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Makerspaces spécifique à un secteur d’activité : possibilités de collaboration et d’innovation ouverte

Makerspaces específicos de la industria: Oportunidades de colaboración e innovación abierta

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Article abstract

The rise of the maker movement, including hackathons and fablabs, provides new opportunities for companies to boost innovation by collaborating with creative, tech-savvy and intrinsically motivated people, known as makers. This paper connects open innovation and maker movement research by investigating how makers and companies can work together within an industry-specific makerspace setting. We use a qualitative case study design and focus on the German photonics industry. Our results shed light on the expectations makers and companies have when considering a collaboration, along with the perceived benefits and risks. Furthermore, we uncover crucial design factors for industry-specific makerspaces.

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Makerspaces específicos de la industria: Oportunidades de colaboración e innovación abierta

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ABSTRACT

The rise of the maker movement, including hackathons and fablabs, provides new opportunities for companies to boost innovation by collaborating with creative, tech-savvy and intrinsically motivated people, known as makers. This paper connects open innovation and maker movement research by investigating how makers and companies can work together within an industry-specific makerspace setting. We use a qualitative case study design and focus on the German photonics industry. Our results shed light on the expectations makers and companies have when considering a collaboration, along with the perceived benefits and risks. Furthermore, we uncover crucial design factors for industry-specific makerspaces.

Keywords: open innovation, collaborative innovation, makerspaces, fablabs, maker movement, hackathons, photonics industry

RÉSUMÉ

L'essor du mouvement des makers notamment des hackathons et des fablabs, offre aux entreprises de nouvelles possibilités de stimuler l'innovation en collaborant avec des personnes créatives, douées pour la technologie et intrinsèquement motivées, appelées makers. Cet article établit un lien entre l'innovation ouverte et la recherche sur le mouvement des makers en examinant comment les makers et les entreprises peuvent coopérer dans un makerspace propre à un secteur d'activité. Nous utilisons une étude de cas qualitative et nous nous concentrons sur l'industrie photonique allemande. Nos résultats font la lumière sur les attentes des makers et des entreprises lorsqu'ils envisagent une collaboration, ainsi que sur les avantages et les risques perçus. En outre, nous découvrons des facteurs de conception cruciaux pour les makerspaces propres à un secteur d'activité.

Mots-Clés : innovation ouverte, innovation collaborative, makerspaces, fablabs, mouvement maker, hackathons, industrie photonique

RESUMEN

El auge del movimiento maker y, en especial, de los hackathons y los fablabs, brinda nuevas oportunidades para que las empresas impulsen la innovación colaborando con personas creativas, conocedoras de la tecnología y altamente motivadas, conocidas como makers. Este artículo establece un vínculo entre la innovación abierta y la investigación del movimiento maker, analizando cómo los makers y las empresas pueden cooperar en un makerspace de un sector industrial concreto. Para ello, emplearemos un diseño cualitativo de estudio de caso y nos centramos en la industria fotónica alemana. Con los resultados obtenidos, trataremos de arrojar luz sobre las expectativas de los makers y las empresas al considerar una colaboración, así como sobre los beneficios y riesgos percibidos. Además, revelaremos factores de diseño cruciales para los makerspaces de sectores industriales específicos.

Palabras Clave: innovación abierta, innovación colaborativa, makerspaces, fablabs, movimiento maker, hackatones, industria fotónica

Companies constantly need to adapt to their changing economic environment. Emerging technologies (Porter & Heppelmann, 2014 & 2015) and shorter innovation cycles (Gassmann & Enkel, 2004) steadily challenge them to sustain their business. Therefore, innovativeness has become a key capability for companies to remain successful, to grow and gain new customer groups and markets. Due to resource restrictions, many companies are looking for new ways of innovation, and are opening up their innovation process to benefit from external talent and knowledge (e.g. Chesbrough & Crowther 2006; Laursen & Salter, 2006; Van de Vrande *et al.* 2009). This is because companies have recognized that not all smart people work for them. In the scientific community, this development is discussed under the topic of "open innovation" (Chesbrough, 2003). Previously, companies developed new ideas within their R&D department only using internal resources and knowledge, which is described as the paradigm of closed innovation by Chesbrough (2003). In contrast, the open innovation paradigm claims to use internal and external resources to generate new ideas and innovative products.

With the rise of collaborative workspaces inside public or private facilities for making, learning, and exploring – known as makerspaces – new opportunities for shared innovation are available. As Gershenfeld (2005) describes, makerspaces are physical places giving individual hobbyists and other privately interested enthusiasts (hereinafter called "makers") access to easy-to-use machines and technologies where creative ideas, prototypes, and sometimes commercial business ideas can evolve. According to Chesbrough and Brunswicker (2013), many

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companies are placing additional importance on customer and consumer co-creation, as well as in the organization of idea and start-up competitions for their knowledge inbound practices. Von Hippel (2005) already argued that the integration of users into the innovation process of a company leads to better product acceptance and could therefore be an essential innovation strategy for companies. Furthermore, recently published research shows that makerspaces are fostering innovation, and makers tend to be more innovative than others (Halbinger, 2018). Browder *et al.* (2019) argue that the maker movement can positively affect economic development due to the potential makers and makerspaces have for entrepreneurship.

Makerspaces are places where companies can meet potential customers, start-up founders or creative citizens and work together with them to realize collaborative innovations. Therefore, these kinds of spaces, as well as the underlying social phenomenon of the maker movement, could be emerging sources for companies to discover new ideas. As a result, makerspaces might offer a competitive advantage by providing a new source for innovation. However, to enable collaboration, a sensible balance must be found between the makers, who are motivated by self-fulfillment and the companies, that hold a primarily pecuniary interest.

Although some research exists on how to establish, operate and better understand the makerspace phenomenon (e.g. Kera, 2012; Forest *et al.*, 2014; Forest *et al.*, 2016), as well as some studies on the innovation potential of makers (Halbinger, 2018), there is currently no research on industry-focused makerspaces that examines the different expectations, as well as perceived benefits and risks of makers and companies. As a result, the goal of this study is to deliver a better understanding on how makerspaces could be used by companies as part of an open innovation strategy.

The goal of this research paper is to examine under what circumstances companies and makers are willing to collaborate within an industry-specific makerspace and hereby exploit the mostly unused innovation potential of the maker movement for business innovation processes and new business creation. The results could be used to create or improve the collaboration of companies and makerspaces, thereby enhancing open innovation in different industries.

To achieve the research goals, the paper is structured as follows: in the next section, the theoretical background is provided by combining the open innovation and the maker movement research streams. We close this section with a formulation of concrete research questions. In section 3, methodology, research approach and data collection are described, and in the subsequent section 4, the findings are described in detail. Section 5 contains a discussion of the results, as well as implications, limitations of the study, and an outlook on further research.

Theoretical Background: Open Innovation through Industry-Specific Makerspaces

Open Innovation

Open innovation is already practiced in many different industries, e.g. high-tech manufacturing, the wholesale sector and the mining and construction industries (Chesbrough & Brunswicker, 2013). Open innovation means to create and deploy a diffusive innovation process where companies are using internal and external resources and knowledge to innovate and market new products (Chesbrough, 2003). Moreover, the level of openness can positively influence the innovativeness of a firm and reduce time-to-market. Depending on the direction of the knowledge transfer, inbound, outbound and coupled innovation activities are distinguished (Enkel *et al.*, 2009). Inbound innovation happens when the knowledge stream comes from outside of a company and is integrated in the internal innovation process whereas the outbound innovation process describes knowledge being outsourced to another organization (Chesbrough & Crowther, 2006). Further, the open innovation process is described as coupled when the company is merging the inbound with the outbound strategy and develops and markets innovations jointly with partners, e.g. universities, research institutions or other industries (Gassmann & Enkel, 2004; Enkel *et al.*, 2009). West and Bogers (2014) show in their study that current open innovation research can mainly be assigned into the three open innovation modes described above. Also, Enkel *et al.* (2009) agree with this categorization of research fields and refer to papers that examine the outside-in mode (e.g. user integration), the inside-out mode (e.g. IP licensing) and other papers that focus on the coupled mode (e.g. cooperation with other industries). Despite the fact that open innovation is a popular topic of innovation research (Huizingh, 2011), to the authors' knowledge only a very few papers deal with the potential of makers and makerspaces for open innovation. According to Halbinger (2018), makerspaces could be a form of infrastructure supporting consumer innovation, since the individuals joining such makerspaces tend to be highly innovative (Von Hippel, 2017; de Jong *et al.*, 2015). In her empirical study, she found evidence that innovation, collaboration and diffusion rates of makers are multiplied in open access makerspaces compared to those in general innovation surveys (Halbinger, 2018). Building on the research of Goglio-Primard and Crespin-Mazet (2015), makerspaces could possibly hold a knowledge broker position in an innovation network. Therefore, firms may find that involvement in user innovation via infrastructures like makerspaces may provide economic benefits.

Maker Movement, Makerspaces and Maker Events

Makerspaces are physical places where people with different backgrounds (e.g. designers, craftsmen, scholars, artists, engineers, tinkerers and hobbyists) meet to create new things by employing user-friendly machines and technologies like 3D printers or open source electronics. The access to technologies and machines enables the fast realization of creative ideas, prototypes or even small batches of innovative products (Gershenfeld, 2005). The growing importance of the maker movement can be recognized e.g. by the rapidly growing number of visitors to specific maker exhibitions (e.g. the Maker Faire). Over the last few years, the number of visitors worldwide increased from 160,000 in 2010 to 1.4 million in 2016 (Maker Faire, 2017). Furthermore, the number of makerspaces has increased rapidly in the last few years (Rosa *et al.*, 2017).

The people that use makerspaces, called makers, do so to spend time with like-minded others, share knowledge, create new things, and simply learn by doing. The maker movement is characterized by the easy and almost playful usage of new technologies and digital tools (Dougherty, 2012). The atmosphere in makerspaces is typically shaped by collective learning and a culture of participating and sharing. The motivation of makers is mainly intrinsic and driven by self-fulfillment, not by financial incentives. In many cases, the newly designed products are based on open source technologies and have open interfaces for further development by the community (Mauroner, 2017). Research shows that physical models like prototypes help designers to choose the best concepts and also provide more economic benefits e.g. due to better assessment of desired product functions (Forest *et al*., 2014; McMahon, 1994). It is also common sense that the integration of users into the innovation process improves product acceptance and could therefore be an important part of a firm's open innovation strategy (Von Hippel, 2005). The potential of cooperative "bottom-up innovations" could be accessed through open collaboration and collective learning (Kostakis *et al*., 2015), which makes it interesting for companies to investigate the potential of a makerspace participation.

Although the potential for using the maker movement for commercial purposes is largely untapped, some companies are beginning to capitalize on the movement by investing in makerspaces (e.g. BMW Group or Google by co-sponsoring makerspaces) or maker events like hackathons (e.g. Zeiss or General Electric by organizing hackathons). A hackathon is a challenge format where the participants work on a specific topic within a specific time frame. According to Briscoe and Mulligan (2014), such maker events can be differentiated between "tech-centric" (single-application, application-type, technology-specific) and "focus-centric" (socially-oriented, demographic-specific, company-internal) events. In the first case, a specific technology is used to solve a problem or create a new application, e.g. using photonics to create new products. The "focus-centric" approach is broader and has a given topic which becomes the target for innovation e.g. improving local public transport.

Integrating makers into innovation processes can range from short-term, temporary activities, such as participation in hackathons, to permanent strategic involvement, such as the funding of external makerspaces or the founding of internal makerspaces (Rieken *et al*., 2019). This categorization is comparable to the dichotomy of university-industry relationships, which can range from temporary projects to permanent strategic partnerships, stated by Perkmann and Walsh (2007) in their open innovation research agenda. In line with this, Gassmann *et al*. (2010) observed that open innovation activities tend to move from simple outsourcing and risk reduction towards more strategic modes. Strategic modes have become standard in the telecommunications and pharmaceutical industries. Examples are British Telecom with its incubation activities, Bayer with its Creative Center, and Elli Lilly with its Innocentive Initiative (Gassmann *et al*. 2010). Based on this, we propose the following dichotomous framework, illustrated in Figure 1, to distinguish between different open innovation strategies involving makers and makerspaces.

In the practice, there are many companies that involve makers temporarily by organizing maker events like hackathons (e.g. Facebook, General Electric, Zeiss). Normally hackathons last for about 24 or 48 hours, after that the companies return to their day-to-day business. This kind of maker involvement is described in our framework under the name "ad-hoc maker involvement".

On the other hand, there are companies investing in existing makerspaces. For example, BMW is buying memberships from the UnternehmerTUM makerspace at the University of Munich in Garching to give their employees the possibility to experience different technologies and working processes outside of the company. Further, there are even companies building up internal makerspaces, e.g. Bosch, Google, Microsoft. This is the category we described as "long-term maker involvement" because these companies are taking a higher financial risk to build up a makerspace or invest in an existing one.

Despite the obvious creative potential of industry-specific makerspaces, only a few issue-specific makerspaces have been established so far. Examples of this are the "Bio.Kitchen" in Munich (Germany), a publicly accessible biotech lab, or the "NanoŠmano Lab" in Ljubljana (Slovenia), which focuses on nanotechnologies (Kera, 2012; Magaudda, 2012). Due to the existence of just a few issue-specific makerspaces, there has not been a lot of research on them. The purpose of the current study is to investigate if and how makerspaces and maker individuals could be involved in open innovation strategies in the context of specific industries.

FIGURE 1
Strategies to involve makers in open innovation

Involving Makers in Open Innovation Strategies

Ad-hoc Maker Involvement (Temporary)

- Short-term oriented strategy e.g. organization of hackathons
- Lower risk and high flexibility due to lower investment costs and fast results
- Expected ad-hoc effects e.g. new employees, unconventional ideas

Long-term Maker Involvement (Strategic)

- Long-term oriented strategy e.g. makerspace partnerships or internal makerspaces
- Higher risk due to building up an infrastructure or investing in an existing one
- Expected long-term effects: cultural shift in the innovation department through adoption of maker attitudes e.g. trial and error approach, failure tolerance, knowledge sharing

Research Questions

The goal of this research is to examine the requirements, expectations, opportunities, and risks of industry-specific makerspaces from the perspectives of both makers and companies. Hence it is also necessary to learn under what circumstances both are willing to participate and collaborate in industry-specific makerspaces. As a consequence, the following research questions were formulated:

1. Are makerspaces a way of open innovation regarding inbound, outbound or coupled activities?
2. What are the expectations, as well as perceived benefits and risks of makers and companies when cooperating in an industry-specific makerspace?
3. What are crucial design factors for an industry-specific makerspace?

Methodology

Research Approach

Since the object of investigation is largely unexplored, strongly context-dependent and complex, an exploratory research approach was chosen. An embedded-case study approach was selected as the research design, using qualitative methods in the form of semi-structured interviews (Yin, 2014). Our sampling is purposeful in order to collect information-rich data that deeply characterizes the phenomenon (Patton, 1990; Silverman, 2000). To achieve this, the photonics cluster in Jena (Germany) provided a suitable basis for our investigation. It is highly cross-linked and has a pronounced spatial concentration (Mauroner & Zorn 2017). The photonics cluster in Jena consists of about 187 companies with a sales volume of EUR 3.3 billion and is an important economic factor, with a workforce of 16.200 people employed in the industry and attached research field (OptoNet, 2019). At the same time, an industry-specific makerspace with a focus on optics and photonics was created in this region as part of a state-subsidized program. The qualitative research approach seems appropriate because it allows for deeper insights than a quantitative approach.

This research paper focuses on small and medium-sized enterprises (SMEs), but also takes a closer look at two major companies in the German optics and photonics industry, as this industry sector is a critical enabler for a broad range of industrial products and services (Willner *et al*., 2012). With an R&D rate of 9%, it is one of the most research-intensive German industry sectors and is regarded as a driver for innovation. The production volume of the German photonics sector in 2018 was estimated to be EUR 38 billion, which stresses the importance of this industry for the German economy (Trias Consult, 2019). Furthermore, the fields of optics and photonics have experienced dramatic technical advances over the past decades (e.g. laser technology, metamaterials, 3D cameras). Following the above-mentioned arguments, it is interesting how the innovation processes in this industry are organized.

The aim of the present study is to find answers to the research questions expressed in section 2. In doing so, the interview questions followed the recommendations of Mayer (2008) and were used to guide the analysis and enable a detailed investigation (Gläser & Laudel, 2010). Subsequently, the collected data was evaluated with a content analysis methodology based on Mayring (2010). First the interview material was coded to build up overlying categories through paraphrasing similar statements in a second step. This procedure enabled a structured content analysis of the collected data.

Data Collection and Description

In order to provide as complete a picture as possible, we collected data from both sides, the maker individuals and the companies' employees. Data collection started at the end of June 2017 and was completed in October 2017. In total, we conducted 26 interviews with makers and firm representatives. Using saturation as a guiding principle for data collection in qualitative research (Ritchie *et al*., 2003), the sample should be sufficient for first insights on the phenomenon. Table 1 summarizes the methodology pursued and the data collection strategy.

TABLE 1
Overview of methodology and data collection strategy

Research goals	Are makerspaces a tool for open innovation and what are the expectations, as well as perceived benefits and risks of both sides, makers and companies, when thinking about collaboration within a photonics specific makerspace.	
Method	• Case study method • Embedded design • Content analysis of semi-structured interviews	
Data collection & sample description	Makers:	16 interviews with makers using photonics technologies during photonics specific MAKEATHON at Laser World of Photonics in Munich 2017
	Companies:	10 interviews with employees in a leading position within the photonics industry (e.g. CEOs and heads of R&D)

Maker-specific data was gathered in 16 interviews with makers. The interviews were conducted and recorded during the "Laser World of Photonics 2017" fair in Munich (Germany). The fair is the leading industry event in Europe and hosted a temporary makerspace (Laser World of Photonics MAKEATHON) during the period of the fair, where makers and industry members came together. The Munich MAKEATHON event was chosen for data collection because the topic had a great fit to the target audience of an industry-specific makerspace with a focus on photonics. Following the maker event categorization of Briscoe and Mulligan (2014), the Munich MAKEATHON can be classified as a "tech-centric" maker event with an orientation towards photonics technologies for creating new concepts and prototypes. The event lasted 24 hours and was professionally organized by ITQ in cooperation with the German Federal Ministry of Education and Research. 79 participants (mainly students from 24 universities) with different educational backgrounds worked together in 13 international teams (including Germany, Spain, Austria, Columbia, and Italy) with around 3 to 7 people per team. Projects were not predefined, but were to use photonics. At the end of the event, an industry jury judged the ideas and provided feedback regarding the market potential of the created prototypes. The ideas varied from "Smog Dog", a compact mobile vehicle with an optical sensor to detect air pollution, to fashion designs using LED elements for optical effects driven by movement. Although photonics was the chosen topic, most of the makers interviewed did not have any experience with that technology, with makerspaces or with maker event formats at all. Table 2 gives an overview of the 16 different makers interviewed. Each interview lasted between 9 and 24 minutes with an average of 14 minutes. The interview guideline for the makers was segmented into four parts. In the first part, every maker was asked about his or her experience with makerspaces and maker events. In the second segment, the interview partners were to evaluate the Munich MAKEATHON and give some feedback about what could be improved. The third section dealt with the expectations, as well as perceived benefits and risks when makers would work together with companies within an industry-specific makerspace. The fourth and final part asked for social demographic facts.

In order to capture the companies' perspective, we conducted 10 interviews with managers from the German photonics industry. All interview partners held leading positions, e.g. CEO or head of R&D department. All companies are located in the Jena photonics cluster with a radius of 31 miles (50 km) around the city of Jena (Germany). All companies have been operating in the German photonics industry for at least 8 years except for one (3 years); eight of the companies are SMEs and two are larger ones. Four companies already expressed a high level of commitment in participating in a photonics-specific makerspace by signing an according letter of intent. To make sure that all interview partners had the same understanding of an industry-specific makerspace, a short concept presentation was given before conducting the interviews. The interviews lasted between 17 and 66 minutes with an average of 45 minutes. Table 3 gives an overview of the different cases. The interview guideline for the companies was segmented into three parts. The first part contained questions about their innovation process and open innovation attitude. To capture the level of openness of the

TABLE 2
Overview of the makers interviewed

Case	Age	Gender	Photonics experience	Makerspace experience	Maker event experience	Origin	Profession
M1	22	m	yes	x	x	Germany	Bachelor's student
M2	21	m	x	x	x	Germany	Bachelor's student
M3	28	m	x	x	x	Germany	Master's degree
M4	22	f	x	x	x	Germany	Master's student
M5	26	m	x	x	x	Germany	Master's student
M6	22	f	x	x	x	Germany	Bachelor's student
M7	26	m	x	x	x	Germany	Bachelor's student
M8	26	f	x	x	x	Germany	Master's degree
M9	28	m	x	yes	yes	Germany	Bachelor's student
M10	55	m	yes	x	x	Germany	Professor
M11	23	m	x	x	x	Italy	Master's student
M12	24	m	x	x	x	Germany	Bachelor's student
M13	25	m	yes	yes	yes	Germany	Master's degree
M14	24	m	x	yes	yes	Germany	Bachelor's student
M15	21	m	x	x	x	Germany	Bachelor's student
M16	23	f	yes	x	x	Germany	Bachelor's student

TABLE 3
Overview of the companies interviewed

Case	Revenue 2016 in million €	Founding year	Employees	Makerspace experience	Maker event experience	Value-added step
C1	0.3 – 0.5	2004	5	x	x	component supplier
C2	0.5 – 1	2009	10	x	x	OEM
C3	0.5 – 1	2009	4	x	x	system supplier
C4	0.5 – 1	2014	8	x	x	system supplier
C5	14 – 20	1993	100	x	x	research institute
C6	14 – 20	2001	150	x	x	OEM
C7	30 – 35	1992	220	x	x	research institute
C8	80 – 100	1984	800	x	x	component supplier
C9	3.000 – 4.000	1923	12.000	x	yes	OEM
C10	4.000 – 5.000	1846	25.433	x	yes	OEM

companies, some questions from the research of Chesbrough and Crowther (2006) were adopted and integrated into the interview guideline. In the second part, companies were asked about their experience with makerspaces and maker events, and about their expectations, as well as perceived benefits, and risks when working together with an industry-specific makerspace. In this section, they were also asked if they could imagine cooperating with a makerspace. The third and final part captured some general information about the company, the level of competition, and the interview partner.

Results

The results of this study reveal whether makerspaces are a tool for open innovation, and if so, what kind of open innovation, considering the outbound, inbound, or coupled mode. In addition, the study illuminates the innovation process within the photonics industry to better understand whether and how open innovation is practiced. Additionally, the study delivers insights on what the expectations, as well as perceived benefits, and risks of cooperating within an industry-specific makerspace are from the perspective of makers and from the perspective of companies within the photonics industry. This delivers insights on how the collaboration between an industry-specific makerspace, makers and companies, especially SMEs, could work. Figure 2 shows the assumed potential of an open photonics makerspace on the one hand for makers and on the other hand for companies.

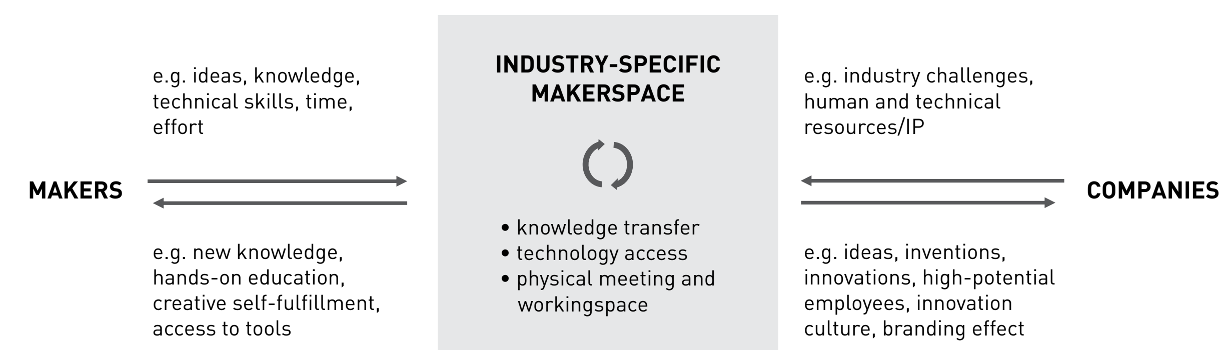
Makerspaces as a Way of Open Innovation

First of all, the makers interviewed were all open to collaborating with companies within a makerspace or during a maker event, but most of them expected some kind of financial reward (e.g. prize money, sponsored vacation trip) if their ideas ended up being used commercially by a company. This issue should be clarified before the start of the maker event to avoid IP problems later on.

Our data analysis shows that makers are quite open in the sense of integrating external knowledge resources to generate new ideas (inbound). They stated that they appreciate working together with people with different backgrounds and using technologies offered by companies to create early-stage prototypes of their ideas. Regarding the knowledge outflow (outbound), they are willing to share their ideas and creativity with the companies and other makers. Furthermore, some makers said that they could imagine using the resources of companies to get a more promising and faster market access for their ideas. This included a willingness to work together with companies to further the development of early stage ideas and marketing them together with a company (coupled). The following quotes are provided from the interviews as examples of the openness the makers expressed toward a collaboration with companies in an industry-specific makerspace. *"I would not have a problem with that, but if we had invested a lot of work then I would like to get some profit out of it…"* (M2, 21 years, male) or *"I would probably find it cool because I can claim I launched a product on the market."* (M8, 26 years, female).

The companies interviewed also indicated that they are interested in working together with makers in an industry-specific makerspace, and hope to find enthusiastic people with different backgrounds. The openness regarding intellectual property (IP) sharing varied across the value chain position. The OEMs and component suppliers in our sample were stricter with IP than research institutes or companies at a very early stage of the value chain. The research institutes argued that by finding new applications, they probably create new customers that need their supply if they build something up on the shared IP. One of the research institutes interviewed even stated that they see an advantage if makerspace users would use their patents free of charge because if they "*…can start a business …[they would] possibly buy our sensors.*" (C5, research institute). That means they see the possibility to generate future customers by sharing their internal IP with makers and makerspaces. The main argument for OEMs and their strict IP policy was to protect property rights and process knowledge to preserve their competitive advantage. Knowledge outflows in the sense of explaining current products and offering some kind of workshop to a specific area the company is operating in, e.g. production of glass, application fields of CO2 lasers, or demonstrating 3D image capturing were mentioned as possible knowledge outflows.

FIGURE 2
Benefits of an industry-specific makerspace



Based on Zakoth *et al.*, 2019

All companies were quite open to knowledge inflows (inbound) – *"…to integrate external knowledge is actually something which is always good…"* (C8, component supplier) – because that helps companies to find new product ideas or applications for existing products. One company also made it clear that a chance to work together with a makerspace or makers could be very good for identifying problems which they have not thought about and which could be used to develop new solutions either by them or others. *"…the open character… to look deeper and really understand where are problems and easy solutions… that's a really interesting point."* (C6, OEM).

For generating new product ideas, especially the small firms stated that they actually use customer queries as a source for new product inspiration. Other aspects were conferences, industry fairs, start-ups, and for the larger firms competitor analysis or even buying small firms with their venture capital business unit. All companies stated that a makerspace could be a source for generating ideas, but probably not completely new products.

To sum up, our collected data shows that both sides are open to collaborate in an industry-specific makerspace. Therefore, in the next step it is important to understand what expectations both sides, the makers and the companies, have when thinking about a collaboration within an industry-specific makerspace.

Expectations, as well as Perceived Benefits and Risks

The data we collected shows that the makers are willing to share their ideas and creativity with companies if they get some kind of reward or incentive should the idea be used commercially by the company. In addition, they expect a serious interest of the company when they participate or organize a maker event. This includes direct access to technology experts in order to get substantial support when facing technical problems. In fact, access to new and unique technologies is one expectation makers have when they think about collaborating with companies in an industry-specific makerspace, which can be seen in the following statement: *"… you get to know something new apart from the standard sensors you always have…"* (M1, 22, male).

Moreover, the makers saw a potential with the financial backing that companies can provide beyond their own personal resources. One of the makers stated that easier market access is an advantage when cooperating with companies within an industry-specific makerspace. Additionally, some makers saw the cooperation during maker events as a way to find a job and get some company insights.

For all makers, the benefits outweighed the risks, which is also shown by the following statements: *"I actually see a lot more chances. So I find it great to work with companies, because they have quite different financial resources."* (M6, 22 years, female) or *"…there are more opportunities than risks because there is the opportunity to grow, to learn a lot of things and use some things that … [you] cannot use at home … For me there is more to win than to lose."* (M11, 23 years, male). The only risk which was mentioned more often was the risk that firms exploit ideas without giving back some kind of reward or incentive, but *"… some kind of participation must be given…"* (M3, 28 years, male).

The component suppliers interviewed are open-minded and do not have specific expectations. They stated that the knowledge needed for a cooperation is very specific and therefore it could be difficult to work with makers who are not experts in photonics technologies. Students, for example, may not have the long-term practical experience in a specific field the companies operate in. However, an industry-specific makerspace is interesting for them because it provides easy access to hardware and software to test ideas faster. One of the firms stated that it is important to have a straightforward set of rules for cooperation with the expectation that every partner has to inform the other if they are going to protect the generated ideas with a patent.

The two companies with the highest revenues already had some experience with maker events. Both firms had already organized hackathons, but do not have a cooperation with a makerspace. For both companies, maker events or a cooperation with an industry-specific makerspace is a chance to represent the firm's brand. One of the companies stated that it would be important to exclusively equip a makerspace for an event, because if an economically useful idea is created there, they want to have it certified on their own technology. This is because the optics and photonics industry relies on certified processes. If a process is certified with a specific machine nearly the whole market will only use this certified brand, even though there may be other potentially better technological solutions. The other big company in the sample expected that the infrastructure (e.g. PCs, software) would be provided or could be organized by the makerspace. Furthermore, some kind of maker culture which ensures easy access to the makerspace and the maker community should be established.

Two benefits which were identified by nearly all companies were the branding effect and the opportunity to recruit high potentials when working together with a makerspace during a maker event. This is shown by the following statements: *"If we… get involved, we would do it for... generating visibility in a local environment of young, prospective high potentials…"* (C4, system supplier), *"...recruit employees, promote brands..."* (C10, OEM), or *"…you can recruit new people from such a makerspace."* (C9, OEM). Only one company stated that because of the small size of the company the branding effect and the opportunity to find new employees is not the current focus of that company when thinking about a cooperation with an industry-specific makerspace, although it recognizes the potential.

From the companies' perspective idea creation is another possible benefit when working together with an industry-specific makerspace: *"…you just have an easy way to pick up a lot of ideas."* (C9, OEM), although some firms stated that therefore very specific expert knowledge could be required. The smallest OEM company stated that the makerspace could be used to further develop unused ideas and overcome resource restrictions within the common company setting.

IP protection was stated as the main risk when working together with an industry-specific makerspace, which means that there must be rules on how to deal with ideas that have high economic potential. The IP issues were mentioned by all firms, but they all said that it could be solved e.g. with NDAs or a straightforward rule system which guarantees transparency.

One of the bigger firms stated internal barriers as a risk, which must be overcome before working together. This means that authorities must be convinced that a cooperation with a makerspace could be fruitful. Therefore, the generated outcome must be economically useful. The biggest firm stated that a broad target group of a makerspace could be a risk due to a different knowledge base but they are very interested in a cooperation.

To sum up, the companies see a lot of benefits but they are uncertain about the knowledge required to make sure that the makerspace cooperation could be used for new product development. Additionally, the companies agreed that IP protection issues must be clarified before the maker event starts. Nevertheless, they see a chance to find applications for existing products and early-stage ideas. Table 4 summarizes the expectations, perceived benefits and risks of makers and companies which were mentioned by most interview partners.

TABLE 4
Summary of expectations, perceived benefits and risks of makers and companies

	Makers	Companies
Expectations	• meet and work together with people with different backgrounds • exclusive technologies • some kind of reward for ideas	• meet makers with different backgrounds • basic infrastructure
Perceived benefits	• financial resources of companies • faster market access for ideas • company insights • job opportunity	• finding new applications for existing products / new ideas (not innovations) • branding • recruiting
Perceived risks	• exploitation of ideas without reward	• IP protection • lack of expertise required for real innovations

Required Design Factors of Industry-specific Makerspaces

From the makers' perspective, the makerspace should not be equipped too specifically to an industry topic. Most makers prefer a generally equipped makerspace with some industry gadgets, with equipment not totally focused on one industry. The following example quotes stress the expected design factors from the makers' viewpoint: *"Well, if it's a photonics makerspace, then that particular direction would be photonics, of course it would be cool too, but I (...) I actually think it's always better to have a bit of everything."* (M4, 22 years, female) *or "For the equipment [it should be] widely diversified. So from everything a little bit."* (M1, 22 years, male).

It is important for the makers to be able to tinker with different technologies, hardware and software. Basic materials should be provided during the event and access to some special materials would be a nice feature for the makers. Furthermore, the makers want to meet people with different backgrounds and technology experts from the companies' side, not human resource managers, which is evidenced in the following quotes: *"…I expect…the cooperation with different people from different areas."* (M6, 22 years, female) *and "I don't want … there to be any human resource managers… There should only be engineers who put their heart and soul into it…"* (M9, 28 years, male). Meeting and working with people with different backgrounds is important for the makers, because it allows them to expand their own knowledge, which is an important part of the maker culture.

In addition it is interesting that most participants of the Munich MAKEATHON did not have any prior experience with photonics technologies, but were still able to build their prototypes because they tinkered around and shared their expertise with one another. During that maker event, the atmosphere and organization was described as an important factor. This included easy access to hardware, technology experts, napping space, and the availability of food and drinks throughout the event. Furthermore, a spacious and calm workspace is needed for high-concentration work phases. To avoid the exploitation of the makers, the rules for commercial use of the maker ideas by a company should be clarified before the event starts. The makers are open to sharing their ideas and creativity with the companies, but they expect some kind of reward should their ideas be transformed into a product by a firm.

Industry respondents clearly state that for them the biggest issues when working with a makerspace is the IP issue. For example: *"I see risks in… IP protection especially…"* (C2, OEM) or *"... the problem if there is really something coming up... who has which rights then."* (C10, OEM). Therefore, there should be a possibility to clarify that issue before any event within an industry-specific makerspace. Thus, there should be a guideline, e.g. an NDA, addressing the issue of what happens if a commercially useful idea is created during a maker event. Smaller firms are a little bit more open concerning that topic, but mentioned it as well to be discussed before any cooperation. Regarding the IP issue, it seems to be reasonable to start with a broader topic instead of a very IP-dominated one. This enables open-minded learning experiences for companies and makers and avoids IP-related risks. The question is, is it more a marketing and recruitment tool or could it be a place to really generate new ideas and commercially useful innovations for an industry partner? Regardless of the purpose of use, the companies are all open to try working together with an industry-specific makerspace. Expectations for new product development are not that high due to the know- how-intensive industry sector, but at least the other effects (recruiting and branding) are regarded as useful for a company. Furthermore, the industry and the makers expect to meet people with different backgrounds within the makerspace, which could be solved by addressing a broad target group (e.g. students, post-docs, professionals, start-ups, people interested in photonics) when announcing a maker event through different marketing channels.

Small companies typically do not have any experience with maker events or any cooperation with a makerspace, but they stated all that the concept is interesting for them. They prefer quick and easy access with informal ways to organize an event, although most of them had some uncertainties regarding which topics could be the focus in such a cooperation. Two of the smaller companies had concrete ideas of what kind of project they want to realize within the makerspace. They stated that in their company it was not possible to explore the ideas because of resource restrictions, and the fact that the ideas diverge from the current business segment of the firm. Therefore, they felt that the chance to test ideas in the makerspace would be highly beneficial. All companies but one stated that there is a lot of competition within their market segment. The firm which stated that competition is not that strong is the smallest one and focuses on a highly specialized, niche market. All firms stated that ultimately some kind of outcome is very important for a long-term cooperation with a makerspace.

Requirements on design and operation also depend on firm size, due to the fact that smaller firms are mostly positioned at the beginning of that value chain. The results show that smaller companies prefer faster and informal access whereas the bigger ones tend to prefer a more structured way of cooperation.

To sum up, the cooperation with an industry-specific makerspace is seen by companies as a way to find new applications for existing products, to test ideas which are not in the business field of the company, and additionally as a chance for talent scouting and branding. Therefore, the design of the makerspace should enable the above-mentioned purposes in the best possible way.

Discussion and Outlook

Conclusions

The goal of the study was to link the open innovation research with the research stream on maker movement, makerspaces, hackathons, and other open lab spaces for creating, tinkering, peer-to-peer learning, and experimenting. The results provide initial insights on how industry-specific makerspaces could be established and further developed as collaboration hubs within a firm's open innovation network.

In particular, the results show that makers are basically willing to work together with companies and some of them are even excited about the opportunity to use state-of-the-art equipment provided by firms. Consequently, makers would be attracted more than affronted by the participation of companies within an industry-specific makerspace. As Mauroner (2017) mentioned the motives of makers are intrinsic and not primarily economically motivated. Our research confirms this finding and shows that makers are willing to share their ideas. However, if these ideas are going to be used commercially by firms, makers typically expect some kind of reward or financial benefit. Consequently, it is necessary to think about reward systems when companies are involved with a dedicated plan for the commercial use of emerging ideas.

Additionally, when talking about an industry-specific makerspace our research shows that most of the makers interviewed prefer a makerspace that is equipped in a more generalist and interdisciplinary manner (for all-rounders) with some industry-specific gadgets instead of totally industry-focused equipment. This indicates that makers like variety when tinkering and experimenting with different technologies, hardware and software. During the Munich MAKEATHON only a few participants had already worked with photonics technologies, but they were all willing to use photonics technologies and become familiar with them by trial and error. To summarize, when building a new industry-specific makerspace, our results indicate one should not be too narrow-minded when it comes to both equipment and participants.

On the other hand, companies also have expectations when working together with makers in an industry-specific makerspace. Our results show that companies are open to cooperating with makers, but although they claim to "be open", they are not really willing to offer maker projects, e.g. as open source code, to the maker community. The companies stated that they are interested in a cooperation with a makerspace even though they are not quite sure if they can expect commercially useful product ideas or just new applications for existing products. Firms see the cooperation as a new way to present their brand. Additionally, another interesting result is that companies recognize a recruitment potential in maker events (e.g. job walls or human resource managers as reference persons during the event) because they can easily observe the problem-solving skills or teamwork abilities of makers during these events. As our data shows, not all makers like this practice. They prefer to have access to technology experts instead of human resource managers so they get a competent reference person when experimenting with the hardware and software provided.

Large companies often organize maker events, such as hackathons, to recruit talent and to position their own brand. For these companies, the cooperation with an industry-specific makerspace is more a source of inspiration and idea creation than an opportunity for the development of highly sophisticated new products. It raises the question of whether the makerspace could be used at the beginning of the innovation process, during the idea creation and selection phase, e.g. supported by design thinking workshops within the makerspace. However, makerspaces could also be useful on the other end of an innovation process, namely when a product is already established in the market and a company needs to find other applications due to the fact that the product life cycle is ending. This potential was stated by nearly all companies. It is fitting, therefore, that makers like the idea of using and even abusing – in the sense of hacking – already existing products and technologies.

One big issue for companies when working together with makers in an industry specific makerspace is the protection of their intellectual property (IP). This issue was mentioned by nearly all cases. The perceived risk of the companies interviewed about sharing internal IP is consistent with the recurrent discussion in open innovation research. On one hand, the open innovation outbound strategy is stated to be a very important part of open innovation due to the fact that companies can benefit e.g. commercially by out-licensing unused IP (Chesbrough, 2003; Van de Vrande *et al.* 2009). On the other hand, there are also risks of losing the competitive advantage with an external technology commercialization following the outbound strategy (e.g. Helm *et al.*, 2019). However, in our sample some stakeholders were very open to sharing the IP due to the fact that they produce semi-finished materials and components, such as technology suppliers or research institutes. Not being a final supplier, their argument was that if someone uses their IP to create new products or applications they will probably get new customers. Therefore, a follow-up study with a focus on technology suppliers could be interesting, in order to find out if the openness in sharing IP is specific to companies positioned at the beginning of the value chain in the photonics or even other industry sectors.

While many companies consider themselves "open" to a two-sided knowledge exchange, from the maker's perspective, some companies were focused more on sponsoring hardware and promoting their own technologies. In these cases, the knowledge outflow was focused on firm branding or on educating people in how to use their products and technologies. Our research shows that the companies in the photonics industry are open during the innovation process mostly in the knowledge inflow direction (inbound), and not so much in the outbound direction. The companies which have already organized maker events consider these events mainly as possibilities to find new employees and to position themselves as progressive brands.

Regarding the proposed dichotomy when firms intend to integrate makers in open innovation strategies, our research shows interesting results. In fact, most companies implement a 'temporary approach' when integrating makers into their innovation processes, characterized by short-term actions, low risk, and high flexibility when choosing partners. Besides that, the focus is clearly on knowledge inflows instead of outflows. Nevertheless, the study provides indications for the benefit of a more 'strategic approach' of maker involvement. A 'strategic open innovation' concept could include long-term relationships with makerspaces as a form of infrastructure supporting firms' innovation processes. This leads to profound knowledge inflows and outflows when companies cooperate with industry-specific makerspaces, resulting in a higher degree of openness. In some industries the strategic mode has already become a standard, e.g. in the pharmaceutical industry where Bayer has established its Creative Center or Eli Lilly with its Innocentive Initiative approach (Gassmann *et al*., 2010). Also, in other sectors like the photonics industry managers are realizing that opening up the innovation funnel could generate a competitive advantage in the marketplace (Chesbrough & Eichenholz, 2013).

The phenomena we observed in the photonics industry fits better to the term 'temporary open innovation', meaning that companies are in search of ad-hoc knowledge inflows, but only a weak outflow (e.g. workshops), and that the photonics makerspace is seen more as a tool for idea creation support instead of a strategic partner in the development of new products and markets. Therefore, in the long run it could be a goal, especially in the photonics industry, to shift the cooperation between companies and an industry-specific makerspace from the 'temporary open innovation' approach to the 'strategic open innovation' concept, which would mean a deeper and a long-term integration into the innovation process.

To sum up, our results show that both sides, makers and companies, are basically willing to cooperate within an industry-specific makerspace. From the makers' and companies' perspectives, it is very important to specify the IP management before starting a cooperation or before conducting a maker event. The rules should determine the handling of intellectual property, while at the same time be transparent and easy to understand. The predominant motives of the makers for participation are that they get exclusive access to unique products, equipment, and technologies. Additionally, they stated they appreciate meeting people with different backgrounds and expanding their own knowledge. They also mentioned that it is an interesting opportunity to get company insights and maybe find a job by coincidence. The motives of firms vary from using the makerspace for idea creation, as a recruiting tool or a new way to position the company brand in an environment full of high potentials.

Managerial Implications

Based on our findings, some managerial implications for companies as well as for makerspace operators could be formulated. First of all, it is important that an industry-specific makerspace could be used as a collaborative innovation institution where companies work together with intrinsically motivated makers. Furthermore, working together with an industry-specific makerspace and makers involves different potential benefits for companies, e.g. idea creation, innovation, branding, recruiting or changing the culture of the company through sustainable maker event participation.

From the companies' perspective, it is important to develop some kind of reward system (e.g. prize money, travel packages, revenue participation models) for the makers if their ideas should be used commercially. Also, it is appreciated by the makers when technology experts are available and some technology highlights are offered during a maker event by a company.

Recent research examines whether makerspaces should diversify or specialize (Bergman & McMullen, 2020). Our results show that makerspace operators should ensure that they offer a generalist-equipped makerspace, even if they are focusing on a specific industry sector like optics and photonics. For the makers it is important that they can tinker with different technologies and meet people with different backgrounds, which means that the marketing of a makerspace should try to address a lot of different target groups to attract a diverse mix of people using the makerspace.

In section 3 we introduced a framework on maker involvement strategies. Based on this, there are some things SMEs and larger firms should consider when thinking about involving makerspaces and makers in their innovation strategy. For SMEs it is much more convenient to start with the ad-hoc maker involvement strategy due to the fact that it would require fewer human, financial and infrastructural resources. They could also try to cooperate with other SMEs when they are planning to organize a maker event to reduce the costs even more. Doing so will reduce the benefits mentioned as well because the brand is not that visible, they compete with other SMEs for new employees, and they also share the best generated ideas directly with other firms. One way to lower these effects could be by organizing maker events only with companies that are positioned in different parts of the value chain to avoid a situation where a direct competitor benefits.

On the other hand, in our data one of the bigger firms said that they would strongly prefer to equip a maker event exclusively with their own products to make sure that, if something commercially useful comes out of such an event, they are the only one who profit from it commercially. Following that logic, sponsoring an event exclusively is more cost-intensive, but the positioning of the brand is much more visible, recruiting is exclusive and the generated ideas could be used exclusively and are easier to protect. To sum up, for larger firms it seems to be much more logical to organize such an event exclusively and without the involvement of other firms. Due to their financial strength, larger firms could even think about a long-term maker involvement strategy by investing in existing makerspaces (e.g. BMW) or building up their own internal one (e.g. Bosch, Google, Microsoft). The long-term strategy will probably lead to a stronger maker exchange or even attract makers to work within the company, which is beneficial for companies, as Halbinger (2018) found out empirically that makers enhance innovation and innovation diffusion. Following this argument, it makes sense to integrate the makers into companies' innovation projects, regardless of which of the two strategies a firm ultimately chooses to follow.

Limitations and Future Research

This study provides initial insights into the circumstances that would allow makers and companies to cooperate and access the mostly unused creativity of makers for collaborative innovations. Nevertheless, the study has some limitations. First of all, due to the qualitative research design and the fact that only companies from the optics and photonics industry around Jena have been interviewed, the generalizability of our results is restricted. Therefore, it is not clear if the results could be transferred to other industries, although the optics and photonics industry is an enabling industry for many other industries. Nevertheless, the results of this study could be used for follow-up studies, e.g. the generation of variables for quantitative research or qualitative research focusing on other industries. Additionally, future work could investigate industry-specific makerspaces with a different industry alignment to verify our findings, e.g. on the "NanoŠmano Lab" in Ljubljana (Slovenia) which focuses on nanotechnologies (Kera, 2012; Magaudda, 2012).

Since the goal of this exploratory study was to get a broad picture of the photonics industry, we interviewed companies of different sizes. Future research could focus on companies of the same size or a specific position in the value chain to explore if there are differences when thinking about collaboration between companies and makers in an industry-specific makerspace. A first impression of our research is that entities that are positioned at the beginning of the value chain (e.g. research institutes) are generally more open regarding the IP topic. This is because the research institutes that we interviewed stated that they might create a future customer for their supplies by sharing their IP.

Moreover, future research could take a closer look at the proposed framework of maker involvement in open innovation strategies. It would be interesting to interview companies which are investing in makerspaces, like BMW, or have recently built up an internal makerspace to find out more about their motives, expected outcomes, and perceived benefits and risks. These companies can be compared with a sample of companies, like the two larger ones in our study, that only get involved with makers when organizing maker events.

As our study shows, companies presently see a collaboration with a makerspace more at the beginning of the innovation process, which means for idea creation. It could be interesting to investigate whether there are other stages in the innovation process where companies can benefit from makers and industry-specific makerspaces or if there are phases in which one side is not willing to cooperate. This also could be combined with a more in-depth investigation of the distinction between ad-hoc (temporary) and strategic (long-term) approaches when involving makers in open innovation strategies by applying a different and larger sample.

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