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MAKING THE MOST OF MAKERS: AN EXPLORATION OF THE NEED FOR A PROTOTYPING TOOL FOR COMPANIES TO ENGAGE WITH THE MAKER MOVEMENT

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Abstract

Makers have proven to be skilled at prototyping and therefore present a unique opportunity for companies, who seek to improve their capabilities, to learn from them. In this study, a mixed methods approach was used to understand possible benefits to both companies and makers from collaborating in prototyping, and to identify a set of design considerations to guide the future development of a tool to facilitate such collaboration. Despite challenges to collaboration, a tool designed to help companies engage with makers in prototyping could be beneficial to both and should be developed.

Keywords: prototyping, co-design, open innovation, design tools

1. Introduction

Prototypes play a critical role in product development and innovation (Gengnagel et al., 2016). In the context of the design of physical prototypes, they can be defined as an embodiment of critical elements of the intended design, to enhance communication, enable learning, and inform decision-making (Lauff et al., 2018). Prototyping has been shown to be beneficial to many successful organisations, in various ways (Coutts et al., 2019), and is being applied earlier and earlier in the development process (Elsen et al., 2012; Neeley et al., 2013), despite potential design fixation (Gerstenberg et al., 2019). Since the barriers of entry into prototyping are dramatically lowering (Camburn et al., 2017) due to the proliferation of open source materials and digital fabrication, it should be asked; to whom can companies turn to increase their prototyping capabilities? The maker movement has many lessons to teach (Singh, 2018), particularly in prototyping (Camburn et al., 2016). Makers apply DIY principles when they make, which can have a positive impact on designing with low cost prototypes (Camburn and Wood, 2018). In this sense, makers can be seen as adaptive experts who share practices with engineers (Larson et al., 2017), indicating there is much to be gained from observing and collaborating with them. There are also opportunities for companies to improve their prototyping in makerspaces (Jensen, 2017), which has led to many organisations setting up their own internal makerspaces (Rieken et al., 2019). Moreover, individual makers, applying DIY principles and using modular components, are very effective at producing prototypes and have enhanced creative confidence (Sadler et al., 2016). If designers could engage with, or open up to, some of the entrepreneurial (Hui and Gerber, 2017; Browder et al., 2019), technological (Richardson et al., 2013) and educational (Papavlasopoulou et al., 2016) aspects of the maker movement, then they might achieve real benefits and increase their prototyping capabilities. In

light of the changing role of the designer as a facilitator for collaboration (Baldwin and von Hippel, 2011; Wilson and Zamberlan, 2015), the importance of prototyping in product development (Wall et al., 1992), and the rise of the maker movement (Dougherty, 2012), this study asks if a tool to help companies open up their design process and engage with makers in prototyping would be beneficial and if so, how should such a tool be developed?

1.1. Background

1.1.1. Open design, co-creation and involvement of communities

Open design has a key role in the broader open paradigm in the field of design, the "collaboration" and "access" characteristics of which could be used to bring makers into the fold of prototyping (Gasparotto, 2019b, 2019a). Open design of hardware products is increasingly meaningful and continues to be experimented with in product development (Raasch et al., 2009). Different models of innovation, relating to open design, could be employed to engage others outside the firm in the design process, such as: participatory design and co-creation (Sanders and Jan Stappers, 2008); open innovation (Chesbrough et al., 2006); and collective/distributed design (Özkil, 2017). More broadly, there are many examples of organisations, both in the public and private sectors, that have exhibited great success in involving communities into the development process; such as Lead Users and Crowdsourcing (Franke et al., 2006; Quinn and Bederson, 2009). Provided that the individuals involved in the process are sufficiently reimbursed, co-creation and collaboration can be beneficial to the user as well as the firm (Brockhoff, 2003). These models constitute the theoretical landscape surrounding open design and its potential application to makers and prototyping, especially since open innovation and co-creation are measurably successful in industry (Dervojeda et al., 2014). Within this space of open design, co-creation and community involvement, there are a number of existing tools and frameworks which companies could tap into.

1.1.2. Current tools and frameworks

Design toolkits offer a plethora of generative tools (Sanders, 2000) and methods, and there are many frameworks to help understand and communicate how these tools are applied. Despite this diversity of tools, methods for engaging with makers are under explored in design research (Smyth and Helgason, 2017), despite the potential opportunities. The designer has many open source toolkits to hand, such as the REMODEL kit (REMODEL, n.d.), developed by the Danish Design Centre, who also integrated the Open-O-Meter tool (Bonvoisin and Mies, 2018). Another tool, related to prototyping strategy, is the Prototyping Canvas (Lauff et al., 2019). Some of these toolkits, tools, and methods would be in part applicable for engaging with makers, but there is no tool specifically designed to engage with the maker movement that exists. Nor has there been an explorative study on the potential offerings such a tool might provide, and how the tool should manifest itself.

1.1.3. Purpose and research questions

It is clearly indicated in the literature that; prototyping is critical for companies, makers exhibit skill at prototyping, companies benefit from engaging with others in the process, there are successful tools that help companies to engage, but there is no such tool facilitating maker engagement with prototyping in companies. Given this gap in the research, this study proposes the following research questions (RQs):

a) How beneficial would a tool to help companies engage and collaborate with makers in prototyping in product development be for companies and makers?
b) What would be the design considerations for a tool to help companies engage and collaborate with makers in prototyping in product development?

These RQs are the foundation for this explorative study to investigate the problem space for a prototyping tool, which facilitates engagement, collaboration and co-creation with makers. If both these questions are answered, then this study will be instrumental in deciding if such a tool should be developed, and if so how?

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2. Methods

2.1. Research design

This is an exploratory study, which lends itself to qualitative methods to provide insights into answering the RQs. The research design is a fully mixed concurrent dominant status design (Leech and Onwuegbuzie, 2009). In practice, this means that both qualitative and quantitative methods were applied in the study whereby one type of method, in this case qualitative, was dominant in the analysis. This study used interviews as a qualitative method, and online questionnaire surveys as a quantitative method. As seen in Figure 1, a preliminary and exploratory literature review was conducted to identify a gap in knowledge, i.e. prototyping tools that encourage engagement with makers. Then interviews and surveys were carried out concurrently. Data from the interviews and surveys were analysed individually and finally compared to answer the RQs.

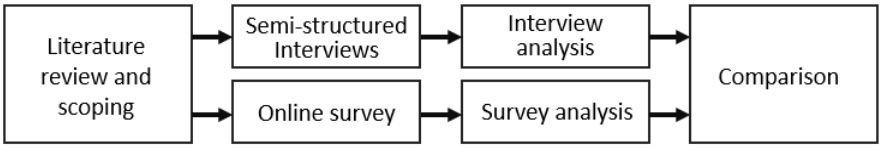

Figure 1. Research methodology

2.2. Definitions

There are three key terms needing delimitation for this study: companies, prototyping, and makers. The companies concerned in this study develop hardware products, or in other words physical consumer goods. Within the companies, the employees of interest are design and engineering practitioners, or anyone involved with prototyping activities within the firm. With regard to prototypes, this study discusses only physical artefacts, as opposed to digital, virtual or hybrid prototyping, at any level of fidelity. The focus within prototypes may be on, but not limited to, low fidelity, low cost and early design stage models. Makers are defined as people who identify themselves as makers, although colloquially a maker is someone with an interest in digital fabrication, open source platforms and DIY.

The term prototyping tool is left undefined but is implied to mean an aid, method or framework used by design and engineering practitioners to plan and improve hardware prototyping capabilities, activities and outcomes. The Prototyping Canvas is a good example of this; however, it does not expressly facilitate engagement with makers from the maker movement in order to improve prototyping. As such, the tool concept, this study is investigating would be some kind of aid for designers to help companies engage with makers in order to improve prototyping.

2.3. Interviews

Seven semi-structured interviews were carried out, each lasting an hour. Three sample groups were identified: Experts, makers, and companies. Three experts, two makers and two companies were interviewed either via Skype or in person. There were two women and five men, across five different nationalities and a range of professions. Every interview was recorded, transcribed and analysed. Experts were selected using non-probability judgmental sampling, chosen at the discretion of the authors based on convenience, relevance, and usefulness. The experts included a Project and Events Manager at a Makerspace, a Project Assistant involved in the design of an Open Source tool and a professor specialising in generative design tools. The companies were represented by senior designers working for two Danish design consultancies. The two makers were found through the Distributed Design Market Platform (About - Distributed Design Market Platform, n.d.). The experts were interviewed using tailored interview guides, because the variation of their expertise would make it unproductive to write comparable questions. Interviewees were sampled using non-probability, convenience sampling. These interviews were semi-structured, with one guide for the makers and one guide for the companies, for comparability. The maker guide primarily concerned itself with motivation, capabilities and willingness to collaborate, whereas the key themes for the company

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interview guide were current prototyping activities, challenges to collaboration and advantages of working with makers.

2.4. Interview analysis

The semi-verbatim transcriptions were coded and analysed using NVivo 12, a qualitative analysis software. The approach for coding the transcripts was both open and axial, as concepts and themes formed during the analysis. The seven interview transcripts were coded into 50 code tags, which were clustered into nine code sets.

There are two clear analysis goals, derived directly from the RQs: 1) Identify if and how beneficial a tool might be and 2) Identify the design considerations for such a tool. Consequently, the analysis took a two-pronged approach, which will hereafter be termed the 'How analysis' and the 'What analysis', after the prefacing interrogatives of the RQs. Figure 2 shows a model for the analysis.

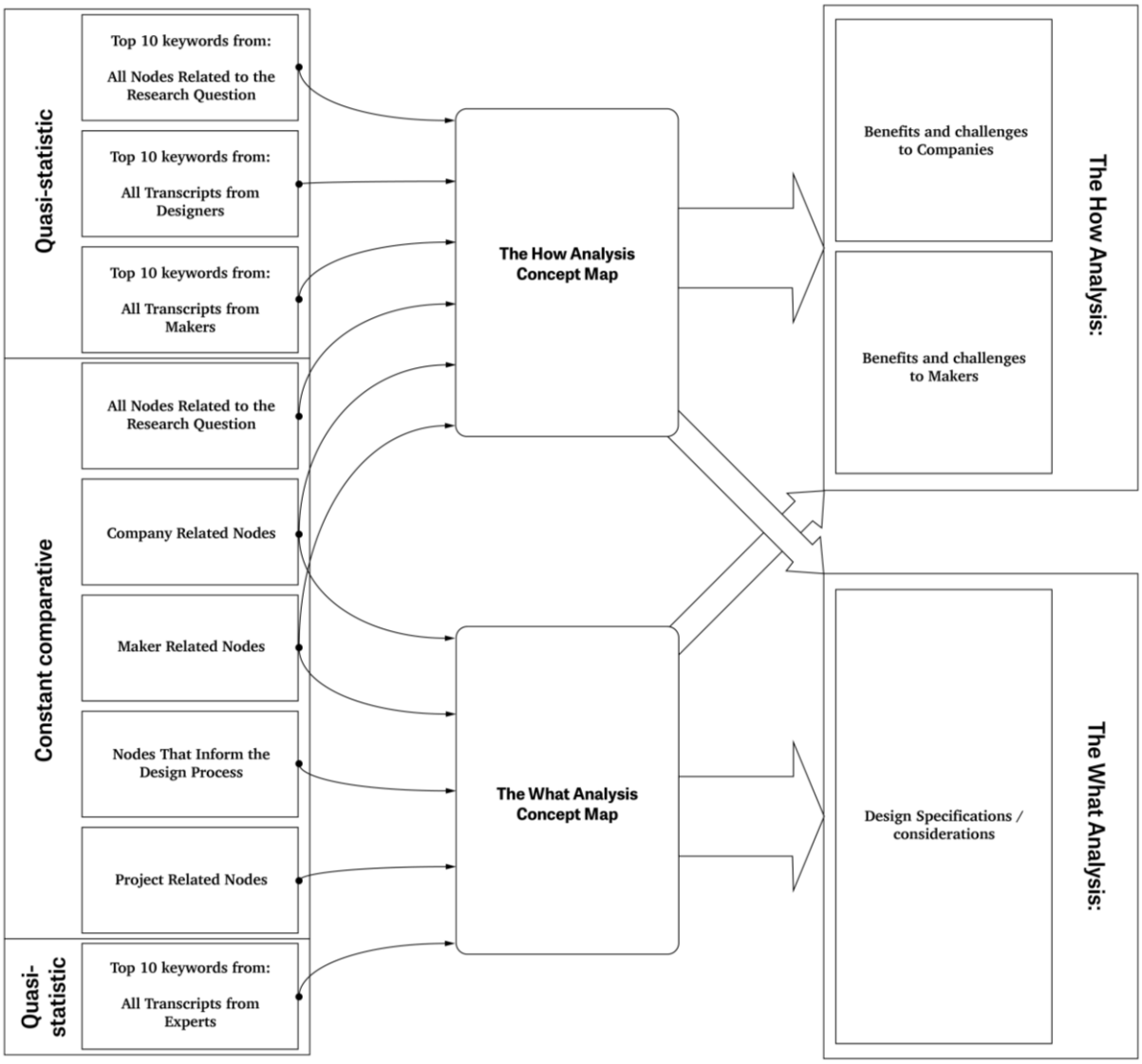

Figure 2. Analysis model. The left-hand side shows the code sets and the analysis approaches. Thin arrows indicate to which concept map themes from each set was fed. Company and maker related nodes informed both concept maps. The large arrows on the right of the concept maps are approximately proportional in scale to the number of findings that entered each outcome.

The goal of the How analysis is to identify if and how the tool would be beneficial to companies and makers. As for the What analysis, the primary goal is to identify what the design considerations should

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be, to help facilitate the possible development of the tool. These considerations are presented as design specifications that could be used in future concept synthesis (Service Specifications | Service Design Tools, n.d.). To ensure the two goals of the analysis are met effectively, two main approaches are used, in both the How and What analyses, to mitigate oversight of key themes from the data: Quasi-statistical and constant comparison (Ratcliff, n.d.). The quasi-statistical approach means conducting a word frequency query and determining the top ten keywords from a given code set or transcript and thereafter extracting themes. This way the themes are data driven and less biased. The constant comparison approach meant analysing sets of nodes determined by the researcher, comparing and contrasting node from node, until common themes that arose from the data could be formulated. This approach relies heavily on the insights of the researcher but provides greater flexibility. Both approaches together afford the analysis good coverage of the data. Figure 2 shows a model of the exact division of the two approaches across the different code sets and how those findings are split between the two goals.

2.5. Surveys

Two surveys were made, one for makers and one for companies. Both the makers and companies were sampled using non-probability convenience sampling. They were distributed online via several social media platforms. The anonymous maker survey was published on several subreddits on reddit.com, over 10 maker related Facebook groups, and emailed directly to a number of Fablabs and makerspaces. The survey targeted towards companies was distributed by posting on LinkedIn, messaging relevant participants directly on LinkedIn, posting on relevant subreddits, and emailing businesses directly to share among their employees. There was a concerted effort to reach out to makers and companies globally to get a good sample distribution and therefore more representative results. The maker differentiated inputs from people who self-identified as makers from those who did not, by asking the question "Do you identify with being a maker?". This way, all participants were directed to the relevant questions. The company survey posed the question "Does your company engage in prototyping during product development?" This way, companies that do not prototype were excluded. The questioning, in both the maker and company surveys, aligned in subject matter with the interview guide questions, so that the results can be more easily compared in the analysis.

2.6. Survey analysis

The sample sizes were 39 for the maker survey and 28 for the company. These sample sizes followed the pragmatic approach (Denscombe, 2014), by ensuring there were approximately 30 usable results or more, which is similar in scale to relevant studies, albeit lower than desired. The maker survey produced several results, which highlighted attitudes towards identity and community within the maker movement and ascertained the demographics. The makers represented 11 nationalities, although 71% were either American, Danish or British. The mean average age was 34 years old. 81.6% of participants identified as male and over half worked as engineers, technicians, managers, or were students. This may not be representative of the maker movement overall, but it does indicate that the sample was predominantly male and technically oriented. 80.8% of respondents came from SME's and the vast majority were designers or design engineers (71.4%), but the sample also included engineers, management and directors.

2.7. Interviews vs. survey

After analysing the interviews and surveys, the results were compared. Results from the interviews provide a qualitative understanding on the topics in focus, which is supplemented by a quantitative perspective from the surveys. The mixed method research design means the surveys can advocate for the suitability and representativity of the interviews. As the results of the survey align with that of the interviews it can be said that the analysis was representative of the respective populations.

3. Results

The aforementioned goal of the How analysis is to address the first RQ by determining how beneficial the tool might be. Table 1 provides an overview of the identified benefits and compares results from the qualitative and quantitative research.

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Table 1. Benefits to companies and makers

Benefits to companies	
Benefits identified in the interviews	**Benefits identified in the surveys**
Companies could widen their range of materials and their capabilities in prototyping.	"Makers could use alternative prototyping methods" (59.3%)
	"Makers could reduce prototyping costs" (63%).
By observing the way makers solve the same design problems, new inspiration can be found, like simpler and more elegant solutions.	"Makers could help to reframe the design problem" (29.6%)
	"Makers could create novel solutions" (44.4%)
The benefit to companies, if wider prototyping capabilities and new solution inspiration can be found, could be improved products, improved innovation and ultimately greater revenue.	3 out of 4 respondents said prototyping was a "Very important" activity
	92.8% answered either "Yes" or "Maybe" to the question, "Do you believe your company could benefit from collaborating with others...?"
Even if no collaboration happens, the tool may still help them better understand their own shortcomings in their prototyping process and capacity.	"Makers could improve company creative culture" (40.7%)
Other benefits of collaboration with makers includes: talent hunt, reduction in development costs, unknown unknowns and connections with other competitors products and industries.	57.1% perceived the maker movement as an opportunity for their business
Benefits to makers	
Benefits identified in the interviews	**Benefits identified in the surveys**
Makers could experience the satisfaction in making, in contributing and in learning by prototyping.	"I enjoy turning ideas into a physical object."
	"I enjoy learning new skills"
	"It's a wholesome activity"
By being involved in such a collaboration and being seen as/treated as a 'Lead user', 'expert' and 'maker doctor', could lead to greater self-efficacy and subsequently better creative confidence.	"motivated by my desire to deepen my understanding of the built environment and the materials, tools, philosophies, and politics that have shaped it."
Other maker benefits: Job opportunities, paid subcontractor work and new contacts in industry.	90.6% said "Yes" to, "Do you think makers would benefit from collaborating with companies in the product development process?"

3.1. Design specification

The purpose of the What analysis is to answer the second RQ, by finding out the design considerations that may be necessary for the development of a tool for engaging with makers in prototyping. The design specifications, derived from the qualitative data, are:

1. The tool should use makerspaces as a channel, but it cannot be the only channel. Other channels must be available to reach out to makers who do not use or have access to these spaces.
2. The tool should help makers understand, quantify and communicate their limitations, expectations and commitment to the collaboration, in order to maintain a lifestyle balance.
3. The tool should communicate to the maker the concrete outcomes and benefits, in terms of their contribution to the design, the level of creativity required, the opportunities for them to learn and the level of commitment required.
4. The tool should support or encourage self-efficacy in the makers.
5. The tool should facilitate fair pay and/or compensation for the maker, in all collaborations.
6. The tool should target SME's, whereby small companies are defined as having up to 50 employees and medium companies are defined as having up to 500.
7. The tool should help companies assess and diagnose their own prototyping capabilities and identify what expertise and level of engagement they might need.

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8. The tool should communicate to the company the concrete outcomes of the collaboration and benefits to innovation from doing this - which is often best done with examples and case studies.
9. The tool should be adjustable/agile to the needs and understanding of the company.
10. The level of engagement needs to be clearly defined at the outset and the subsequent IP protection necessary for that level of engagement.
11. The tool should be applicable within a 2-3 week design sprint and should not take more than half a day, defined here as 4 hours, out of a designer's day and should not take more than two days out of a designer's week. Eg. maximum 16-24 hours across 2-3 weeks.
12. The level of commitment of the maker should be led by the maker and should respect the maker's "balance".

The results from the survey support some of the design specifications. 65.6% of respondents said they had used a makerspace in the last 6 months, suggesting specification number 1 is appropriate. The makers that commented, "the end result should be satisfactory and usable" and, "I feel I have ownership into the product" showed that specification 3 is relevant. Intellectual property concerns, relating to specification 10, were critical in the survey, as shown by 64.3% agreeing that, "Intellectual property issues" was a challenge. Finally, since 32.1% of survey respondents would need a new prototyping strategy to fit within an agile or lean framework, specification 12 affords companies that flexibility, without excluding other firms.

4. Discussion

4.1. Commonalities in literature

This analysis aligns with the culture of innovation in the maker movement and the impact of the maker movement in general. As Camburn and Wood (2018) discuss, the DIY principles makers apply in their work could translate into positive design outcomes due to effective low-cost prototyping, such as the principle of repurposing functional blocks. This point is echoed in the analysis, where companies could widen their range of materials and their prototyping capabilities, which was summed up by one interviewee, "just getting the idea that we could use another material…could be beneficial." Further to the immediate benefits to prototyping practices, Hui and Gerber (2017) demonstrate that there is a culture of entrepreneurship within makerspaces, which fosters skill development and self-efficacy, both of which appear in this analysis. This symmetry with the literature and the analysis indicates that the findings presented here do have a place in the discourse on learning new ways of prototyping from makers.

4.2. Challenges to overcome

However, there are challenges and barriers to collaboration between makers and companies, such as cultural differences, perceptions, intellectual property, and motivation. Part of the motivation for makers to engage is knowing that their work contributes to something greater and will not be shelved. This is a communication challenge for companies, to reassure the makers that their work is valued and implemented. Furthermore, it can be challenging for companies to connect with makers, because most makers communicate in local communities and over platforms like Facebook and WhatsApp. Singh (2018) writes that organisational norms need to be re-examined if companies are to adopt a similar culture and mindset as makers. This was put quite simply by an interviewee, "Companies just don't get how they work". This culture shift could be good for the company to embrace, but it is nonetheless challenging. Also, as Baldwin and von Hippel (2011) express, deeply rooted assumptions regarding the virtues of intellectual property, particularly in larger organisations, are being challenged by open innovation. A collaboration between makers and companies would fall within this paradigm, the concerns of which were poignantly deliberated on by one of the designers interviewed for this study, "You have no clue how those NDA's look. It's 20 pages of some psycho lawyer stuff." Another challenge which was made clear in the analysis was motivation - how do you motivate makers to participate? Makers involved in open source hardware development are not driven by extrinsic motivations like pay but are in fact motivated by internalised intrinsic factors like personal use,

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reputation and learning, as well as joy (Hausberg and Spaeth, 2018). One of the makers interviewed for this study mirrored this finding, "If I get paid without any meaning or meaningful approach, I don't want to do that." One interesting contradiction is that makers are motivated by self-expression, creativity and self-efficacy, however the company prototyping needs, especially within a corporate context, may not allow for such maker autonomy. On the other hand, SME's are more likely to share cultural norms with makers and will have less IP protection, however they lack the time and resources to engage properly with makers. In sum, this analysis implies that a tool designed to aid companies in opening up their prototyping process to makers could be beneficial and that the development of such a tool should aim to resolve the trade-off relationships addressed in the challenges. If the design of this tool for engagement helps companies to consider how to tackle these challenges, it should increase the probability of a successful collaboration with makers.

4.3. Shortcomings of the study

The core shortcomings of this study lie in the methodology, nevertheless the RQs were satisfactorily addressed. The surveys should have had much more than approximately 30 respondents each, to be more statistically significant. In the interview samples, there should have been one or two more makers interviewed for a greater range of perspectives, and within the companies sample there should have been one or two more participants representing larger companies that developed their own products in house. Despite the sub-optimal sampling, enough credible results were produced to carry out a thorough analysis. This study does not recommend that further research or tool development be exclusively justified by the results of this study but should seek to validate any proposition by a more contextual and empirical means.

4.4. Relevance

This study is relevant to industry and academia, because it explores the intersection between the maker movement and professional design practice. By investigating the problem space for a tool, to aid companies in engaging with makers to improve prototyping practices, this study has laid the foundations for its possible development. The results from this qualitative study have shown that if the challenges to collaboration are overcome, companies could see real benefits to their prototyping capabilities by engaging with the maker movement, which in turn could have a broad impact on design in industry. Furthermore, the notions that makers can help companies in prototyping and that a tool could be developed to help companies engage with makers, stem from a body of examples and research, to which this paper contributes. These results could therefore be used as springboard for more detailed research or the development of an applicable tool.

4.5. Further research

Firstly, the position of this study is that a prototyping strategy tool, designed for engagement and collaborations with makers and the maker movement at large, should be developed, tested and proposed. This study has laid out some of the potential benefits of a tool and what the design considerations should include in order to overcome the challenges discovered. The development process and methodology of a future tool should apply: co-designing with makers, companies and relevant experts; validating empirically with a test involving real stakeholders, i.e. makers; and presenting the tool and the findings to gather feedback and peer review. Ultimately, this tool would be used in conjunction with other tools, or a system of tools, and strategies to suit the requirements of the company's situation, and therefore should be designed with applicability and compatibility in mind.

4.6. Conclusion

The capacity to prototype is becoming democratised, with ever greater accessibility to digital fabrication and technical knowledge. As a result, the role of the designer and their relationship to the consumer is changing, from a prescriptive stance to a collaborative one. Concurrent to this new paradigm arises the maker movement, where passionate and creative people have banded together to connect with each other over their love for making. They have proven to be skilled at prototyping and therefore present a unique opportunity for companies, who seek to improve their capabilities, to learn

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from them. It is in that context that this study has asked how companies might benefit from a tool to help facilitate that learning, and what design considerations should be made in the development of such a tool for collaboration. The qualitative exploration of this space has resulted in the understanding of possible benefits to both companies and makers, and a set of design considerations, which could guide future research. These findings were supported by a survey and align well with the literature on prototyping, the maker movement, innovation, co-creation, and design tools. The results specify that collaborating with makers could widen the range of materials used in prototyping, produce more elegant solutions and reduce development costs. Therefore, it can be said that despite challenges to collaboration, a tool designed to help companies engage with makers in prototyping in product development could be beneficial and should be developed.

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