von Hippel, 2015), and as such entrepreneurial success and potential returns from innovations are contingent on institutional and infrastructural arrangements (Nambisan et al., 2018). Hence, an understanding of the structuration (occurrence and emergence) of such community-driven innovation platforms, degree and extent of user participation, type of material and cultural exchanges, and finally the make-up of innovation process within these networks can help realize the underlying mechanisms that could enable the effective diffusion (scale-up or scale-out) of values, practices, and innovation models.

The aim of this paper is to make a comprehensive analysis on the emerging phenomenon of distributed innovation in CBPP platforms. To this end, we start by exploring the existing scholarly body of literature focusing on collaborative innovation ecosystems. The next section describes in brief the research methodology as well as the data sources used in this study. The final sections present both the results and an in-depth analysis yielding the conceptualization of socio-technical spaces as multi-sided platforms for common-based peer production.

2 | THEORETICAL BACKGROUND

2.1 | Increasing need for a discourse from innovation to innovation ecosystems

Across most innovation models, the end-user, albeit an active user of the innovation artefacts, is still anything but a passive beneficiary along the innovation chain. Despite increasing academic emphasis for open innovation (Bogers & West, 2012; Christensen, Olesen, & Kjær, 2005; Harhoff & Lakhani, 2016) and the study of innovation evolving from its roots in economics into a multidisciplinary field today, innovation models are still predominantly top-down or pseudo-open. This parochial view on innovations by discounting (a) prime stakeholders, i.e., the users or actors involved in non-R&D undertakings (Arundel, Bordoy, & Kanerva, 2008), and (b) the relevance of non-technological or social innovation (Edquist, 2011; Piva & Vivarelli, 2002) can only yield inadequate solutions to persistent socio-economic problems, and in some instances could even exacerbate them (Loorbach & Rotmans, 2010).

Early innovation processes—the so-called “linear” or “phase gated models”, were a strict sequence of modularized activities with inadequate interactions outside their boundaries (Cheng & van de Ven, 1996; Tidd, Bessant, & Pavitt, 2005). Herein lies the problem. As linear models operate in innovation silos, they neglect the dynamic complexities that entail a product or processes' lifecycle. Thus, modern innovation theories have evolved from simplistic unidimensional, firm-centric models to complex networked models with permeable boundaries (Enkel, Gassmann, & Chesbrough, 2009). With knowledge being spatially dispersed and more often than not located outside the typical boundaries of a firm (Bogers & West, 2012), traditional players are forced to broaden the scope of institutional R&D to embed external actors or communities of actors in what is known as open innovation (Chesbrough, 2003) or user-innovation (c.f. von Hippel, 2005).

While both open innovation and user innovation emerge from a common understanding to address the innovation problem in light of shorter innovation cycles, they, however, take diverging routes in addressing (capturing dispersed external knowledge) and managing innovation flows and networks. Community-based innovation models differentiate themselves from market-oriented open innovation models through a distributed innovation process (Benkler, 2016). They are by design conducive to innovation and rely on an open sourced pool of information, domain knowledge, software, hardware, and infrastructure.

Platforms that enable grassroots innovations have increasingly gained relevance in the business sector in recent years. Owing to the commercial success of start-ups such as Airbnb, Dropbox, and Uber, an increasing focus on the role of collaborative platforms—in fostering digital innovations (Trabucchi & Buganza, 2020), facilitating networking and amplify networking effects (Ferdinand, Petschow, & Dickel, 2016), enabling supply–demand matchmaking and access to market (Cheng, Tao, Xu, & Zhao, 2018)—is of heightened interest to both business practitioners and scholars. Equally important resources are the participants, user-communities, and proprietary platform owners themselves who add to the heterogeneity of innovation platforms and contribute to the indirect network effects (Ceccagnoli, Forman, Huang, & Wu, 2012). Together, they shape a collaborative innovation ecosystem that is often self-described as fablabs, makerspaces or hackerspaces.

With a common consensus that ideas do not occur in isolation, collaborative innovation ecosystems are part of an emerging innovation paradigm based on the principles of solidarity and conviviality, collaboration and co-creation along with openness to exploit technology to undertake entrepreneurial pursuits (Nambisan et al., 2018). Hence, to understand the social utility of the innovation artefacts emerging from these structures, it is not only important to analyze the impact of innovation outcomes but also the typology of agents (users) and the topology of the structures (platforms). This in turn could reveal the user types that make up these innovation communities and divulge the nature and pathway of the innovation process therein.

2.2 | How community innovation platforms facilitate decentralized solutions to local challenges

Forms of society-driven social or sustainable innovation have long been in existence and are traditionally considered as a peripheral activity by mainstream businesses. However, following the global financial crisis of 2008, several social movements, initiatives, networks, and assemblages driven by post-growth philosophy (KHK/GCR21, 2014), millennial values (Credit Suisse, 2017), and digital nomadic culture (Morgan, 2014) have sprouted across the world. With access to high-tech tools, these groups are actively exploring the possibilities of challenging the primacy of market economics, with non-market decentralized solutions to address local sustainability challenges (Benkler, 2007).

The power of tinkering or in other words experimentation in decentralized niches has often been highlighted as drivers for social innovation in transition management theory (Geels, 2010; Grin, Rotmans, & Schot, 2010; Oldenziel & Hård, 2013). From personalized fabrications to sophisticated means of peer-production and transition experimentations, the community of actors in these networks engage in a class of activities that can be deemed as creative production or decentralized co-creation (Smith et al., 2013). Van Holm (2017) observes innovation within such localized community platforms can enhance entrepreneurial output and innovation quality by: (a) increasing the probability of "accidental entrepreneurs"; (b) enabling plurality in innovation derived from the inherent diversity of a network; and (c) lowering initial prototyping costs and minimizing transaction costs to pave the way for bringing an idea to fruition.

The potential of physical spaces with low-cost access to resources, including 3D printers, laser and plotter cutters, easily programmable microcontrollers, and computers is paving the way for an emerging pool of global tech-savvy knowledge communities (Troxler, 2010). When viewed as sheer experimental spaces, learning-by-doing or in other words iterative and reflexive learning, can aid individuals in capability building (Clarke & Ramirez, 2014) and life-long learning (Wittmayer & Loorbach, 2016). With this structuration, these decentralized platforms become much more than just physical spaces that use sophisticated tools. In fact, they are the modern-day public sphere where ideas and knowledge are shared (Wong & Partridge, 2016) and could potentially provide vital grassroots institutional support for sustainability transitions.

In Germany, a large number of physical spaces and forms of cooperation are currently emerging, which can best be summarized as Offene Werkstaetten (open workshops) (Lange, 2017). The spectrum of activities is similar to makerspaces or fablabs elsewhere in the world, in which the notion of alternative consumption practices, self-sufficiency, creative independence, and personalization are tested and realized through a range of both low-tech (handicrafts) and high-tech (digital fabrication) undertakings. On one hand, these platforms enable the community participants or the social actors to increase innovation effectiveness through networking, transforming design into innovation for localized sustainable production, and finally provide mechanisms to safeguard innovation outcomes toward common goals (Feller, Finnegan, Fitzgerald, & Hayes, 2008). On the other hand, the individual participants have diverse motivations ranging from nerdish tech-enthusiasm to a search for technical solutions and foundation of start-ups, from establishing tech-savvy urban production methods to innovating based on the principles of sufficiency and dematerialization (Lange, 2017).

The existing body of research on the maker movement has thus far mostly focused on the values of the movement and its potential in shaping or to some extent disrupting the conventional linear innovation process. However, in order to foster innovation through these emerging community-based structures, it is vital to analyze both the type of participants that are attracted into these platforms, their motivations and goals, as well as the platforms in themselves with respect to the embedded social interactions. It is necessary to systemically classify the diversity within these collaborative platforms and interpret the developments within these structures in the context of a broader process of societal transformation.

In this paper, we aim to drive the focus on important questions and relevant research issues that surround the emerging phenomenon of distributed innovation in CBPPs. To this end, we draw from responses received from about 200 collaborative innovation platforms, six semi-structured interviews focusing on socio-technical innovation cases, as well as four in-depth narrative interviews from maker turned entrepreneurs. We start by analyzing the topology of community innovation platforms in Germany, with the aim of identifying any common classification of the activities undertaken that hold important implications in understanding the nature and extent of user engagement. Next, we analyze the participants by identifying their key motivations, objectives, and contributions, along with how they evolve over time within a collaborative platform. This indeed provides a deeper understanding of how to sustain active participation and continued contribution beyond the early induction period of a user into a platform. Finally, we focus on the innovation process and identify an underlying innovation ecosystem that is shaped by the social and creative exchanges between the identified user typologies.

In essence, through an in-depth and holistic analysis, we contribute to the conceptualization of peer-to-peer distributed innovations in community-driven collaborative platforms. In addition, we identify relevant questions for future research that could enhance our understanding of the underlying mechanisms that could enable the effective scaling-up or scaling-out of values, practices, and innovation models in such platforms.

3 | METHODOLOGY

This study aims to profile the topology of networks, the typology of actors, as well as understand the underlying innovation process in community-driven distributed innovation ecosystems. Owing to the exploratory nature of this research, it makes use of qualitative interviews in combination with quantitative data gathered from the survey of diverse societal actors (participants, institutions, and platform managers) involved at various levels of engagement across several collaborative platforms in Germany. The platforms investigated in this study included a spectrum of low-tech and high-tech collaborative spaces ranging from fablabs, makerspaces, and hackerspaces, to repair cafés and screen printing workshops.

3.1 | Selection of survey participants and interviewees

The main aim of conducting interviews besides the quantitative data was to explore individual motivations for engaging in peer production, the expectations and experiences of long-term participants, as well as grasp from their insights, the needs for further development of the overall CBPP landscape in Germany. The criteria that went into selecting the interviewees were: (a) project cases focusing on innovation rather than preserving craftsmanship, and (b) long-time experience in the maker or hacker movement. The interview respondent samples were chosen by their accessibility, using a convenience approach (Bryman, 2016).

3.2 | Data collection and analysis

The survey was sent to collaborative platforms across Germany and consisted of 76 questions, which were rated on a Likert-scale. The questionnaire was sent to the targeted sample via e-mail. From the 453 targeted sample, responses from 200 participants were received, of which 103 responses were valid. This corresponds to a response rate (RR) of 23%, which could be considered a reasonably good and representative RR for e-mail surveys (Fincham, 2008).

The six semi-structured guided interviews were conducted via telephone. For each of the platform managers listed in Table 1, a predesigned questionnaire containing 42 questions was sent in advance. The questionnaire was divided into five sections: (1) story, motivation, and aim of the platform, (2) product or outcomes of the platform, (3) resources used, (4) work and knowledge base, (5) commercialization and path to market. Upon receipt of the answers, follow-up interviews were conducted with each of the six project members who worked on the socio-technical innovation case since its inception. In addition, four in-depth narrative interviews, consisting of 12 questions, were conducted in person with maker turned entrepreneurs (see Table 2). The semi-structured interviews helped to delve deeper as well as supplement the quantitative data obtained from the questionnaire and thus enabled a thorough analysis. For all cases, the interviews were recorded and coded into themes relating to the make-up of the collaborative platforms, type of users, trajectory of innovation process, and finally on the innovation outcomes and the nature of innovation.

4 | RESULTS AND DISCUSSION

In this section, we discuss at length the findings of the study as presented in three parts. First, we start with the analysis on CBPP platforms; this is followed by the analysis on users within these networks;

TABLE 1 Selected socio-technical innovation projects

Project name	Topic	Location	Interview duration
XRP Robot	Robotics	Cologne	28 minutes
Airfling	Wind energy	Dusseldorf	35 minutes
3dator	3D-printing	Darmstadt	20 minutes
Laydrop	3D-printing	Berlin	22 minutes
Plants & Machines	Aquaponics	Weimar	27 minutes
Mycovation	Bio-hacking	Dortmund	38 minutes

TABLE 2 List of in-depth narrative interviews of maker turned entrepreneurs

Maker code	Topic	Profession	Employment	Interview duration
A	Micro wind turbines	Business manager	Bank	92 minutes
B	Aquaponics	Chemical engineer	University	89 minutes
C	3D-printing	Mechanical engineer	Self-employed	95 minutes
D	Bio-hacking	Biologist	Research institute	102 minutes

and finally on the nature of innovation within distributed innovation networks.

4.1 | Analysis on platforms: Topology of CBPP ecosystem in Germany

4.1.1 | Platform makeup: Actor demography and background

Contrary to clichéd connotations of associating collaborative platforms with young tech-savvy millennials, the survey found a diversified range of participant demography instead. The age group of the investigated sample (*n* = 103) had a distribution from 20 years old to 75 years old, with 41 years being the average age. Figure **1** shows the age distribution and gender of the surveyed participants. The majority of the participant community, about 31%, lie between the age group 25 and 35. At 18%, the next largest participant community belonged to the 35–45 year age group.

Finally, and interestingly, an increased interest among 60 years old and above was observed within these spaces. Standing at 13%, this age group adds to the strength and reflects a healthy affinity among older adults in life-long learning, expertise sharing, and openness to using professional tools. When analyzing the gender aspect, 24% of the survey respondents identified themselves as female, 56% respondents identified as male, while the remaining 20% chose not to reveal their gender.

When exploring the educational background and professional skills of the participant pool, it was observed that the majority of participants had a formal college degree or were currently a student (see Figure **2**). The platforms were found to attract a large pool of participants with engineering and IT background (about 30%), this was followed by artisans at 19%. While the artisan pool consisted of traditional hand workers, the designer pool was a mixed group of digital and industrial designers. On the whole, it was found that these platforms are meeting and collaboration points for engineers and IT experts, artisans, and designers. Notably, the share of these skilled actors found within these concentrated yet distributed pools of collaborative spaces was well above the German national average. For instance, the share of artisans, engineers and IT experts, natural scientists, and designers amongst the wider German population stood at 12.5%, 4.4%, 1.2% and 0.3%, respectively in the year 2017 (BA, 2018; Statista, 2017; VDI, 2018; ZDH, 2017).

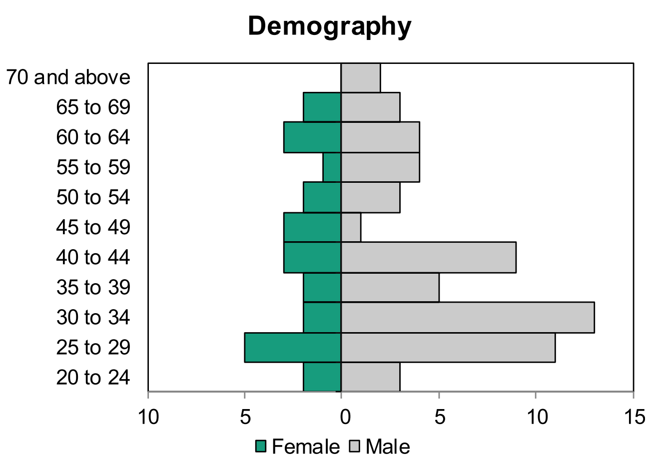


FIGURE 1 Participant demography [Colour figure can be viewed at wileyonlinelibrary.com]

In the interviews, as established in the survey data, the platforms were identified as "*the melting pot of ideas*" [B2]. At the same time, the focus on technology was predominant: "*Open workshops should focus on technology*" [D1]. However, it was also criticized that, despite having a technical background and the necessary tools, "*90% of people simply* […] *do not have the ability to make/hack*" [A1] and simultaneously "*the diverse educational backgrounds of users though on one hand is the source for multidisciplinary innovation, at the same time it also leads to numerous communication problems*" [A2]. Finally, from the point of view of some interviewees, the platforms "*cannot be inclusive places for everyone if ambitious results are to be achieved*" [D3].

4.1.2 | Topology of collaborative platforms: A broader classification of undertaken activities

Due to the wide range of both low-tech and high-tech activities accompanying the maker movement, it is not possible to draw distinct boundaries and create neat definitions between the types of collaborative physical spaces. Therefore, this study chose to categorize the class of activities and engagements conducted in collaborative platforms in more inclusive and broader terms than is usual to achieve three groups: (a) makerspaces, (b) hackerspaces, and (c) fablabs. Makerspaces can be associated with a variety of collaborative undertakings that enable self-sufficiency, personalization of goods, and creative independence. Hackerspaces are not meant simply to denote traditional software or hardware hacking but also include concepts of upcycling and repair culture that are quintessential to the maker movement ideology (Bertling & Leggewie, 2016). Finally, fablabs can be associated with spaces that engage in prototyping and fabrication of new products often with sophisticated digital machines and tools. These classifications were chosen to reflect the ongoing socio-technical transitions emerging from diverse types of collaborative

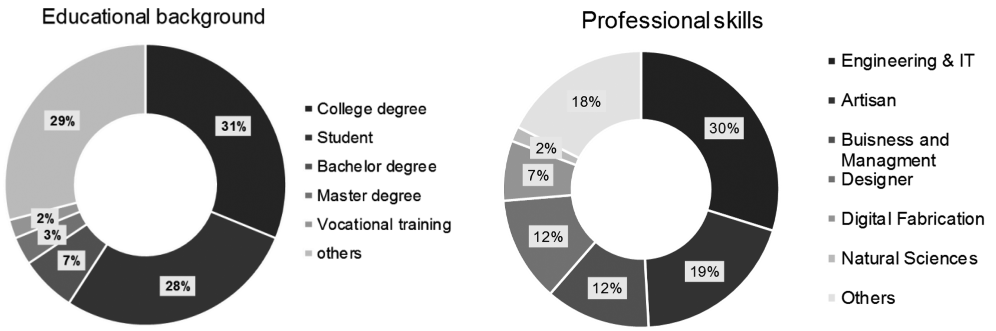


FIGURE 2 Educational background and professional skills

spaces (Smith et al., 2013; van Holm, 2015). A mapping of these collaborative platforms into the three above mentioned platform types was self-identified by survey participants (see Figure **3**). About 44% of respondents identified their platform as a hackerspace focusing on areas of environment, consumption and societal transformation through alternative forms of value exchanges. Around one-third or 33% of the respondent identified themselves with fablabs focusing on developing new prototypes and digital fabrication. Finally, the remaining 23% of the respondents identified with makerspaces where artistic creation, capability building, knowledge and innovation commons are prime pursuits.

From the point of view of the interviewees however, apart from the typology identified, it was fundamentally necessary for the platforms to "*focus on specific core topics*" [B4] and "*leave other convivial topics to other mediums or to the pubs*" [D2]. The comparison with pubs or bars was quite often quoted, "*there is no difference between an old-style hackerspace and a pub*" [A3]. Above all, this tension between technology focus and sociability dominates the everyday discourse of these platforms.

4.1.3 | Business model

Unlike FLOSS (free/libre and open source software), where collective organization and execution of open source projects are not necessarily limited by financial constraints, physical peer-production activities have to overcome the burden of financing their material and equipment requirements in addition to financing their day-to-day activities. In fact, it is this very access to physical spaces and professional grade tools that enables them to create and capture value. Although the cost of high-tech tools has significantly lowered in the past decade, these physical spaces are faced with high operating and maintenance costs.

The survey found that the financing models adopted by collaborative platforms were therefore rather diverse and often multi-streamed. With the exception of platforms that are run directly by institutions (foundations, city councils, universities, etc.), most collaborative platforms relied on hybrid models of financing. Table **3** shows the typical revenue streams of the project cases investigated in this study.

When exploring revenues, on average, 34% of the survey respondents listed donations as the prime source of funding, a further 18% mentioning membership fees, and only 12% was declared to be generated from project-based products and services rendered. In addition, other commercial activities such as conducting open workshops, leasing and sharing of tools, and private contributions added a significant portion to the revenue stream (about 36%). When looking into the operational costs, besides equipment costs that are often obtained through institutional funding or sponsorship, material costs were found to be the largest expense. From the survey, it was reported that on average 51% of the used materials were purchased by the platforms themselves. The remaining 49% was obtained through means that could be characterized as bootstrapping.

A central problem facing the platforms was that their current business models do not aim at remunerating their users. It was often criticized by participants that "*some platforms ultimately take advantage of their users by free exploitation of their results*" [C1]. Repeatedly, the idea of "*universal basic income*" was put forth as a viable business model or income stream to unleash the full potential of innovation commons [A4].

4.2 | Analysis on users: Typology of peers in CBPP ecosystem in Germany

4.2.1 | User motivations and objectives for engagement in collaborative spaces

The data reveals that community orientation and not economic utility maximization are the principal reason for engagement in collaborative

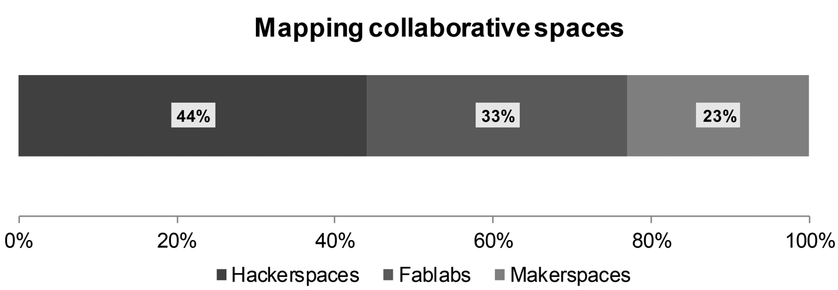


FIGURE 3 Mapping of collaborative spaces in Germany

TABLE 3 Major revenue stream of the project cases

Project	Revenue stream
XRP Robot	Workshops
Airfling	Licensing the brand, workshops
3dator	Selling construction kits, workshops
Laydrop	Selling construction kits, workshops
Plants & Machines	B2C: Selling construction kits, workshops, B2B: Selling tailored solutions and services
Mycovation	Workshops

platforms. Community orientation and non-economic benefit maximization are the main reasons for the long-term commitment in collaborative platforms. The prime motivations found for engagement could be classified as follows: (a) imparting knowledge, (b) enabling and leading societal transformation, and (c) involvement in hands-on practical work. Interestingly, these dominated other aspects like artistic creation, which is concomitant to digital fabrication communities. Figure 4 shows the initial personal motivations versus pursued common goals. The initial motivations were the motivations self-described by the survey respondents that led to their initial engagement in collaborative spaces. The pursued common goals were quantified by the survey respondents based on the projects undertaken by them. The values shown in the figure are the averaged values.

About 88% responded imparting knowledge to the community as their key motivation for engaging in collaborative platforms. This was closely followed by 80% favoring societal transformation and hands-on practical work respectively. Furthermore, experimentation and new learning through collaborative work, and building of community networks were vital elements to the participation culture. Notably, economic gain was found to be one of the least motivating factors, where only 12% of the respondents found it very important. However, this was in marked contrast to the experiences expressed by the interviewees. Especially after many years of unpaid voluntary work, the prevalence of economic interest was frequently noted. As collaborative platforms are distributed networks with diverse participant pools, the motivation and objectives of these networks naturally reflected those attributes. Besides characteristic structural objectives that would enable effective exchange of knowledge and information, their broader social objectives towered over their regional presence. It was found that a majority of participants considered facilitating knowledge sharing, aiding in capability building of others, and including wider community in peer-production as their primary goals. Broader societal goals that were mentioned also include promoting sustainable development, strengthening ecological awareness, and exploring alternative economic systems to capitalism.

4.2.2 | Typology of users in collaborative platforms

Peer production in collaborative platforms takes place in an organized yet decentralized framework of systems or networks, wherein people with diverse skills, values, motives, and anticipations embark collectively in acts of production and innovation. As such, these networks provide low-cost or cost-free symmetrical access privileges (Benkler, 2016) to their members and thus attract a diverse participant pool. This opens up such networks to a large number of participants who otherwise might have been left out, if participation fees were a prime factor. Therefore, the success of a collaborative platform and the wider peer-production model rests in its ability to capture, organizes, and bring together the inherent diversity of participants and the interdisciplinary pool of skillsets therewith. Hence, new and effective practices of participation, cooperation, and coordination are crucial pre-requisites to amass and channel dispersed knowledge and resources into effective problem solving besides the generation of artefacts.

Based on the survey and interviews, the study identifies the roles and the extent to which citizens engage in peer production and in facilitating distributed innovations (see Table 4). The participation and contribution of users could be categorized into three core archetypes: (a) core-creators, (b) situational-contributors, and (c) enthusiasts. As peer production has no rigid hierarchies, and it is the participant who chooses the physical space as well as the project to which they want to contribute, self-motivation, self-regulation, and self-organization play a key role toward successful and meaningful contributions (Benkler, 2007).

In traditional innovation systems, participants engage in the generation, codification, and retention of new knowledge as an asset in exchange for a reward, recognition or remuneration (Cheng, 2016). However, within peer-production communities, partaking is voluntary and there is no guarantee of a monetary reward (Wasko & Faraj, 2005). Furthermore, in most cases it could merely be a need or

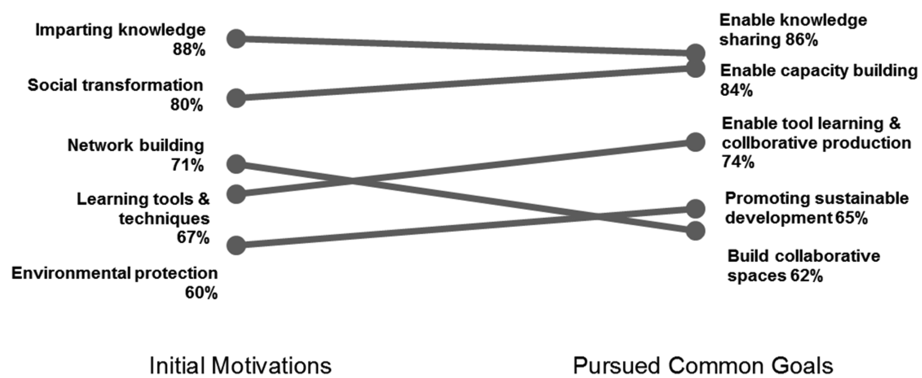


FIGURE 4 Motivations and pursued goals in collaborative spaces

TABLE 4 Typology of users: Core archetypes

User role	Contribution level	Archetypes	Main focus	Intrinsic motivations	Extrinsic motivations
Core-creators	High	Avant-garde	Systems	Belief in the need for social transition	Peer recognition, Reputation
Situational-contributors	Medium/high	Transactional	Products	Utility maximization	Entrepreneurial intentions
Enthusiasts	Low/medium	Zealots	Ideas	Leisure time pursuit	Skills development

means for a social exchange or connection (Botsman, 2017). Hence, their contribution levels could be relatively asymmetrical (Yuan, Cosley, Welser, Xia, & Gay, 2009). This asymmetrical contribution can lead to what many have attributed to as a core-periphery gap (Balestra, Cheshire, Arazy, & Nov, 2015; Lakhani & Wolf, 2003) that could cause an undersupply of information and knowledge flows, and compromise the effectiveness and interests of collaborative platforms and peer-production networks as a whole (Cheliotis & Yew, 2009). Interviewees expressed it thus: "*It was so often that I ran ahead holding the flag and when I turned around, I saw that I was alone*" [A12], and "*In the end it is like in any shared living, some work for the community others do not*" [A10].

Some studies argue that participation in CBPP follows the power law (also known as the 1% rule or 1–9–90 rule), where 1% of the community is involved in creating original artefacts, the remaining 9% engage in support activities, while the majority 90% are just passive participants (Heckathorn, 2016). Therefore, this passive majority, without counterbalancing mechanisms, could silence or overwhelm the influence of the creative minority and thus render them powerless (Yuan et al., 2009). However, in reality several successful FLOSS examples such as Wikipedia, Linux, and Mozilla foundation have proven otherwise. If one could dismiss this creation of utilities as something characteristic only to online software communities, several successful OSH (open-source hardware) such as Rep-rap, Arduino, SparkFun, Adafruit, etc., provide evidence to the contrary.

Nonetheless, core motives for contribution in peer-to-peer (P2P) communities include community citizenship, reciprocity, self-interest, pro-social behavior (Tedjamulia, Dean, Olsen, & Albrecht, 2005; von Hippel, 2017), and value systems (e.g., FabLab manifesto) in combination with mechanisms like reputation, peer recognition, or ranking (Ehls, 2014). These value systems that are built into collaborative platforms and networks enable the participants to collectively overcome both conflicts and challenges (Bennett, Segerberg, & Walker, 2014). In practice, the balance between shared and individual utility maximization is often as follows: "*People share knowledge, but then work on their individual private projects*" [D5]. Benkler (2016) argues that unless the core-community is committed to generate common goods and has the ability to self-organize and take concerted actions, the function of CBPP as a potential system is questionable.

Furthermore, when exploring the nature of participant engagement, it was found that an overwhelming majority of the survey respondents, about 70%, were primarily associated with one of the above-mentioned collaborative spaces as volunteers. A further 11% were engaged directly on a permanent basis and 3% were associated in contracted projects (see Figure 5). Owing to its decentralized grassroots origins, the maker movement has created physical spaces and resources that are inclusive in nature. Hence, it was not surprising that volunteers predominantly administered the logistics and functioning of these spaces and the projects within. While some platforms were found to follow the fab charter (FAB Foundation, 2018) and the maker manifesto (Hatch, 2014), others were found to have altered forms of self-styled governance structure derived from the former two.

Likewise, when examining the extent of participation, it was observed that participants volunteered their time as much or as little as they can, want, or were able to. It was noted that about 40% of the respondents contributed between 3 and 10 hours per week, while the other 40% worked between 10 and 35 hours in total. As self-organizing communities, the projects were bottom-up and hence often self-selected or collaboratively developed. In particular, it was found that the community through consensus decided around 36% of the total projects. Ihl and Piller (2016) argue that the access to technology, physical space, and technical knowledge in combination with the urge to create something personal or customized, make these communities a testing ground for sophisticated peer-production systems. The interviewees also described this high degree of freedom to operate and the great differences in the amount of time involved as both a "*curse and blessing at the same time*" [A5]. On the one hand, the activity can be customized to meet individual interest and available spare time; on the other hand, this makes it difficult to organize efficient teamwork.

4.2.3 | Defining factors in selecting a collaborative platform

Given the varying degree of participation and co-creation, with the constant ebb and flow of peers in and out of collaborative platforms, it is important to understand why and how peers choose a specific platform in the first place. While these decision factors might still be less-informed and formative at best, these are however, the initial defining factors, which might change as a participant begins to engage within the chosen community and physical space. When analyzing the data, four key factors reveal the initial motivations that aid participants to self-select a specific platform.

a Proximity to a collaborative space

Considering most of the participants were students or working professionals, who are involved in the maker movement during their

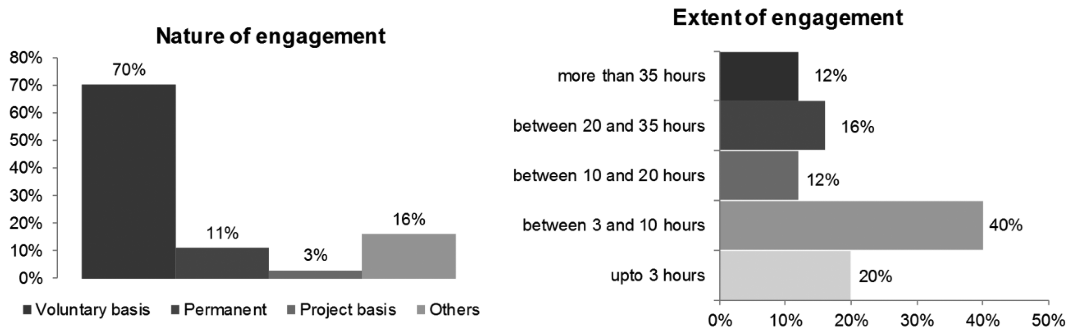


FIGURE 5 Nature and extent of engagement in collaborative platforms

spare time, it was self-evident that geographical location and spatial distance played a key role when choosing a platform close to their dwelling or workplace. Hence, besides fun and learning, staying close to the community and engaging in activities that could enable providing solutions to local problem was identified as one of the prime reasons in choosing a collaborative space close to one's location. Larsen and Guiver (2013) suggest three layers of distance from a psychological and behavioral perspective: One measured by distance (spatial), the second by physical separation and relational aspects (zonal), and the third by cultural dissimilarities (ordinal). In those terms, it could be argued that proximity is only a factor when collaborative platforms are sparse. In inner cities and larger towns where access to such spaces is easier, spatial distance is not a factor. Instead, other concerns such as one's ideological values and the corresponding platform's value system plays a bigger role. Furthermore, proximity is a factor only when choosing a CBPP platform for the first time. As participants engage and evolve within their communities, they often branch out and contribute to projects across their region and the globe. It is indeed this spill-over effect that enables CBPP to extend beyond its regional boundaries and evolve into new forms of innovation communities engaging in social production (Anthony, Smith, & Williamson, 2009; Benkler & Nissenbaum, 2006).

b Ideological values and orientation

Besides spatial proximity, the second deciding factor was the alignment of common interests. As revealed in the survey data earlier, the material and cultural exchanges in these platforms mean much more than peer production or the act of 'making'. Predominantly and repeatedly in collaborative platforms across the world, the culture and value system is shaped by the acknowledgment of faults in present-day knowledge and innovation/production systems: "*I am not enthusiastic about the term Innovation. Today, what we attribute to innovation above all is what saves money, for example, Uber & the likes*" [A6]. At the same time, they are actively redefining the role and nature of a consumer, producer, designer, or manufacturer on the basis of their ideological beliefs and adapt them into an emerging value system (Benkler & Nissenbaum, 2006). The ideological drive includes addressing a range of socio-technical shortfalls such as information asymmetries in traditional knowledge systems, and market imperfections created by economic activities or even challenging capitalist logics (Rifkin, 2016). It was also observed that post-growth values and propelling the notion of sustainable lifestyles through self-sufficiency and personalized production took center place. Hence, the notion of what is sustainable and inclusive development was quite contentious: "*we* [*the younger generation*] *do not need a precautionary principle* [*that limits us*], *instead we want full participation*" [C2]. Interestingly enough, this has also occasionally been linked to criticism of third sector organizations: "*When NGOs call themselves civil society representatives, this is presumptuous and arrogant. Labs and Spaces are the places for an inclusive, technology-friendly, undogmatic civil society discourse*" [C5].

c Access to physical space and tools

CBPP platforms are pre-figurative spaces deliberately designed to increase access to physical and digital tools and thereby improving skill-sets and grassroots innovation capacities. The data found no typical specifications or dimensions these platforms occupy. The average size of a collaborative platform in Germany was found to be about 170 m^2. Likewise the tools available depended on the topologies described in Section 4.1, and varied from low-tech hand tools and craft tools to more sophisticated 3D printers, laser cutters, CNC machines, and collaborative robot arms. Although a majority of the investigated platforms were inclusive and open to the general public (on a free/nominal-fee access), the availability of the workspace, tools, and the possibility to straightaway contribute in a project was rather limited. Therefore, access both in terms of entrée to the physical space, and along with it a sophisticated range of tools and equipment, was an important factor in choosing a specific CBPP platform. Interestingly enough, the view on the usage of tools was sometimes rather anarchic: "*Standards, norms and regulations do not really play a role here, presumably much of what we do is rather partly illegal along mainstream view on intellectual property and copyrights*" [D4].

d Costs (participation fees)

Finally, participation costs were found to be one of the sticking points or even a barrier in some cases. Participation fees varied depending on the raisons d'être and the social shaping of the platforms by its members. Platforms that were inclined close to the values of the maker movement were accessible to members for a nominal monthly fee between €20 and €50. However, depending on the use intensity of specialist tools, this fee increased up to €100 per month. In addition to paid members, these types of platforms also offered free access to non-members for a few hours per week. Interestingly, an experienced maker, who was once in favor of low participation costs, now has a contrasting view after many years: "*Only €15 for the membership? … one uses a lot of machines and equipment, but has no willingness to clean up the workplace*" [B5] and "*In the beginning we took everyone in, it was unwise*" [B6]. On the other hand, platforms that were too close to commercial or industry-funded projects, had comparatively high membership fees. This in turn poses an entry barrier to students and the wider community, and hence a potential stream of new entrants into these collaborative spaces is turned away.

4.2.4 | Evolution of a user/peer in collaborative platforms

Sustaining active participation and continued contributions beyond the early induction period is vital for the functioning of peer production as an innovation system. As "communities of innovation", collaborative platforms provide access to a spectrum of material and nonmaterial resources and thus enable a constructive interference of technology, art, design, and sheer human vision in creating proprietary or commons artefacts. Here, individuals with aligned interests and shared vision amalgamate to create what is known as "affinity spaces" (Gee, 2004), through which the established or the core members engage in forms of informal mentoring to instill knowledge and, most importantly, culture and values in new entrants. This sort of exchange and informal learning can deepen participation and enhance subsequent reciprocal contribution to the community and thus strengthen the overall "participatory culture" of a platform (Jenkins, Clinton, Purushotma, Weigel, & Robison, 2006). A strong participatory culture can indeed result in a sizable output of a diverse range of artefacts with varying degrees of social and economic value. As a result, earned trust, social capital, and legitimacy enable the creation and sharing of artefacts, which more often than not are shared freely (freely revealed) within and outside these communities of innovation.

As a new entrant embarks on their journey within a platform, the data show that they typically evolve through six stages that could be categorized into three key phases: (a) capability building phase, (b) reflection phase, and (c) realization phase. Table **5** shows the evolution of a user through various phases over time. It was observed that this evolution takes place in three phases: Each of these phases require distinct skill-sets, knowledge, expertise and, above all, the affinity to learn and unlearn. However, these stages are not mutually exclusive nor is their progression strictly sequential.

It was observed that the potential for a novice member to create or make depends strictly on the available tools, technology, and the wider access to the maker community and the knowledge (explicit and tacit) that comes with it. Depending on several factors such as the

TABLE 5 Stages and phases in user advancement

Phase	Stage	User description
Capability building	Novice	Someone who wants to learn new skills
	Tinker	Someone who has some practical skills, but has no idea or affinity for collaborative innovation
	Hack	Someone who has an affinity for co-creation and collaborative innovation, but is focused on technical challenges alone
Reflection	Design	Someone who has a broader view on things, values, and needs
	Fabricate	Someone who actively shares skills and technology, and feels obliged to create social equity
Realization	Maker	Someone who feels obliged to enable economic, social, and environmental transition

ideological belief system within the collaborative platform, the nature of the project, prior domain knowledge and personal goals, a new entrant may perhaps just fiddle around on DIY projects forever or evolve through the stages starting from a novice member to a maker. The stages refer to the knowledge and skills gained in each stage, but are not to be interpreted as a professional title (e.g. hacker or designer).

As it is customary for users to self-select and define their activities in these platforms, intrinsic motivations such as learning, fun, and improvement of skill-sets, as well as extrinsic motivations like pecuniary rewards (Harhoff & Lakhani, 2016) play a major role in knowledge building and overall development of the user. As a result of active participation and tangible contributions in self-selected projects, thereby accrued new knowledge through interaction with tools, technology and the wider CBPP community can aid in capability and confidence building in users. This in combination with the initial enthusiasm is reflected in the actual or perceived progress experienced by a novice member, as shown in Figure **6**.

Tinkering and hacking can foster learning in novice members in a variety of ways. In typical makerspaces or fablabs these could predominantly take kinesthetic and logical routes, where the former is learning-by-doing and the latter involves reasoning and some level of systems thinking. Being tight-knit communities, these spaces also provide and facilitate exchanges with other analogous networks around the globe and thus create or generate forms of social capital. Such interactions create both bonding and bridging types of social capital and embed trust into the CBPP system as a whole (Carrincazeaux & Coris, 2011).

In other words, these interactions increase social proximity between collaborative platforms and networks and enable the exchange of tacit knowledge, domain expertise, etc., despite being geographically separated. As a result, the less-experienced enthusiastic user is now exposed to new knowledge, designs, and guidelines to test and validate their ideas and fabricate prototypes without the fear

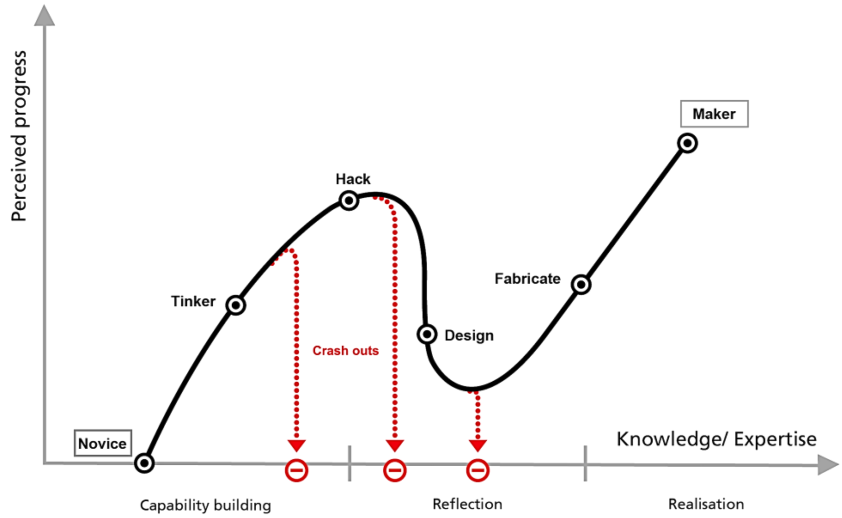


FIGURE 6 Evolution of a user in a collaborative platform [Colour figure can be viewed at wileyonlinelibrary.com]

of failure. Finally, through continued levels of engagement, receptivity, and reflexivity, a user is able to proceed from the fabricator stage to the maker stage.

From several cases interviewed in this study, it can be deduced that a user does not necessarily have to develop the necessary skills and rational in order to progress within a collaborative platform. In most cases, the platform was just the means for a user to build on their pre-existing know-how corresponding to their educational background or professional training with the available locally-bound knowledge and expertise drawn from networking.

However, from the survey data obtained from the platform owners and managers, it was also reasonably evident that the observed amounts of initial enthusiasm from novice members rescinded with time. It was found that the attrition rate (crash-out, shown in red in Figure **6**) was higher in the early phases, more so in the capability-building phase than in the reflection phase. This was largely attributed to a mismatch in the user skill-sets, diverging user expectation (ideological world-view) on the purpose of CBPP platforms, or in many cases due to a sheer loss of interest to progress beyond toying and experimenting. In any case, the user either evolved over time, or just kept working on simplistic DIY hobbies or gradually lost interest in the process. The résumé of those interviewed (interviewees A, B, C, and D) confirmed this development.

4.3 | Innovation pathways within distributed innovation

4.3.1 | Process of peer production observed among core and situational users

Despite the innovation process being bottom-up with tasks often modularized and distributed, an evident structured flow from knowledge utilization and knowledge creation to knowledge diffusion was observed. Along with the evolution of a user as discussed in Section 4.2, the data show that the value creation and value capture in peer production occurs in six stages (see Figure **7**).

As novice members make their first contact with a platform through either membership, referral, or invitation, it was observed from both users' self-descriptions and platform managers' statements that they are not straightaway integrated within these communities. Despite them being a full member, they were indeed weak members initially. In the first stage, though a novice member had access to workspace, tools, and the community, the extent to which they could leverage those resources for advancing their motivations and objectives is rather very limited. Therefore, the first stage is principally about building trust and gaining legitimacy amongst their peers. Although this stage does not quantify one's potential to learn, create, or contribute, it does qualitatively identify free-riders from prospective future contributors. As a result, some users also perceived the first stage as an entry barrier and therewith leading to a high attrition rate as discussed earlier.

In the second stage (access to tools), as a novice member gains legitimacy within the community, they now have access to physical resources and knowledge (both tacit and domain knowledge) (Maravilhas & Martins, 2017, 2019). This wider access in combination with the available high-tech tools enables the user to now self-educate and improve their technical or creative skills to operate, use, or utilize the freely available resources for experimentation, creation, or artistic expression. Equipped with the required skill-sets, core-creators and situational-contributors were found to be naturally motivated to engage in projects or activities that either were self-designed, community driven, or commissioned by external organizations.

The subsequent three stages (ideation, design, and prototyping) were often iterative and depended on the individual's skills, newly developed capabilities, and the extent of networking with internal and external knowledge pools. Although these stages do not fundamentally differ from the traditional innovation process, their organizational implementation, however, varies and was found to be rather inefficient. In particular, the process often ended abruptly following the prototyping stage, at times even without critical validation. The interviewees reflect the role of platforms and actors quite modestly on this particular operational element: "*Ideas always arise, their implementation is what matters*" [A14], "*Ideas are worth nothing,*

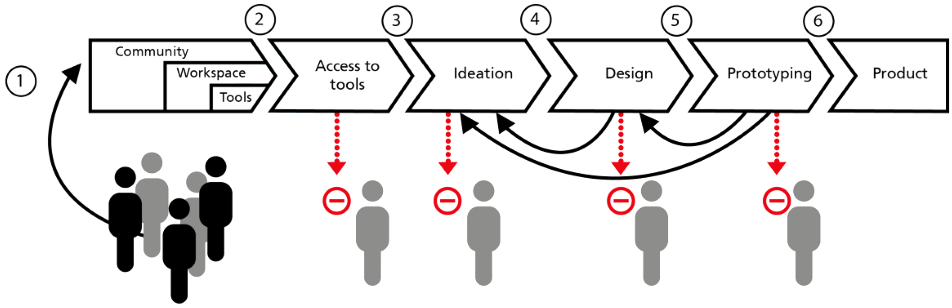


FIGURE 7 Innovation process in a collaborative platform [Colour figure can be viewed at wileyonlinelibrary.com]

they emerge independently of each other at the same time. What matters is their technical realization" [D9]. Presumably, the structural deficits of today's platforms regarding realization and exploitation of ideas could be identified here. Although there is a recognition for an evident need to steer innovation outcomes (products or services) toward wider societal value rather than just a leisurely pursuit, there are still deficits in the downstream end (productization) in comparison to the ideation phase.

4.3.2 | Innovation ecosystem in distributed innovation networks: through and around peer production

As observed thus far, collaborative platforms do not conform to a monolithic form of operation or organization. Nonetheless, they do tend to share and exhibit commonalities that reveal a distinct set of values, norms, and ideological inclinations. Notwithstanding the distributed nature of the peer-production process, these platforms provide the basis for an informal yet organized peer-to-peer cooperation and exchange that can steer in alternative innovation pathways and enable both intended and non-intended knowledge exchanges.

Innovations within these networks is an iterative process enabled by digital technologies and sustained by collective learning in a social setting (Williams, Slack, & Stewart, 2005). As knowledge collectives they encourage creativity and innovation (Suire, 2016) and thus shorten the learning curve from ideation to prototyping through shared learning. In spite of thematic diversity, one particular notion that was found to drive deeper engagement was their acknowledgement that innovation does not happen in isolation. This fundamental philosophy and the desire to feel connected encourage the participants to share and exchange knowledge through social learning (Kuznetsov & Paulos, 2010). In addition, inter- and intra-organizational networking was found to be vital for the existence of these structures and such networking often contributed to knowledge spillover effects outside.

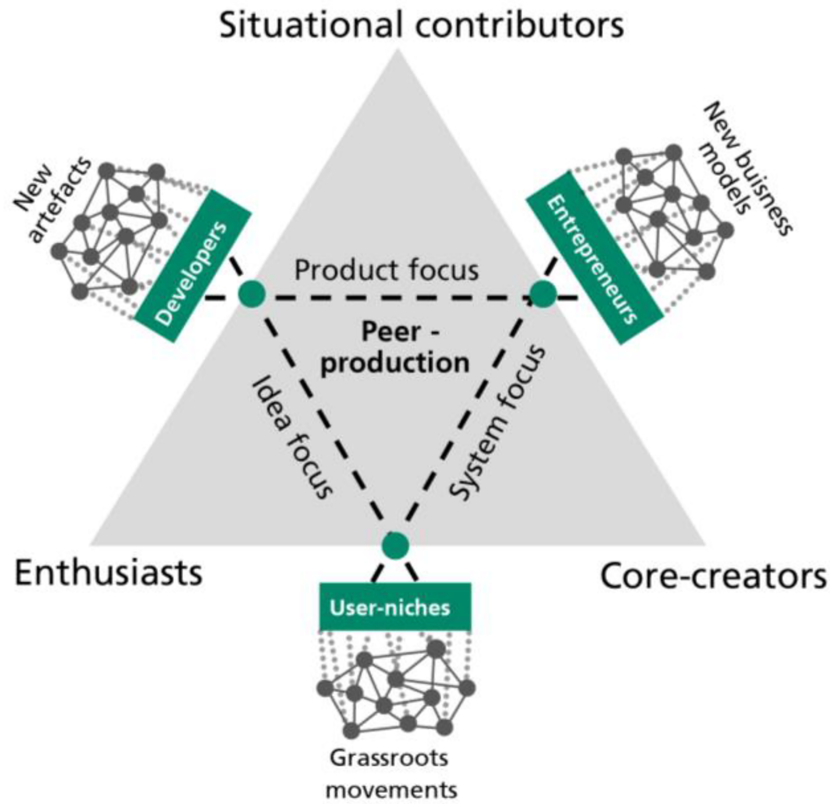
With tinkering, prototyping, and learning as systematic on-going practice, there was also a heavy emphasis on deliberate open design. This is vital as it can enable modification, replication, repair, or the effective downstream innovation of artefacts at later points in time. Furthermore, attributing to the notion of free-revealing (von Hippel, 2005) and the maker ideology, also known as the maker's bill of rights (Makezine, 2018), innovation in these networks is an incessant process that is subjected to a constant advancement from each wave of new and existing users. Consequently, the innovation outcome also becomes distributed rather than concentrated and entails a broad spectrum of artefacts that could either be a mere replication or the improvement of an existing product or creating something that could be entirely radical.

With designs openly available, domain knowledge freely exchanged, and tasks modularized, each interaction, contribution, and the resultant products benefit from sequential and successive value additions from the three user archetypes. When examining the creations emanating from these platforms in view of the social interactions between the user typologies revealed in this study (see Section 4.2), it was found that three dynamic structures emerge that create, shape, and sustain the innovation ecosystem around these platforms. Along the process of peer production (see Section 4.3), the users identify, conceptualize, analyze, and manage new knowledge that results in the emergence of new niches, creation of new artefacts, and generation of new business models. This in turn propagates what Chesbrough and Appleyard (2007) attribute to as value ecosystems. Figure 8 shows the social and creative exchanges between the three user typologies—enthusiasts, situational-contributors, and core-creators—yielding an underlying innovation ecosystem model.

The complex set of relationships between the three user typologies enables the opening-up of new realms within these collaborative structures to provide space and resources for novel value creation. Firstly, the collaborations and transient interactions between the core-creators who are systems focused and enthusiasts who are ideas focused, gives rise to a subset of value-driven user niches. These user niches are core to the culture and values of peer-production platforms and have the potential to grow into grassroots movements. Secondly, between the situational-contributors who are product focused and enthusiasts who bring in a multitude of ideas lies a subset of developers. These developers create new innovative artefacts with practical yet community relevance. Finally, the collaboration between situational-contributors who aim to maximize utility and the core-contributors nurtures a subset of entrepreneurs, who are often but not always aligned with sustainability thinking. These entrepreneurs generate new business models and practices that aim at equitable economic, environmental, and social value creation.

Hence, this analysis establishes that the new dynamic structures that emerge and shape peer production and distributed innovation

FIGURE 8 Innovation ecosystem and the interactions between user archetypes [Colour figure can be viewed at wileyonlinelibrary.com]



ecosystem characteristically contrast with both market-based and firm-based innovation. While contributions from participatory innovation and peer production may not always be altruistic in nature, they, however, in principle, are free from monopolistic inclinations.

5 | CONCLUSIONS, LIMITATIONS, AND FURTHER RESEARCH

Considering the tough global competition, uncertain economic environment as well as sustainable development challenges faced by businesses today, it is imperative that innovation processes reflect the dynamics, complexities, uncertainties, and the diverse interests of the players and social structures it operates within. Maker culture presents an alternative innovation construct where innovation is predominantly distributed, organizational hierarchies are flat, decision-making is democratic, and its partakers are typically dispersed globally but strive to solve local problems.

In brief, this paper addresses the existing research gap on this emerging phenomenon by (a) adding empirical evidence to the sparse body of literature on distributed innovations; (b) understanding distributed innovation as a process rather than an individual pursuit; and (c) revealing the triadic nature of actors within these platforms and their contributions to the emergence of an underlying peer-to-peer innovation ecosystem. In doing so, we contribute to the conceptualization of peer-to-peer distributed innovations in collaborative platforms within the German and the wider European institutional context.

Based on the holistic analysis of this study, the following aspects can be highlighted as key observations:

Platforms and actors: Collaborative platforms are not a representative social phenomenon. They address a small sub-set of technology-savvy and yet technology-critical communities who lay greater emphasis on the social shaping of technology and innovations. These communities were dominated by users self-described as artisans, engineers, scientists, and designers. The analysis found that the topology of the collaborative spaces could be mapped into three main types: hackerspace, fablabs, and makerspace. Likewise, the typology of the users can be classified into three user types: core-creators, situational contributors, and enthusiasts.

Motivations: Emphasis on the common good in combination with convivialist motives dominated participant motivation. This was followed by strong socio-technical and environmental inclinations. The core social motives for user contributions ranged from community citizenship, reciprocity, self-reward, and pro-social behavior in combination with feedback mechanisms like reputation, peer recognition, and ranking. While other aspects such as promoting localized production or development of prototypes were not revealed to be very important in the overall results, it should be noted that the results reflect the goals of the entire CBPP landscape in Germany and not just those that engage with digital fabrication.

Technology: Value systems built into these platforms and networks were found to enable participants to collectively overcome both conflicts and challenges. The participants see few technological barriers from inadequate infrastructure or lack of methodological knowledge. They have a high level of confidence in their technological competence and believe that the required technological resources and competencies are readily available or learnable. At the same time, it must be noted that there was a consistent disregard towards established norms, standards, or intellectual property rights.

Innovations: It could be concluded that these platforms and networks expand the national system of innovation by creating commercially viable artefacts on the one hand, and simultaneously give rise to alternative forms of economic, social, and environmental value creation in lines of common good. The social and creative interactions between the three user archetypes was found to provide the basis for precipitating new culture and values that have the potential to become grassroots initiatives or new business models. Furthermore, this interaction and exchange was found to lower barriers for community engagement and enhance innovative and creative manifestations. However, the main obstacle for many actors was the difficulty to earn their livelihood through their activity. Hence, one central dilemma was the simultaneous desire for free-revealing and remuneration for one's own intellectual achievement. The actors favored the notion of a universal basic income as an approach that could unleash the potential of innovation commons.

In conclusion, these findings reflect a present need for a pluralistic approach to innovation, wherein innovations are not just reduced to a top-down approach to merely gain competitive advantage. Instead, the innovation process should be an inclusive activity that can collectively pool globally dispersed knowledge, tools and resources to adequately address targeted local problems amongst which environmental sustainability takes precedence.

5.1 | Limitations and future research

Although this study draws from 103 valid responses from 453 collaborative innovation platforms, it only presents a snapshot of the investigated research themes at the time of survey. In order to compensate, we carried out ad hoc interviews with six selected socio-technical innovation projects and four maker turned entrepreneurs to delve deeper into factors such as initial motivations, common goals, extent of participation, and preferred innovation diffusion pathways that might change over time. We believe a longitudinal study involving the collaborative spaces along with their participants could validate or negate the conceptualizations theorized in this paper.

The maker movement is now a global phenomenon and is fast expanding. In order to understand its true potential in enabling socio-technical transitions through distributed, localized, and environmentally sensitive innovations, the following research questions have to be answered:

1. To what extent are social and environmental sustainability values embedded in the maker movement and in collaborative platforms today?
2. Should the future development and differentiation of collaborative platforms be dominated by technological topics or social and ecological aspects?
3. Are there any positive spill-over effects of knowledge and innovations emanating from collaborative platforms on firms and the wider regional or national innovation ecosystems?
4. How and to what extent are the collaborative platforms capable of shaping technology and society? Are there any manifestations of this social shaping on a micro-level today (e.g. the constructs of work, spare time, community, and neighborhood)?
5. To what degree can micro-financing or universal basic income boost the innovation capabilities of collaborative platforms?

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ORCID

Venkat Aryan https://orcid.org/0000-0001-8542-8791

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AUTHOR BIOGRAPHIES

Venkat Aryan has degrees in engineering and business and works as a Research Associate at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. He is currently conducting research on the integration of sustainability science and sustainability design for inclusive innovations. His main research activities are in the fields of responsible research and innovation, sustainable business models and strategies, digital fabrication and distributed innovation concepts, and integrated sustainability assessment and product life cycle analysis. In parallel, he is a visiting researcher at the Wuppertal Institute for Climate, Environment and Energy.

Juergen Bertling is a Senior Researcher at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. His research focus on interdisciplinary approaches to materials, technology, and innovation. They include bionics, perception of materials through haptics; digital manufacturing, open and alternative models for innovation as well as the technological and psychosocial conditions of longevity and reparability. He teaches technology and industrial design at the Folkwang University of the Arts.

Christa Liedtke is a Professor for sustainability in design at the Folkwang University of the Arts. In parallel, she heads the department of Sustainable Production and Consumption at the Wuppertal Institute for Climate, Environment and Energy. With her team, she develops concepts and strategies for a sustainability-oriented management of production and consumption patterns which includes life cycle assessment-based indicators as well as the analysis of behavioral patterns for sustainability improvements. She is particularly interested in design research in the field of sustainability—this includes approaches to social design and transition design as well as the challenges of resource-efficient and recycling-oriented design of product-service systems. Since 2013, she is president of the Resource Commission at the German Environment Agency.

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