How Do Makers Obtain Information for their Makerspace Projects?

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Abstract. Makerspaces are places for construction and creative expression using tools such as 3D printers, laser cutters, and sewing machines. In this study, we investigate how makers obtain information for their makerspace projects. The study focuses on four sources of information: people, documents, experimentation, and prior knowledge. On the basis of interviews with thirteen makers, we analyze their use of these information sources in relation to different knowledge areas, creative-process stages, and relevance criteria. Our main findings are that (1) experimentation is a prime source of information, (2) ease and pleasure are the dominant relevance criteria, (3) process and situation receive little attention, and (4) information sources vary across process stages. Specifically, experimentation is the dominant information source during the construction stage. In addition, the relevance criteria show that the makers turn to people because it is pleasurable, to documents because it is easy, and to experimentation because it results in quality products. These results emphasize the importance of experimentation and suggest that it warrants closer attention in studies of the information behavior of makers and, more broadly, creative professionals.

Keywords: creative process, experimentation, information seeking, information source, makerspace, making

Introduction

With the advent of makerspaces, a variety of citizens have become involved in creative design processes that were previously the realm of artists, craftspersons, designers, engineers, and similar professionals (Anderson, 2012; Gershenfeld, 2012). These creative design processes are information intensive. Like creative professionals, the users of makerspaces – so-called makers – need information to get ideas for projects, appreciate situational parameters, devise processes, evaluate sketches, operate technologies, ensure product quality, and so forth (Koh, Snead, et al., 2019; Li & Todd, 2016). Yet, making differs from professional work by being a leisure activity. As a leisure activity, it is undertaken occasionally, with little training, and in ways that seek to avoid tedious elements. Therefore, makers' information behavior may differ from that of creative professionals and must be understood in its own right. However, it has not yet been studied much. Building on the extensive literature on creative professionals' information behavior, this study investigates how makers seek information.

Makers engage in projects from printing images on T-shirts, through repairing consumer products, to building robotic devices. The common thread in these projects is the creative activity of expressing ideas in materials. Makerspaces provide makers with access to tools such as 3D printers, electronics kits, glue guns, laser cutters, sewing machines, and so forth (Willingham, 2018). With this equipment, makers can engage in complex projects and make quality products. These uses of makerspaces are examples of serious leisure (Hartel, 2003). However, makerspaces are also places for meeting other makers, exchanging information, and forming communities. Without this social dimension, most makers would enjoy the makerspace less or be unable to use its equipment competently (Koh, Abbas, et al., 2019; Taylor et al., 2016). For some makers, the social dimension takes precedence over the creative design process.

This study is about maker projects in Danish library makerspaces. While library makerspaces also host pre-planned activities for schools, families, and other groups (Einarsson & Hertzum, 2020), this study is about makers' self-driven projects. We focus on self-driven projects because the makers in these projects are responsible for the entire creative process from idea conception to final product and can select from a wider array of information sources compared to the pre-planned activities. In this context, we ask the research question: *How do makers obtain information for their makerspace projects?* To answer the question, we investigate 13 makers' use of four information sources in relation to four knowledge areas, four creative-process stages, and four relevance criteria. The study is based on interviews, which are content analyzed (Hsieh & Shannon, 2005) and thickly described (Creswell & Miller, 2000).

The four investigated information sources are people, documents, experimentation, and prior knowledge. While people and documents are commonly researched information sources, experimentation is surprisingly absent in most studies of the sources from which people obtain information (Hertzum, 2014a). We contribute an analysis of the role of experimentation relative to other information sources in creative processes. This study also contributes insights about how different information sources are favored at different stages of the process, for different reasons, and by different makers. These insights begin to identify differences between makers' information behavior and that of creative professionals.

Related work

Makerspaces are being implemented in libraries around the world to provide access to digital fabrication tools, support learning, build communities, and reinvent libraries (Born et al., 2018; Slatter & Howard, 2013). While the learning potential of makerspaces is widely discussed (Berland, 2016; Blikstein, 2014; Li & Todd, 2019), few studies examine makers' information behavior. As exceptions, Chen, Kuo, and Chang (2019) find that makers combine information sources; Li and Todd (2016) remind us that making is an information-intensive activity that involves trial-and-error inquiry; and Koh, Snead, and Lu (2019) find that makers spend much time to try things out, obtain information, and plan future steps. We aim to expand on this limited body of research by investigating makers' use of information sources.

Information Sources

Making is a leisure activity that involves learning about tools, materials, and techniques as well as connecting to people and crafting creative expressions (Gauntlett, 2018). To do so, makers seek information from other people, documents, experimentation, and their prior knowledge.

Makerspaces assemble people with similar interests (Koh, Abbas, et al., 2019). By being in physical proximity, they can support one another with advice, help, and inspiration. Studies of creative professionals show that people are widely used as information sources (Hertzum, 2014a). The reasons for seeking information from people include that it is perceived as easy and that the source can help tailor the provided information to the information seeker's need

(Fidel & Green, 2004; Hertzum, 2014a). Furthermore, people can provide explanations and be queried about how confident they are about the advice they offer.

While people are a frequent source of information, they are often combined with documents (Hertzum & Pejtersen, 2000). Artists and designers use documents such as biographies, films, magazines, and objects in their creative processes. For example, artists skim magazines for inspiration, but they also scrutinize specific styles and techniques relevant to their creative expression (Hemmig, 2009; Mason & Robinson, 2011). While there are magazines about making (Hepp, 2018), makers tend to search for documented information on platforms with user-generated content (Gauntlett, 2018; Li, 2021). Thingiverse provides access to other makers' 3D models for remixing or reproduction purposes; Instructables and YouTube provide step-by-step insights into other makers' processes (Gauntlett, 2018; Tseng & Resnick, 2014).

Davies (2018) argues that makers conform to a lifestyle of "just doing" that is in opposition to analyzing and waiting. Elsewhere, making is described as a way of learning through the trialand-error process of exploring, tinkering, testing, failing, and iterating (Blikstein, 2014; Koh, Snead, et al., 2019; Li & Todd, 2016). With a few exceptions (Allen, 1966; Hemmig, 2009), such experimentation is largely bypassed in studies of information seeking. However, Schön (1983) contends that designers reflect in action. While designing, they engage in a dialogue with their materials, reflect on the qualities of their designs, and make in-the-moment adjustments. They draw lines and respond to the resulting drawing.

Finally, the creative process is informed by prior knowledge and experiences, including learnings from prior projects (Mace & Ward, 2002), knowhow from immersion in a field (Cross, 1982), and personal life experience (Hemmig, 2009). Prior knowledge is available in memory. Thereby, it differs from the other information sources, which require interaction with people, documents, or materials. The starting point for many makerspace projects is an interest anchored in the maker's everyday life, thereby tying the project to personal knowledge about the targeted situation (Li & Todd, 2019). Makers get a sense of accomplishment from resolving such situations by applying their accumulated knowhow about tools and materials (Davies, 2018).

Knowledge areas and creative-process stages

The choice of information source depends on the knowledge area to which the information should contribute (Hemmig, 2009) and the process stage at which the maker currently is (Mason & Robinson, 2011).

Making requires knowledge in multiple areas. For example, studies on computational literacy argue that it involves the combination of cognitive, material, and social competences (Berland, 2016). Specifically for self-driven projects about technology design, Hertzum (2014b) delineates four knowledge areas that design students apply in their projects: *Analyzing the existing situation* involves a situated understanding of the use context with its prospective users, current practices, existing solutions, and environmental constraints. *Constructing technologies* involves a practical understanding of technical possibilities, acquired by exploring materials, constructing prototypes, and testing iteratively. *Specifying processes* is a procedural understanding of the project by allocating time, setting deadlines, managing activities, and deliberating on who should be involved in the process. *Developing visions* is an understanding of the future situation by imagining and articulating the desired change and the product features that will support it. All four knowledge areas are present in any design project, yet to different extents depending on the nature of the problem, maturity of the technology, and even personal preferences (Hertzum, 2014b).

The prominence of the different knowledge areas can also evolve across the creative process. While several models (e.g. Kuhlthau, 1991) describe the information-seeking process, Mace and Ward (2002) examine the stages in the creative process. On this basis, they suggest a four-phase model. First, *idea conception* is the phase where the artist conceives the idea. The idea can be the result of prior knowledge, information seeking, or encounters in everyday life. Second, *idea development* is an iterative process of structuring, enriching, restructuring, and evaluating the idea. Third, *making the artwork* is the phase in which the artist prepares the construction process, constructs the artwork, evaluates the outcome, and iterates. This phase is hands-on. Finally, *finishing the artwork* consists of either abandoning or presenting and storing the artwork. In spite of the apparent sequential progression from one stage to the next, Mace and Ward (2002) emphasize that the artist can, at any time, return to a previous stage or skip forward to a following stage.

Relevance criteria

When people select information sources, they weigh source accessibility against source quality (Hertzum, 2014a). While some studies find that accessibility dominates, most studies are consistent with a sufficiency principle: people select sources that are sufficiently accessible and of sufficient quality (Lu & Yuan, 2011).

Accessibility is about the process of using a source and includes both ease of access and pleasure of interaction. A source is easy to access if it, for example, is physically nearby, familiar, understandable, and in an easy-to-use format (Fidel & Green, 2004). Easily accessible sources are used more. Likable sources are also used more (Barry & Schamber, 1998). Because leisure activities, such as making, often deal with higher things in life (Kari & Hartel, 2007), information sources are likely also selected for being pleasurable, interesting, or nicely laid out. Literature on makerspaces often emphasizes the pleasure and well-being associated with makerspace communities (Taylor et al., 2016).

While accessibility is about the process, quality is about the content of the information provided by the source. As a relevance criterion, quality involves the reliability of the information and its relevance to the information need (Hertzum, 2014a). Reliable sources provide accurate, precise, and trustworthy information (Barry & Schamber, 1998). These qualities cannot be determined in an absolute sense, so information seekers actively form a perception of them and employ this perceived reliability in their source selections. Relevant sources provide information that pertains to the problem at hand (Saracevic, 2016). That is, it connects to the information seekers' need by filling, partly or fully, the gap in their knowledge. Chen, Kuo, and Chang (2019) add a social dimension to this criterion by noting that makers attribute quality to sources that connect them to other makers and use situations.

Method

To study how makers obtain information for their projects, we interviewed 13 makers and analyzed the data using a mixed-method approach that combined the quantitative method of directed content analysis (Hsieh & Shannon, 2005) with the qualitative method of thick description (Creswell & Miller, 2000).

Interviewees

The interviewees were recruited through a contact form in a user-satisfaction survey, which was distributed in five Danish library makerspaces through their Facebook groups. The five makerspaces were open to the public and spanned rural, intermediate, and urban municipalities. All five makerspaces had allocated staff, communities of regular users, and equipment for 3D printing, laser cutting, electronics, and textile printing. Thirteen makers who engaged in self-

directed projects were recruited for interviews (see Table 1). The gender distribution in the sample roughly equated the gender distribution of the makerspace populations.

ID	Frequency of	Age	Gender	Project
	makerspace use			
1	Monthly	50+	Male	3D redesign of a wheelchair
2	Weekly	50+	Male	Smart-home ventilation system
3	Monthly	50+	Female	Remake of a folding table
4	Monthly	50+	Male	Distance measuring device
5	Monthly	50+	Male	Laser-cut nameplate for a boat
6	Quarterly	50+	Female	T-shirt printing
7	Weekly	50+	Male	CNC-milled cutting boards
8	Weekly	50+	Male	Laser-cut houses for model-train environment
9	Weekly	20-29	Male	3D-printed objects for role-playing games
10	Weekly	50+	Male	Unmanned underwater vehicle
11	Quarterly	30-39	Female	T-shirt printing
12	Monthly	50+	Male	Laser cut remake of a board game
13	Weekly	50+	Female	Laser-cut pieces for a board game

Table 1. Profile of the interviewed makers

Procedure

The interviews were semi-structured and conducted in Spring 2020. Due to the COVID-19 pandemic, all interviews were conducted online on Zoom, Microsoft Teams, or the phone. Each interview started with questions about the interviewees' background and general use of the makerspace. On this basis, the interviewees were asked to select a single makerspace project for a detailed walkthrough (Table 1). This walkthrough was the main part of the interviews.

For the walkthrough, the interviewees were introduced to a project breakdown form and asked to complete it in collaboration with the interviewer as the walkthrough progressed. The form (see Appendix A) had columns for the different project steps encountered in the walkthrough and rows for information about project temporalities, transfers among contexts, information needs/sources, moments that sparked emotion, and barriers encountered. In ten interviews, the form was shared by screen sharing. In the last three interviews, the form was described orally to the interviewee over the phone. The form served to guide the interviews by providing a common point of reference.

We considered the interviewees' information behavior deeply embedded in their projects and, therefore, asked them to walk through their projects, rather than to describe their information behavior. This way, we aimed for a dialogue that also revealed situational, tacit, and seemingly mundane information behaviors. In addition, the project breakdown form helped obtain details about all steps in the process. The interviewees tended to rush through the initial steps of their projects. When this happened, the form facilitated redirecting the focus to earlier steps by asking probing questions such as "If we then jump back in time, could you...?"

Data analysis

The interviews were audio-recorded. In preparation for the data analysis, we transcribed the interviews and segmented the interviewees' statements into units of meaning (Elo & Kyngäs, 2008). Figure 1 summarizes how the transcripts were analyzed.



Figure 1. Process of data analysis

After transcribing and segmenting the interviews, we selected two transcripts for open coding. The open coding served to develop a shared understanding of the data material, detect themes in it, and construct a coding scheme. Specifically, experimentation and prior knowledge were evident information sources, alongside people and documents. In addition, the open coding revealed that the ways in which the interviewees obtained information evolved during their projects and that the two interviewees had markedly different criteria for preferring one information source over another. The construction of the coding scheme was also informed by the literature, which made us appreciate that the evolution in the interviewees' information behavior was about knowledge areas (Hertzum, 2014b) as well as creative-process stages (Mace & Ward, 2002). The resulting coding scheme had classifications for information sources, knowledge areas, creative-process stages, and relevance criteria, see Table 2. The literature explaining the classification categories was reviewed in the section on related work.

Category	Definition		
Information source			
People	Seeking or applying information from other people in face-to-face or phone conversations, for example seeking advice from staff or peers		
Documents	Seeking or applying information from recorded sources, for example watching YouTube tutorials, reading books, and consulting the user's own notes		
Experimentation	Seeking or applying information by experimenting and tinkering, for example exploring new ideas in modelling software, solving		

Table 2. The classification scheme defining the categories in the classifications of information sources, knowledge areas, creative-process stages, and relevance criteria

	problems by trial-and-error, or gaining unexpected insights when evaluating designs			
Prior knowledge	Applying prior knowledge and experiences, for example experiences that inform the idea, knowhow for problem-solving, and repetition of formerly established practices			
Knowledge area ^a				
Situation	Information about the situation for which the product is made			
Technology	Information about the technological possibilities and constraints			
Process	Thoughts about what the design process should be like			
Product vision	Thoughts about what the product should be like			
Creative Process ^b				
Idea conception	Initial phase in the maker process, including (1) the situations and thinking that relate to initiating the project and (2) the selection of the particular idea over other ideas			
Idea development	Phase where the idea is refined and elaborated, including the structuring, restructuring, enriching, expansion, and evaluation of the idea			
Construction	Phase where the idea is transformed from an abstract concept into a tangible object, including processes of designing, constructing, evaluating, problem-solving, and information-seeking			
Finishing	Phase where the construction is completed and the resulting object is presented, used, stored, or discarded			
Relevance criteria				
Ease of process	Extent to which the interaction with the source is straightforward, uncomplicated, simple			
Pleasure of process	Extent to which the interaction with the source is satisfying, fun, a good experience			
Quality of product	Extent to which the source contributes to a well-designed, durable product			
Connection with product	Extent to which the source contributes to a product that is relevant to the situation or expresses the person			

^a Adopted from Hertzum (2014b). ^b Adopted from Mace and Ward (2002).

On the basis of the coding scheme, we made a directed content analysis (Hsieh & Shannon, 2005) of the interviews. This content analysis proceeded in five steps. First, two randomly selected interviews were coded independently by both authors as training. The interview segments were coded with one category from each classification in the coding scheme, or with 'other' if none of the categories applied. Second, all disagreements in the authors' coding of these two interviews were discussed until a consensus was reached. The discussion also served to create a shared understanding of the classifications and to finetune the category descriptions. Third, another three interviews were randomly selected and coded by both authors independently. The Kappa value of the agreement between the authors' coding of these interviews was .69 (information sources), .72 (knowledge areas), .73 (creative process), and .69 (relevance criteria). That is, all four Kappa values were above the threshold of .60 recommended by Lazar et al. (2017) as indicating satisfactory reliability. Fourth, the authors

discussed all disagreements in their coding of the three interviews until they reached consensus. Fifth, the eight remaining interviews were randomly divided into two sets of four interviews and each set was coded by one of the authors.

In the analysis of the coded interviews, we first analyzed how the interview segments were distributed across the categories of the four classifications (Table 2). For this analysis, we used analysis of variance (ANOVA) to determine the more frequent and less frequent categories. To assign equal weight to the makers irrespective of the number of segments in each interview, the statistical analysis was performed on the percentage distribution of the categories for each interviewee. Post hoc, we conducted pairwise comparisons. They were Bonferroni adjusted to compensate for multiple comparisons. We report only pairwise comparisons that were significant at p < .05.

After the ANOVA analyses, we made a cluster analysis to group makers with similar information-source patterns. For this analysis, each interviewee was described by the percentages of the four information sources. We then used K-means clustering to classify the interviewees into clusters with a similar information-source pattern. K-means clustering requires pre-selection of the number of clusters. We made classifications with two to five clusters and inspected the results. On the basis of these inspections, we chose a classification into three clusters because it yielded clusters with distinct profiles and intuitive interpretations. Finally, we selected one interview from each cluster for thick description (Creswell & Miller, 2000). These descriptions served to add qualitative detail about the interviewees' backgrounds, creative processes, and information behavior.

Results

The 13 makers mentioned information sources in 715 interview segments. In the following, we first quantitatively analyze these segments with respect to their distribution across the categories of the classification scheme and then, on the basis of a cluster analysis, select three makers for thick description.

Information sources

The makers frequently needed to learn new information to move forward with their makerspace projects. Table 3 shows that an average of 41% of the information sources mentioned by the makers were people, in particular other users of the makerspace. Another 18% of the information sources were documents, such as design sketches, tutorials, and other makers' YouTube videos. Information was obtained through experimentation 25% of the times the makers mentioned a need for information. The makers, for example, experimented to get technology settings right, to learn about materials, and to try out product designs. Finally, the makers drew on their prior knowledge 15% of the times they mentioned a need for information. They mostly drew on knowledge from previous makerspace projects and their professional careers. The four information sources were mentioned to significantly different extents, F(3, 10) = 7.39, p < .01. Pairwise comparisons showed that people were used more often than documents and prior knowledge. No other pairs of information sources were used to significantly different extents.

Classification	Frequency	Percentage ^a	
		Mean (± standard deviation)	
Information source **			
People	286	41 (±15)	
Documents	128	18 (±9)	
Experimentation	193	25 (±12)	
Prior knowledge	108	15 (±11)	
Knowledge area ***			
Situation	66	8 (±6)	
Technology	307	44 (±10)	
Process	27	4 (±4)	
Product vision	179	23 (±10)	
Other	136	21 (±13)	
Creative process ***			
Idea conception	58	8 (±6)	
Idea development	160	20 (±19)	
Construction	192	28 (±12)	
Finishing	39	5 (±5)	
Other	266	40 (±17)	
Relevance criteria ***			
Ease of process	228	33 (±9)	
Pleasure of process	165	22 (±11)	
Quality of product	152	20 (±12)	
Connection with product	95	12 (±6)	
Other	75	12 (±12)	

Table 3. Frequency (N = 715 segments) and percentage (N = 13 makers) distribution across the categories of the four classifications

^a The percentage of segments in a category (e.g., people) was first calculated for each maker and then averaged across makers, thereby avoiding that makers who made many statements received higher weight than makers who made fewer statements. ** p < .01, *** p < .001

Knowledge areas

The makers sought information within one of the four knowledge areas 79% of the times they mentioned an information source (Table 3). In the remaining cases, they did not refer to a specific knowledge area; we coded these 21% as 'other'. The knowledge areas were mentioned to significantly different extents, F(4, 9) = 46.60, p < .001. Pairwise comparisons showed that information sources were (a) more often consulted to learn about technology than about any other knowledge area, (b) more often consulted to learn about product visions than about the situation and process, and (c) less often consulted to learn about the process than about any other knowledge area, except the situation.

Figure 2 shows how the information sources were distributed across knowledge areas. For situation, the information sources were mentioned to significantly different extents, F(3, 10) = 5.39, p < .05. Pairwise comparisons showed that prior knowledge was used more often than

experimentation to obtain information about the situation. For the three other knowledge areas, the test for differences in the distribution of the information sources was not significant, F(3, 10) = 1.97, 0.56, and 0.70 for technology, process, and product vision, respectively (all ps > .15).



Figure 2. Distribution of the information sources across knowledge areas, N = 13 makers. For each knowledge area, the information sources are (top to bottom): people (•), documents (•), experimentation (•), and prior knowledge (•). * p < .05

Creative process

The makers referred to a specific stage in the creative process 60% of the times they mentioned an information source (Table 3). They referred to the different stages to significantly different extents, F(4, 9) = 40.59, p < .001. Pairwise comparisons showed that information sources were more often consulted during construction than during idea conception and finishing.

Figure 3 shows how the information sources were distributed across the stages of the creative process. For all four stages, the information sources were mentioned to significantly different extents, F(3, 10) = 6.45, 3.38, 16.11, and 7.49 for idea conception, idea development, construction, and finishing, respectively (all ps < .05). Pairwise comparisons showed that experimentation was used less than people and prior knowledge during idea conception. Conversely, experimentation was used more than the three other information sources during construction. No pairwise comparisons were significant for idea development and finishing.



Figure 3. Distribution of the information sources across the stages of the creative process, N = 13 makers. For each process stage, the information sources are (top to bottom): people (•), documents (•), experimentation (•), and prior knowledge (•). * p < .05, ** p < .01, *** p < .001

Relevance criteria

The relevance criteria applied in selecting information sources were also mentioned to significantly different extents, F(4, 9) = 15.98, p < .001. Table 3 shows the distribution. Pairwise comparisons showed that the choice of information sources was more often about ease of process than connection with product. Furthermore, a test in which we collapsed ease and pleasure into one category (about the process) and quality and connection into another category (about the process than product) showed that information sources were more often chosen on the basis of process than product criteria, F(2, 11) = 24.38, p < .001.

Figure 4 shows how the information sources were distributed across relevance criteria. For ease of process, pleasure of process, and quality of product, the information sources were mentioned to significantly different extents, F(3, 10) = 6.29, 5.94, and 4.73, respectively (all ps < .05). Pairwise comparisons showed that (a) ease of process was a more frequent criterion for choosing documents than people and experimentation, (b) pleasure of process was a more frequent criterion for choosing people than documents and prior knowledge, and (c) quality of product was a more frequent criterion for choosing experimentation than people and documents. For connection with product, the test for differences in the distribution of the information sources was not significant, F(3, 10) = 1.99, p = .15.



Figure 4. Distribution of the information sources across relevance criteria, N = 13 makers. For each criterion, the information sources are (top to bottom): people (•), documents (•), experimentation (•), and prior knowledge (•). * p < .05, ** p < .01

Clusters of information-source use

The cluster analysis identified three clusters with distinctly different patterns of informationsource use, see Table 4. The largest cluster consisted of seven makers who differed from the others by a distinctly higher percentage of experimentation. These makers valued the makerspace for its tools. The second largest cluster consisted of four makers who predominantly obtained their information from other people. These makers valued the communal qualities of the makerspace. The third cluster differed from the others by consisting of makers who obtained more of their information from their prior knowledge. These makers valued the possibility for personal experiences. Notably, documents were merely a supplementary source of information in all three clusters.

In the following, we present a case from each cluster: Eva (Cluster 1), Karen (Cluster 2), and Per (Cluster 3). The names are pseudonyms.

Information source	"Experimentation"	"People"	"Prior knowledge"
	Cluster 1, $N = 7$	Cluster 2, $N = 4$	Cluster 3, $N = 2$
People	33%	60%	36%
Documents	20%	18%	13%
Experimentation	34%	14%	14%
Prior knowledge	13%	8%	38%

 Table 4. The three clusters of information-source use

Eva's folding table ("experimentation")

Eva is a retired textile designer with decades of professional experience in creative processes. She enjoys designing, modelling, and experimenting. A few times a year, she uses the local library makerspace to make designs. Her professional background makes her appreciate quality materials and well-designed products, but in her everyday life she has a plastic folding table that does not meet her standards. While she finds its design *"super clever"*, the plastic materials make her hide it in a closet. One day, she decided to reconstruct her folding table with the end goal of having it produced in wooden materials that match her other furniture (Figure 5). She started out by researching online for local manufacturers and available wooden materials: "*If I cannot find the right materials there is no point in constructing the table.*." After identifying a potential manufacturer, her makerspace project was to construct a 3D model specifying the design of the table.

Her construction process is thorough and involves multiple information sources. She draws multiple 2D models of the table to get measures and angles right, she adapts and experiments with the model in 3D-modelling software, she problem-solves by watching online tutorials, and she stores every version of the model by date to be able to return to old ideas. Eva explains that new ideas emerge while experimenting. The ideas are processed by implementing them in her model and then spending days mulling over the quality of the results. It is important to Eva to be in control of the model, ensure that every measure is accurate, and arrive at a harmonic and aesthetic design.



Figure 5. Eva's makerspace project

Eva mostly avoids the community in the makerspace because it mainly consists of men who are more interested in electronics and technology than design. However, she appreciates their advice when she has something specific to run by them. For example, she got valuable feedback from another maker who told her that larger hinges were necessary for wooden materials. This feedback triggered further experimentation to ideate, measure, model, print, and evaluate a revised design.

After many iterations, Eva's model is now finished (see Figure 6), and she is ready to have a manufacturer produce the table for her. She has enjoyed the creative process, but her objective

is neither the fun of it, nor to display the product to others. For Eva, making the table has been about removing an annoyance in her everyday life.



Figure 6. Eva's folding-table project. The photos show the reference folding table she has in her home (left), the hinges and folding technique (middle), and the final 3D-printed model (right).

Karen's board-game pieces ("people")

Karen is a retired teacher and a dedicated member in her makerspace community. She is a creative person who has constructed all her life. In the makerspace, which she attends on a weekly basis, she feels part of a community where help is always at hand. Therefore, all activities relating to her creative process take place in the makerspace. Most of her makerspace projects are about repairing and reusing old objects with the help of other makers. Her most recent project involved 3D printing missing board-game pieces for her son (Figure 7).

The pieces should be veteran racing cars, so Karen first searches online for pictures of cars with the right look. Then, she redraws them by hand and starts constructing them in 3D-design software. During the modelling, she encounters multiple technical challenges, such as shaping the wheels and mirroring objects to achieve symmetry. She spends some time experimenting in the software to solve these problems but eventually asks other users for help. In Karen's view, it is more efficient to ask others than to seek information online because she avoids sifting through lots of irrelevant information. In addition, the other makers are knowledgeable and prepared to offer their assistance. Yet, Karen stresses that "*I don't want them to do it for me.*" She seeks advice and instructions that enable her to do it herself.



Figure 7. Karen's makerspace project

Karen receives some of the best advice about how to make the cars from a child at about nine years of age. This child provides explanations at a level of detail that the other makerspace users may not have the time to provide. Karen values that she can get different kinds of

information from different users, for example because they differ in age and thereby outlook. The makerspace community consists of children, adults, and retirees. With the assistance of the other makers, Karen has successfully 3D printed 12 pieces for her son's board game and given them to him as a present. In addition, she has made her 3D models freely available to others.

Karen rarely takes on complicated projects, but for every project she refines her skills and learns from the other users of the makerspace. While the makerspace gives her access to technologies she would not otherwise have access to, these technologies would not be useful to her unless the makerspace also provided a community of users ready to assist her in the use of the technologies and make it a pleasurable experience.

Per's wheelchair ("prior knowledge")

Per has spent his professional career holding leading positions in sales, marketing, and communication. He uses the makerspace to solve a problem he has experienced in his life. Five years ago, he had a stroke. Since then, he has had to use a wheelchair to move around because his legs are partially paralyzed. Per experiences that he cannot reach objects at the upper shelves in the supermarket and that people literally look down at him when they are standing and he is in his wheelchair. With a background in business, it also bothers him that wheelchair users do not look very good in suits. Hence, Per began to envision ways in which electric wheelchairs could be redesigned for improved appearance, control, and feelings of self-efficacy (Figure 8).

Per wakes up one day with a clear vision for an improved wheelchair. He has little prior skill in construction and design but knows that a prototype can help him communicate his idea. Therefore, he contacts a friend who recently purchased a 3D printer. From him, Per is redirected to the makerspace and its 3D-construction software. He explores the software in the makerspace and then goes home, downloads the software, and constructs his first prototype.



Figure 8. Per's makerspace project

For several months, Per works sporadically on improving his prototype. In parallel with modelling, he seeks advice and feedback from innovation consultants and local companies. However, a personal experience and a coincidental conversation also affect his vision of the wheelchair. First, he crashes with a wheelchair while on vacation. This personal experience teaches him that stability, solidity, and safety are crucial requirements that necessitate changes in his prototype. Second, at a party, he sits next to an engineer from a company that produces electric scooters. After talking with this engineer, Per extends his design with a remote control.

Per's project is ongoing. His 3D-printed prototype has come quite far and he has started looking for a company that is interested in his product vision. He will not produce the wheelchair himself but provide the idea and the prototype design. Therefore, he is currently starting a collaboration with a company that is technically capable of producing the wheelchair.

Discussion

The main findings of this study are that (1) experimentation is a prime source of information, (2) ease and pleasure are the dominant relevance criteria, (3) process and situation receive little attention, and (4) information sources vary across process stages. We discuss these findings in the following.

Experimentation is a prime source of information

The 13 makers obtain their information through experimentation 25% of the time. Experimentation is even more prominent (34%) for the seven makers in the largest cluster. This finding corroborates Li and Todd's (2016) finding that makers engage in iterative trial and error. It also corroborates previous findings that experimentation is the most frequently used information source for visual artists (Hemmig, 2009) and engineers (Allen, 1966). The reliance on experimentation for obtaining information may, to some extent, be specific to people who create or design. At least, Allen (1966) found that experimentation was a less prominent information source for scientists, who mainly relied on literature and personal experience. However, few studies of information-source use include experimentation (Hertzum, 2014a); much more is known about how people and documents serve as information sources. When experimentation is included, it is often not called out but rather subsumed in discussions of how information is obtained by learning through participation in a community of practice (Lave & Wenger, 1991).

Experimentation is the makers' primary source of information during the construction stage of their projects. In contrast, it plays a secondary role during idea conception and in learning about the situation for which the product is made. While the situation involves the world as it is, construction is about the world to be. Experimentation gives material form to tentative ideas about what the product could be like. By inspecting these materials, the makers learn about their ideas. This process of trying out ideas is effective because it is as though the materials "talk back" (Schön, 1983) to the makers, who learn by listening and iterating. The effectiveness of experimentation is emphasized by the finding that quality of product is a more frequent criterion for choosing experimentation to obtain information than for choosing people and documents.

Ease and pleasure are the dominant relevance criteria

The ease and pleasure of the information-seeking process are more important to the choice of information sources than criteria about the product. While this finding may be unsurprising in a leisure activity such as makerspace projects, previous studies find that accessibility and likability are also key criteria in selecting information sources at work (Fidel & Green, 2004; Lu & Yuan, 2011). For the makers, the different relevance criteria mainly apply to different information sources. Specifically, the dominant criterion for selecting documents is ease of process, whereas it is pleasure of process for people and quality of product for experimentation.

The association between people and a pleasurable process is a recurrent theme in makerspace research, which often emphasizes their communal qualities (Koh, Abbas, et al., 2019; Taylor et al., 2016). The four makers in the second largest cluster value these qualities highly and, as a result, seek 60% of their information from people such as other makers. For some of them, including Karen, taking part in the makerspace community is as important as seeing their personal makerspace projects through to completion. The makers in the two other clusters attend less to the communal qualities of the makerspace and merely obtain 33% and 36% of their information from people. For example, Eva feels peripheral to the community in her makerspace because it mostly consists of men with interests different from hers.

Process and situation receive little attention

The makers devote little attention to the situation for which they make products and even less to active thinking about the process through which they make the products. These two knowledge areas account for 8% (situation) and 4% (process) of the makers' information-source use. When they obtain information about the situation, it is mostly to set the scene during the early stages of their projects. With respect to process, it appears that the makers associate active process thinking with deadlines and tedious planning and deliberately avoid it. Several of the makers are explicit about not wanting to – and not having to – structure their makerspace projects like a project at work.

The modest attention devoted to the situation and process begins to characterize how maker's information behavior differs from that of creative professionals. In contrast to makers, creative professionals devote considerable attention to obtaining information about situational issues, such as client needs, and process issues, such as deadlines and planning (Freund, 2015; Solomon, 1997). The reasons for this difference between makerspace projects and professional projects may include that makers are not accountable to a client. Instead, making is serious leisure (Kari & Hartel, 2007; Stebbins, 2020): It is an uncoercive hobby activity that requires special skills and knowledge. Being a hobby activity, the makers are free to focus on the creative, experimenting, pleasurable, and social aspects of making (Li & Todd, 2016; Meyer et al., 2018). That is, they are free to pursue their own interests and can bypass the situation and process requirements inherent in work projects.

Information sources vary across process stages

The mix of information sources changes as the creative process progresses. The change is most evident for experimentation, which is used less than people and prior knowledge during idea conception but more than any other information source during construction. Eva and Per are examples of how prior knowledge and people are the dominant information sources at the beginning and end of the projects, while a broader mix of sources are consulted during the middle stages of the projects (Figures 5 and 8). Overall, the makers seek more information during construction than at the beginning and end of their projects. These findings support previous findings that information seekers use a mix of sources (Hertzum, 2014a). However, previous studies find either similar information-source use at the beginning and middle of projects (Koh, Snead, et al., 2019; Yitzhaki & Hammershlag, 2004) or more extensive information seeking at the beginning of projects because more issues are still unresolved at this initial stage (Ellis & Haugan, 1997; Freund, 2015).

We see two reasons for this difference between the makers and creative professionals. First, the focus of the makerspace projects tends to be a situation that is already known to the makers, at least partially. That is, they can draw on their prior knowledge, which is readily available. In contrast, creative professionals such as engineers do projects for clients and, thus, need to obtain information from the client before they can proceed from understanding the situation to devising the solution. Second, the makers learn the makerspace technologies as part of their projects. Learning the technologies is central to several of the makers' motivation for conducting their projects. In contrast, creative professionals already master the technologies; it is for example on the basis of this mastery they attract clients.

The information source affected the least by the process stage is documents. They are a supplementary information source in all stages but idea development. A reason for the tendency toward more document use during idea development could be that their ease of process is particularly important at this stage because the makers are still exploring multiple options in a somewhat uncommitted manner. Once they begin to commit to one option, they shift to experimentation, which is more resource-demanding but also experienced as yielding better

quality of product. While the makers in all three clusters make some use of documents, no cluster has documents as its primary information source.

Limitations

Three limitations should be remembered in interpreting the results of this study. First, it is restricted to adult makers' self-driven projects in Danish library makerspaces. Makerspaces also host pre-planned activities for schools, youngsters, and other groups, who likely use and mix information sources differently. It is for future work to explore such differences. Further work is also required to establish whether our results extend to countries where libraries and their makerspaces have a different role in the local community. Second, we cannot rule out that modest sample size masked additional effects. One indication that real effects may have remained nonsignificant is the low observed power of the nonsignificant ANOVA tests. Third, most of our data concerned only two of the stages in Mace and Ward's (2002) model of the creative process. Thus, the model merely provided a rough temporal breakdown of the makers' projects. Future studies should consider other models of project stages or opt for longitudinal study designs to collect data as the creative process evolves.

Conclusion

Makerspaces are places for creative construction and a recent addition to libraries. In this study, we have investigated how makers obtain information for their makerspace projects. The interviewed makers seek information from people because it is pleasurable, from documents because it is easy, and through experimentation because it results in quality products. Furthermore, prior knowledge often supplies information about the situation for which the product is made. We see three implications of the study findings:

First, experimentation is the dominant source of information during the construction stage of the projects. It is also the characteristic information source in the largest cluster of makers. Yet, experimentation is often bypassed in studies on information behavior. Future work should elaborate how experimentation complements other information sources: Under what circumstances is experimentation preferred? What competences does it require? What is its relation to serendipitous encounters? How is it done effectively? We consider such studies particularly warranted in relation to the information behavior of makers and creative professionals.

Second, the makers' information behavior differs from that of creative professionals. The main differences are that the makers devote modest attention to the situation and process and that they seek more information during construction than at the beginning of their projects. Future work should verify and extend these differences. Several of the makers in this study had a background as creative professionals, but were now retired. Other makers, especially younger ones, may transition in the opposite direction – from makers to creative professionals. These transitions provide interesting possibilities for future work on the similarities and differences in the information behavior of makers and creative professionals.

Third, makers' information seeking is intertwined with their experience of the communal qualities of the makerspace. Thereby, the diversity of the makerspace community influences not just the makers' community participation but also whether information appears accessible and projects doable. It is a considerable practical challenge to balance an inclusive community against one that stakes claims to the makerspace. This challenge emphasizes the importance of the human information sources in maintaining a community that invites information seeking.

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Appendix A

The project breakdown form. All text in grey is example text based on the interview with Eva.

Steps	Idea	Constructing 3D model	3D printing of the model	Second iteration	Manufacturing folding table
Context (time, place, situation, people involved)	Physical context: At home. The maker has furniture in matching materials (oak). One exception is a folding table that she considers very functional, but the material annoys her. Owing to this annoyance, she wants to remake the folding table in oak.	Physical context: At home. Over a period of a week, the maker develops a 3D model of her project.	Physical context: In the makerspace. The maker mentions that most design takes place at home, but production is in the makerspace where she also has access to feedback.	Physical context: Makerspace and home Redesign of the prototype at home and printing in the makerspace.	3D model is to be produced by a local manufacturer. [Total project: about 6 months]
Information behavior (information needs, sources, problems or question, and information use)	Online information seeking: - Q: How much would the table weigh? A: Calculation of weight based on material density. - Q: Where could the model be manufactured? Is it possible? A: Yes, a local manufacturer is identified by online search. Measurement and documenting seale and size of folding table.	To make the model, the maker: - Makes 2D drawing with pen and paper. She includes correct scaling and angles. - Reflects on the best hinges to select. They must be both hidden and functional. - Models in 3D. She is already experienced in 3D modelling from prior projects but uses YouTube tutorials for help when she encounters a problem. - Notes tutorials and advice in her notebook. Her approach is based on her background as a professional designer. She spends time reflecting and knows that design takes multiple iterations. Solutions come to her as she thinks about the problem on and off for a while.	Model is produced and assembled. A user, who also is a carpenter, provides (redback and explains that her hinges are not durable. She receives details for hinges and serveys. She writes these details in her notebook and looks them up on the internet.	Iterates on the first model and makes a new one. - Draws model by hand - Remodels based on existing model - All iterations stored by date - 3D printing in the makerspace.	A local manufacturer is contacted
Emotions occurring in the process (motivation, frustration, persistence, achievement)	She explains that she is motivated by the outcome of her project, and she would never design anything without it having a purpose.	Loves the challenge Feeling of being goal-oriented and determined.	The makerspace is good for help and guidance. Grateful for receiving advice.	Persistence, doing things the right way, and caring about detail.	Other things take priority at the moment, and therefore she has not finished the project even though most of the work is completed.
Barriers (technical problems, social barriers, other constraints to project completion)		No barriers constraining her project, but challenges occurred when designing the hinges and folding techniques. Y et, she argues that she enjoys the process of figuring out solutions for these challenges.	The makerspace is useful for advice, but the maker feels no belonging to the community and prefers to work on her project individually.		Time to finish the project