Understanding Knowledge Management Practices for Early Design Activity and Its Implications for Reuse

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ABSTRACT
Prior knowledge is a critical resource for design, especially when designers are striving to generate new ideas for complex problems. Systems that improve access to relevant prior knowledge and promote reuse can improve design efficiency and outcomes. Unfortunately, such systems have not been widely adopted indicating that user needs in this area have not been adequately understood. In this paper, we report the results of a contextual inquiry into the practices of and attitudes toward knowledge management and reuse during early design. The study consisted of interviews and surveys with professional designers in the creative domains. A novel aspect of our work is the focus on early design, which differs from but complements prior works’ focus on knowledge reuse during later design and implementation phases. Our study yielded new findings and implications that, if applied, will help bring the benefits of knowledge management systems and reuse into early design activity.

Author Keywords
Contextual Inquiry, Design, Knowledge, Reuse.

ACM Classification Keywords
H.5.3 [Information Interface and Presentation]: Group and Organization Interfaces -- Evaluation/methodology; H.3.3 [Information Storage and Retrieval]: Information Search and Retrieval --- Search process.

INTRODUCTION
Prior knowledge is a designer’s greatest resource [30]. For example, during the early phases, designers draw from their own and others’ prior knowledge to formulate the design problem, generate ideas, and evaluate alternatives [5, 35]. By “prior knowledge,” we are referring to the concepts, lessons, and representations captured in the myriad artifacts created or collected in the process of solving a particular design problem as well as in the designer’s own memory. Studies confirm that designers often access prior episodes (experiences) when challenged with new problems [38]. Due to the large volume and diversity of design knowledge produced even for a single project, designers must rely on external methods of storage and retrieval [26]. This has spurred much research into systems that enable rapid access to and promote reuse of prior design knowledge; as such systems may improve design efficiency and outcomes [30].

For example, case-based repositories represent an important class of design knowledge management system [21]. These systems allow prior cases (e.g. artifacts and descriptions) to be efficiently represented, indexed, and retrieved [24]. A second class of system allows the decisions and rationale relating to the construction of design artifacts to be captured [6]. The decisions can be traced to support redesign and maintenance efforts. Emerging systems such as Wikis and blogs also show promise for managing design knowledge. However, despite many technical advances and availability of these systems, they have not been widely adopted for managing design knowledge. A key reason, we believe, is that user’s needs and practices for managing and reusing design knowledge have not yet been adequately understood.

In this paper, we report results and share anecdotes from a contextual inquiry that investigated the practices of and attitudes towards managing and reusing design knowledge. The study consisted of semi-structured interviews with 14 professional designers and an online survey receiving 28 responses. Participants came from several creative design domains such as graphics, industrial, and interaction design.

One novel aspect of our work is our focus on the creative design domains, where problems are often ill-defined and there is no one right solution [39]. We chose these domains because they are widely practiced, would benefit from improved knowledge management, and have been understudied relative to the engineering domains for knowledge management and reuse. Another novel aspect is our focus on reuse in early design activity, which differs from prior works’ focus on the late design and implementation phases.

Analysis of the interview and survey results yielded several important findings. For example, we found that (i) reuse of prior design knowledge is highly valued during early design activity, but seldom performed due to a mismatch between existing work practices and system assumptions; (ii) designers want to know about the ‘stories’ associated with
design artifacts and be able to reflect on past processes; (iii) designers want to reuse other designers’ artifacts more than their own; and (iv) search is necessary, but insufficient for retrieving prior design knowledge. These and other findings were distilled into actionable implications that can improve the design of knowledge management systems. Though not exhaustive, the implications provide a large and important step towards bringing the desired benefits of knowledge management into the early stages of creative design work.

RELATED WORK
We discuss design knowledge and the value of reuse, particularly for early design. We describe design knowledge management systems and how they have not enabled the benefits of reuse to be fully realized. Our study is then situated in context of other studies of design practice.

Design Knowledge and the Benefits of Reuse
Design knowledge typically refers to the conceptual ideas, lessons, and representations captured in the design artifacts created or collected when solving a design problem [27]. In the engineering domains, reuse of design knowledge offers many benefits. For example, solutions from prior problems can provide useful starting points for new problems [27, 30], serve as references for comparing or explaining new ideas, and provide access to relevant design discussions [27]. Reuse can improve design efficiency and lead to higher quality outcomes [31]. However, how well the benefits of reuse can be realized depends on how well prior knowledge can be stored, accessed, and retrieved [27].

Reuse is important in all stages of design, but it can be particularly beneficial during the early, conceptual stages. For example, reuse can improve the quality of decisions made in early design, on which subsequent decisions will be layered [21], and can help foster divergent thinking [29].

Though reuse has been well-studied in the engineering design domains, there has been little research on knowledge management and reuse practices in the creative design domains, especially for conceptual design activity. Our work contributes to filling this gap. Our goal is to better understand the benefits and practices of reuse during the early stages of the creative domains and how systems can be developed to allow these benefits to be better realized.

Systems for Design Knowledge Management and Reuse
Existing knowledge management and reuse systems for design fall into four broad categories: organizational memory systems, case-based design and rationale systems, activity capture systems, and component repositories.

Organizational memory systems record solutions to well-defined and recurring problems and users can interactively navigate the repository to find needed information [1, 10]. However, these systems do not support storage, retrieval, or reuse of the myriad artifacts typical for creative design.

Case-based systems bring computational processes to design repositories [24]. With effective representation and indexing, these systems aim to help designers find solutions from prior problems that may be useful in solving a relevant new problem [27, 30]. Despite many technical advances, these systems have not been widely adopted by designers in the creative domains, especially during the early conceptual stages. We believe this indicates a lack of understanding of the work practices and needs of designers in these domains.

Design rationale systems allow decisions reflected in design artifacts and related deliberations to be captured and traced [6]. This information can then be later accessed to support maintenance and re-design efforts. However, it is not clear how well this type of information would meet the needs of designers during the conceptual stages of creative design, when they are generating new ideas and seeking inspiration.

Activity capture systems focus on the capture and retrieval of design history during the current project [19, 20]. For example, the Workspace Navigator captures context along with design activity for an ongoing project in a dedicated physical workspace [19]. The captured information can be accessed for understanding the design process and recalling decisions. Similarly, Klemmer et al. show how to capture the evolution of an information architecture and allow recall of past states [20]. In contrast to this class of system, our work focuses on understanding how designers collect and reuse knowledge from their own and other’s prior projects.

Reuse of existing components and patterns is a common practice in many engineering design domains; especially to solve complex problems [10, 37] and assist in decision making [27]. Though supporting systems address many issues related to using prior knowledge, their focus is on the detailed design and implementation phases, when designers are seeking solutions to defined problems. However, in early design, the problems are typically ill-defined and designers are usually seeking directions rather than specific solutions.

In sum, many types of design knowledge management systems are available, but few, if any, have been widely adopted for creative design. We argue this is because such systems (case-based systems, rationale systems, Wikis, etc.) do not adequately support the needs of designers. To help overcome this obstacle, our work contributes understanding of designers’ attitudes toward and practices of knowledge management during the early stages of creative design.

Studies of Design Knowledge Management and Reuse
Researchers have conducted several studies of knowledge reuse in the engineering design domains. For example, studies have probed the efficacy of case-based reasoning methods [26, 27] and component-based design [3, 22].

The impact of stored cases on decision making has been studied in software development [10], architecture [27], and manufacturing [31]. Researchers have also studied how storage and retrieval strategies affect reuse of engineering models (e.g. CAD models) [3, 22]. A common thread in
many of these studies is the need for capturing discussions along with the reusable components. However, these studies have focused on late design or implementation phases when the requirements are better understood. It is therefore not clear how well the results from these studies translate into the early stages of the creative domains due to differences in the types of problems addressed (ill- vs. well-defined) or the outcomes desired (inspiration vs. specific solutions).

Outside the immediate scope of knowledge management, there have been many other studies of design practice. For example, Herring at al. studied how and why designers retrieve and use examples in context of a particular design project in the creative domains [17]. Researchers have also investigated the use of different representations of ideas during the Web design process [25], the communication patterns of design teams [34], and the social aspects of team work and the communicative roles of design artifacts [9].

In contrast to these and similar studies, our work is original in that we are studying designers’ practices of managing and reusing design artifacts across project boundaries, and focusing on the early stage of the creative design domains.

STUDY OF KNOWLEDGE MANAGEMENT AND REUSE PRACTICES IN EARLY DESIGN

The purpose of our user study was to develop deeper understanding of the practices of and attitudes towards managing and reusing knowledge during early design and to extract implications for supporting systems. Our study consisted of interviews with 14 professional designers and a Web survey which received 28 responses. Remuneration was $20 for an interview and a $10 gift card for a survey.

<table>
<thead>
<tr>
<th>Method</th>
<th>&lt;5 yrs</th>
<th>5-9</th>
<th>10-14</th>
<th>15-20</th>
<th>&gt; 20</th>
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<tbody>
<tr>
<td>Interview</td>
<td>4</td>
<td>5</td>
<td>4</td>
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<tr>
<td>Survey</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>3</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>9</strong></td>
<td><strong>12</strong></td>
<td><strong>14</strong></td>
<td><strong>3</strong></td>
<td><strong>4</strong></td>
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</table>

Table 2. Years of professional experience of the designers.

Of the 14 designers interviewed, 12 came from three large design firms with a long-standing reputation for innovation. The other two designers were highly competent freelancers. The interview had 18 questions, probing designers’ beliefs and strategies for creating, gathering, storing, and retrieving design artifacts. Interviews were semi-structured in that a script was used but tangents and anecdotes were especially welcome. Table 1 shows a sample of the questions asked.

<table>
<thead>
<tr>
<th>Generation and Collection</th>
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</thead>
<tbody>
<tr>
<td>How would you characterize a design idea? What types of artifacts (e.g., sketches, photos, Web pages, etc.) are associated? How many ideas are typically generated?</td>
</tr>
<tr>
<td>What types of artifacts do you collect to help with ideation and from what sources do you collect them?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Storage and Organization</th>
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<tbody>
<tr>
<td>What strategies are used for storing ideas? How important is it to maintain a record of your past ideas?</td>
</tr>
<tr>
<td>How do you choose which ideas to store?</td>
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<table>
<thead>
<tr>
<th>Retrieval and Reuse</th>
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</thead>
<tbody>
<tr>
<td>For what purposes do you review or reuse artifacts from your own or others’ prior work? How often?</td>
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<tr>
<td>From where are the artifacts retrieved? How do you decide which artifacts to retrieve?</td>
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<tr>
<th>Experiences</th>
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<tbody>
<tr>
<td>What experiences do you have with technologies that assist in long term management of artifacts, if any?</td>
</tr>
<tr>
<td>From your perspective, what would be the benefits and obstacles for adopting and using such a system?</td>
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</tbody>
</table>

Twelve of the 14 interviews were conducted in the designer’s own workspace. This allowed them quick and easy access to physical and digital artifacts (sketches, notes, photos, etc.) and allowed us to observe their environment. One interview was conducted via phone and another via e-mail due to distance. Interviews lasted at most 90 minutes.

At the onset of an interview, we asked a designer to briefly describe a recent or ongoing project, and to share artifacts and anecdotes from this project as much as possible to aid our conversation. For example, one designer was working passionately on a new drug delivery device, another was engaged in designing a new line of luxury watches, and a third was creating banking interfaces for a youth audience.

To gain further information after the interviews and collect additional stories of knowledge management and reuse, we created an online survey. The survey had 17 questions similar to those asked in the interviews. Twelve were multi-selection (i.e. more than one response could be selected). The listed responses were informed by the interview results, but participants could write in their own. Five questions were open-ended, e.g., describe your strategy for organizing design artifacts; describe a recent occurrence when design artifacts from past projects were reused, etc. A link to the survey was posted on newsgroups, forums, and listservs. Twenty-eight responses were received over two months.

Interview and survey participants indicated their primary domain of expertise as: graphic design (17), industrial design (10), interaction design (5), mechanical design (3), product design (2), communication design (1), and other (4). This sample was highly experienced, with most having five or more years of professional experience. See Table 2.

STUDY RESULTS

We report results of our study structured according to the main steps of knowledge management in early design: idea generation, collection of artifacts, storage and organization, and retrieval. Though discussed separately, the steps often occur in parallel and their boundaries are not always clear, as design is complex and often ad-hoc. We discuss results by drawing collectively from the surveys and interviews.
Knowledge Generation

A core activity of the early design process is generating numerous design ideas [23]. Designers interviewed in our study reported that they typically generate a very large number of conceptual ideas for a given design problem, averaging about 50-100, but ranging anywhere from 2 to 2000. For example, one designer was developing a new forward-looking website for a large public university, and generated a minimum of 5 “very different” directions.

Consistent with the concept of divergent thinking [18], designers expressed that generating multiple ideas helps them understand the problem, prevents fixation, triggers new thought, and creates “a rich landscape of possibilities.” Interestingly, most designers considered ideas relatively easy to come by, it was choosing the most promising ideas that required the most work and creative effort.

An idea was usually regarded as a ‘new direction’ relative to the existing ideas rather than incremental modifications. An idea was typically expressed via one or more sketches, storyboards, wire diagrams, physical mockups, or scribbled text phrases. These artifacts were used for exploring the design space, communicating ideas to users, clients, and team members, and reflecting on the evolving idea space. Knowledge management tools that target early design must therefore support these types of informal representations of ideas rather than only polished ‘cases’ (cf. [27, 30]).

Foraging for Inspiration

Generating ideas typically requires substantial background research [32]. Designers stated that they spend many hours foraging for materials that inspire, support, or elaborate on new design ideas. For example, Figure 1 shows a sample of the materials collected by a designer for inspiration.

This behavior reflects the perspective that creative insight comes from the prepared mind rather than ‘aha’ moments [32]. Designers struggled to express precisely what they were looking for, but they described wanting to be aware of current visual trends, product styles, and new technologies. This would help form new connections within the design problem and trigger new thought. Designers characterized this type of background work as necessary and important.

Generating ideas in a vacuum was regarded as being too risky (e.g., there is a risk of unknowingly repeating existing designs or creating inferior designs due to lack of awareness of better solutions). The quantity of artifacts collected ranged from a few dozen to several hundred. Indeed, better support for this type of example finding behavior offers a rich opportunity for future research [17].

Foraged materials came from three sources; the current project as it unfolded, myriad external information sources, and internal project repositories. As might be expected, project-specific artifacts included design briefs, user research profiles, competitive analysis reports, and client communications.

External artifacts included physical products exhibiting a particular function, digital photos or videos of anything that caught a designer’s eye (people, objects, or actions), visual templates, and color patterns and styles. These artifacts were collected from diverse sources such as the Web; online repositories such as Flickr, Google Image, and eBay; design forums and blogs; paper magazines; and shopping excursions to local stores. Finally, designers searched project-specific and external artifacts created or collected as part of previous projects. In two designers’ words:

“I am always looking for designers that inspire me to see what they have done on the way for similar projects…so you hop in the website or something similar … and look at things that are parallel to things that you are working on at that time… that’s always helpful I think, inspiring."

“I go back to my own [past projects]. I end up digging back through and even try to find connections. I don’t do it enough, but when I do it, I find it very valuable just to go back and look through my notes from previous projects because so often there’s some connection between just what I was thinking or some spark.”

There was a strong and consistent belief that one of the best sources of inspiration was their own or colleagues’ prior work. Reasons included that these artifacts were created or collected by people they know and trust and that they would likely be of high relevance, e.g., the artifacts were from a past project for a continuing client or from a similar project for a new client. It is difficult to separate past projects from external sources because so often there is some connection between what was being thought or some spark.

Storing Almost Everything

Designers genuinely believed that storing design artifacts would yield future returns and, as a result, store almost all...
artifacts gathered or generated during early design activity. This is partly due to business reasons (e.g., to justify their bill to a client), but mostly because designers believed that these materials had immense intellectual value. Even if they were unsure as to when or why these artifacts might be later retrieved, they were simply too valuable to discard.

For example, we observed entire bookcases (see Figure 2), filing cabinets, and shoeboxes filled with design artifacts from prior work. As one designer stated:

“I keep everything…my notes, my sketches, everything. A lot of times even old artworks that might have communicated well but not as well for a certain phase or a certain presentation, I will keep it because I know I will reference it back…there’s something that didn’t pass but might work well with this presentation or… be useful for certain things. So I never throw anything away.”

Table 3 lists the common reasons cited in the interviews and the number of related responses from the survey for why designers store design artifacts. Aiding with future ideation, capturing the design process, and benefiting other designers were the main motivations. Design artifacts thus clearly serve purposes over time that move well beyond the reasons for which they were originally created or collected. For example, designers expressed that they would often review the collection of artifacts (not any one in particular) to gain a sense as to the overall process that was followed and use that process as a template for the current project.

An interesting outcome relates to what was not mentioned. Designers eschewed the reuse of solutions as-is from prior work as solutions for the current project. Reasons included the persistent need to present clients with truly fresh ideas, a designer’s intrinsic desire to innovate, and that design problems in the creative domains represented by our study are ill-structured (i.e., no two problems are ever the same and there is always a better or different way). Systems that support reuse in these types of domains should therefore promote foraging behavior and reflection over solution finding, which contrasts with much prior work (cf. [33]). We also asked designers what additional information or artifacts they want to store, but currently do not or cannot. Responses centered on wanting to store decisions, rationale, communications, and processes related to design artifacts as well as descriptions of how those artifacts were used or referenced in later projects. For example, one designer said he wanted to have “records of brainstorming sessions and communication history” as a means for recalling decisions.

### Strategies for Organization

We asked designers to explain their strategy for organizing design artifacts. The most common strategies spanned a mix of personal/shared and physical/electronic dimensions.

Personal-physical strategies included the use of paper notebooks in which designers sketch or write fleeting ideas and attach or glue supporting artifacts. It also included the use of personal shoeboxes and office cabinets to store artifacts (and notebooks once full). Shared-physical included the use of dedicated storage rooms and large cabinets accessible to all. Personal-electronic strategies included the use of folders on personal work machines, blogs, e-mail, and bookmarks.

For example, electronic folders were typically organized using some combination of project title, date, and type of material (sketch, user profile, photo, etc.). Figure 3 shows how one designer uses a mail client for organizing design artifacts as this allows for people search. Shared-electronic included use of centralized file servers and enterprise Wikis. A designer typically employed a mix of strategies, varying by personal preference, project, and company. Table 4 summarizes the distribution of survey responses.

One important problem with existing organization strategies is that there is no consistent structure or naming scheme. Regardless of the strategy, designers universally called it ‘messy.’ For example, this is how one designer described a typical folder: “This is a mess. How many ‘final’ video, ‘final’ presentation, I don’t know how many ‘final’ folders…it’s so confusing.” Similarly, there was no consistent naming scheme for design artifacts and, even if there was a policy

<table>
<thead>
<tr>
<th>Reason for Storing Artifacts</th>
<th>Responses</th>
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<tbody>
<tr>
<td>Aid idea generation</td>
<td>20</td>
</tr>
<tr>
<td>Capture the design process</td>
<td>21</td>
</tr>
<tr>
<td>Share with and help others</td>
<td>19</td>
</tr>
<tr>
<td>Facilitate story telling</td>
<td>14</td>
</tr>
<tr>
<td>Reinterpret design ideas</td>
<td>14</td>
</tr>
<tr>
<td>Reflect on design process</td>
<td>13</td>
</tr>
<tr>
<td>Other (e.g., ability to rework an idea)</td>
<td>7</td>
</tr>
</tbody>
</table>

**Table 3. Reasons for storing design artifacts (max: 28).**

<table>
<thead>
<tr>
<th>Organization Strategy</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic folders on personal machine</td>
<td>22</td>
</tr>
<tr>
<td>Electronic folders on central server</td>
<td>18</td>
</tr>
<tr>
<td>Physical folders and notebooks</td>
<td>17</td>
</tr>
<tr>
<td>Enterprise Wikis</td>
<td>8</td>
</tr>
<tr>
<td>Other websites</td>
<td>2</td>
</tr>
<tr>
<td>Blogs</td>
<td>1</td>
</tr>
<tr>
<td>Version control software</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 4. Organization strategies used (max: 28).**
in place, it was rarely followed. This made locating others’
files on a centralized server or Wiki nearly impossible:

“That’s primarily what keeps me from going back.
Everyone’s project folder is organized in a very different
way. Usually they are a mess. We don’t have consistent
file naming conventions. The closest we have is that the
final folder will get highlighted or something. This folder
was all over the place, it was a complete mess.”

Another problem relating to the use of centralized servers
and Wikis is that designers were extremely apathetic about
the prospect of having to upload all of their artifacts. It was
just not exciting or enjoyable, causing a severe lack of
motivation. Besides, clients compensated them for design
and innovation, not for post project administration of files.

However, it was very intriguing that each firm represented
in our sample was engaged in significant efforts to improve
storage, organization, and reuse of design artifacts. These
efforts involved adapting the use of enterprise-scale Wikis
and formalizing naming conventions and link (folder)
structures. This confirms that there is a need and desire in
the design community to improve the practice of knowledge
management. But it seems clear that such attempts will be
largely unsuccessful without overcoming the contradictory
work habits and motivational issues described here.

“We attempted hard to have a sort of internal database
at [our company] of all our past projects, so in theory
you can go and hunt down certain relevant projects.
What we found is that it’s very difficult to have that sort
of management. It’s a social problem because we’ve got
quite a bit of flux and there’s new people coming and
going … It’s a technical problem because information
storage and retrieval is quite a huge task and there’s
quite a few projects happening at any one time so even
finding those assets and getting people’s behavior to
adjust to the need to go through certain steps to
document, it’s not easy … when you’re doing a project
that doesn’t feel like its immediately relevant because
you can’t easily anticipate the benefit that might come
from you, personally documenting this for somebody
else two years from now.”

Retrieval and Search

Designers reported many reasons for retrieving artifacts
from prior projects. Table 5 summarizes reasons given in
the interviews and the related responses from the survey.
Primary reasons included aiding the current process of idea
generation, gaining inspiration for new ideas, comparing
new to previous ideas, and proactively sharing information
with colleagues. In the words of two designers:

“Early on in idea generation, I will retrieve artifacts to
feed into the ideas being discussed and stimulate more
ideas.”

“A project was proposed recently which closely
matched work that had been conducted five years
earlier. The earlier project had not proceeded, but the
ideas represented were as useful now as they were five
years ago.”

There were also several findings that were unexpected.
First, Table 5 reveals that designers seldom retrieve prior
artifacts for the purposes of storytelling (sharing lessons)
and reflecting on the design process. Yet these were two of
the main reasons that designers stated that they store
artifacts in the first place (see Table 3). The discrepancy is
likely because only the artifacts themselves are stored,
without the associated stories or surrounding process.
Though perhaps fresh in the mind of the designer at the
time of storage, this knowledge dissipates over time [36].

Second, and perhaps as a consequence of the prior finding,
we found that designers often review artifacts as a proxy for
determining who to talk to about a particular design issue.
For example, a designer may browse CAD files (and the
creators, if available) to determine who has experience with
designing a particular type of medical device. This was
described as being more efficient and informative and less
intrusive than broadcasting a company-wide request email.

For types of design artifacts, we found that project-specific
documents, digital photos, sketches, Web pages, diagrams,
and user profiles were retrieved most. But it is difficult to
attach a precise value to the retrieval of any particular
material or retrieval instance. Value must be thought of
from, and perhaps measured by, a more holistic perspective,
e.g., gain in personal design skills, more satisfaction with
the process, improved camaraderie among designers, etc.
These types of measurements should be considered in future studies of design knowledge reuse in addition to the measures of process efficiency and solution quality.

Search was described as a necessary, but complex task for finding desired artifacts. For electronic stores of design artifacts, designers searched using the built-in capabilities of their tool or operating system. Searches were performed using known attributes of the desired item, the associated project, or people involved. Table 6 summarizes responses as to which attributes are used most often. Unfortunately, however, search was generally regarded as ineffective. One reason is because designers often store information on their local machine for convenience, making those artifacts inaccessible to colleagues. As one designer stated:

“I don’t currently have a good way to search by designer. Also, design artifacts tend to get stored with their respective projects, not in a central design repository. Unfortunately, some projects have chosen different asset management systems, which makes cross project searching difficult.”

This ineffectiveness often translated into the use of ad-hoc strategies. Here is what one designer reported doing:

“First I try to find the project or bucket folder I would save it in. [For example] if I’m looking for a skinning file I would go to the GUI design folder. If I can’t find it that way, I search for it in spotlight. If it is a recent file and I know the application I made it in, then I’ll open the application, go to open recent file, then when I find it I’ll do save as and change how I saved it so I will be able to find it easier next time.”

Personal information management systems such as [11] offer one approach, but do not address designers’ need to share artifacts or capture the process and history. A second reason is that designers were often unsure as to exactly what they were looking for and therefore struggled to come up with appropriate search terms. A third reason is that available search tools are text-based, whereas most designers are visual thinkers. Visual search techniques such as CueFlik [13] would help, but techniques that would allow for visual foraging would seem most effective.

Despite being regarded as imperfect, search was still the dominant method used for accessing prior work. Most designers scoffed at the idea of having to navigate a mess of links and cryptic file names to locate items of interest from colleagues’ (and even their own) past work, especially if they were unsure as to what they were looking for. This may explain why designers forage so heavily from the Web. Even if artifacts from past projects are more valued, the cost of access via the Web is disproportionately lower.

Social Aspects

We found that design knowledge management and reuse is much more of a social process than we had anticipated, or that the research literature, especially on case-based design, has indicated. First, designers expressed wanting to browse other designer’s prior work more than their own. This can be explained in part because a designer’s work is already embedded in their own memory, experience, and intuition. Indeed, though it varied, many designers described looking back at their own work “rarely” and “almost never.”

However, designers described a genuine and professional interest in wanting to access, review, and learn from other designers’ artifacts and processes, describing design as a continual process of learning and improvement. Also, we found that designers would be open to this type of sharing, assuming they could control what was available and who could access it. Designers saw this as a form of reciprocity, e.g., to “pay it forward - help others who have helped me.”

Second, designers reported that they often retrieved and shared design artifacts with colleagues that might benefit. For example, as shown in Table 7, 18 survey respondents stated they share their own design artifacts with colleagues (not on the same project) or other designers on a daily or weekly basis. This type of proactive sharing is initiated in response to knowledge requests broadcasted via email (e.g., “anyone know . . .”), reflections after group brainstorming, or meetings in which designers communicate progress and central obstacles for ongoing projects. The shared artifacts then prompt conversation and facilitate storytelling.

Finally, the few designers who made the effort to locate artifacts on a central repository or Wiki were unaware of whether others ever directly accessed or benefited from the artifacts. This could explain in part why other designers expressed lack of motivation for following their lead; they were unable to connect the effort of their contribution to the benefit that others received from it [14].

<table>
<thead>
<tr>
<th>Method</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name</td>
<td>23</td>
</tr>
<tr>
<td>Artifact Name</td>
<td>11</td>
</tr>
<tr>
<td>Approximate Date of Creation</td>
<td>15</td>
</tr>
<tr>
<td>Artifact Type</td>
<td>15</td>
</tr>
<tr>
<td>Location of the Artifact</td>
<td>15</td>
</tr>
<tr>
<td>Artifact Content</td>
<td>9</td>
</tr>
<tr>
<td>Designers Involved</td>
<td>9</td>
</tr>
<tr>
<td>Other (e.g., Client/project code)</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6. Attributes for searching past artifacts (max: 28).

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every Day</td>
<td>10</td>
</tr>
<tr>
<td>Every Week</td>
<td>8</td>
</tr>
<tr>
<td>Every Month</td>
<td>4</td>
</tr>
<tr>
<td>Rarely (few times a year)</td>
<td>3</td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7. Frequency of sharing design artifacts (max: 28).
Reuse of prior knowledge is extremely valued in early design activity. Designers collect and evaluate many types of information from many sources in early design. Studying relevant prior work and existing designs is often the first and most important step [32]. We found that designers value prior design knowledge for generating ideas, gaining inspiration, becoming aware of new trends, and reflecting on past processes. A critical point is that designers were not seeking specific solutions – they were seeking directions. The main implication is that designers genuinely value reuse, but better systems are needed to meet their needs.

Designers want to know about the ‘stories’ associated with artifacts. Storing artifacts alone does not capture the stories (e.g. the lessons, communications, and decisions) associated with them. Yet this is what designers were most interested in retrieving. We learned that designers would compensate by trying to seek the person(s) familiar with the artifacts so they could inquire about and learn the associated stories.

One implication is that a DKMS must provide a lightweight means for capturing stories with artifacts. The challenge is that this always requires some effort from users, effort they would usually prefer to direct elsewhere [15]. One possible solution would be to link communication applications such as e-mail and IM clients to the DKMS (e.g., similar to [40]). This would allow designers to add lessons and stories with artifacts and reference these in the communication, which would be created and sent anyway. Archiving these communications would require minimal individual effort but will create a rich and evolving shared external memory.

Capture the process in which design artifacts were created. One valued reason for looking back at prior design artifacts was to gain a sense of the overall design process. For example, designers look back to reflect on their style of design or to use it as a template for an ongoing project. Storing artifacts alone fails to capture the design process.

A DKMS should provide a means for conveying the overall design process associated with the artifacts in a lightweight and informal manner. For example, a DKMS could convey process through a structured visualization. Artifacts related to the same project phase (e.g. concept design, user research, example finding, etc.) could be spatially grouped or layered channels could be used to show when artifacts were added or modified for different phases of the process. Discussions surrounding artifacts could be captured through the use of tagging or lightweight commenting mechanisms.

Search is necessary, but insufficient for retrieving prior knowledge. When collecting relevant artifacts during early design, designers reported being uncertain as to what they were looking for (e.g. looking for inspiration more than satisfying specific information needs). Search and rigid navigation will therefore not suffice; as also learned in [27].

For a DKMS, in addition to search, one solution would be to employ the use of powerful information visualization and interaction techniques to support rapid visual foraging [28]. This would allow designers to explore the knowledge repository at their desired level of detail and reduce the burden of having to recall specific file names or locations. Visual information seeking [2] and exploratory browsing methods (e.g. berrypicking [4]) offer a useful starting point.

Designers prefer to look at other designers’ artifacts more than their own. A designer almost always stores all of their artifacts created or collected for a project, but rarely revisits them. Responses about revisiting their own artifacts were “Not done much”, “Rarely”, and “Almost never”. In contrast, when asked about reusing other designers’ artifacts, responses were similar to “Oh yes, definitely,” “Absolutely”, and “I do it all the time”. Designers feel that they know their own work well and therefore do not need to revisit it. But looking at other designers’ work allows them to gain new perspectives, compare and reflect on their own process, learn new design skills, and even find inspiration.

This finding indicates that a DKMS must emphasize the collaborative and social aspects of knowledge management much more than has been done in prior work. For example, systems should integrate incentives for making past design artifacts available, perhaps borrowing techniques from [12]. Systems should also allow a designer to connect her sharing with the value gained by others, as this can also motivate contribution [7]. As designers often found desired artifacts by considering ‘who has done that,’ a DKMS should enable people-centric navigation and search. Also, the systems could allow social sub-networks to be formed as a way to facilitate repeated access to relevant artifacts from a person and as a means for reducing information overload.

Sharing of design knowledge is common and not limited within the design team. Designers share design artifacts with colleagues in response to ‘requests for help,’ and other designers via design blogs and forums. Sharing is used to spark creativity, communicate ideas, and receive feedback. A few designers even felt obligated to share their artifacts as a means of repaying the broader design community.

One implication is that a DKMS should allow designers to proactively flag artifacts for each other. For example, to respond to a knowledge request sent via email, a designer could flag relevant artifacts in the DKMS, and a notification could be sent to the intended person. Systems would thus support not just retrieval, but a form of lightweight pushing.

Inconsistent organizational style impedes reuse. The use of messy and inconsistent organizational strategies severely hindered retrieval of prior design artifacts and discouraged reuse. For example, even when designers did upload their design artifacts to a shared repository, others were unable or unwilling to decipher the organizational or naming strategy used. This creates frustration and further impedes reuse.

A DKMS cannot assume or impose the use of consistent naming schemes or folder hierarchies. As noted previously, one possible solution is to employ information visualization techniques that show pictorial representations of artifacts in
different arrangements and/or with different levels of detail rather than only using folder hierarchies and file names.

**Relevant design knowledge is often too disconnected from the project at hand.** Designers felt that prior projects were the most relevant sources of design knowledge, but reported relying on the Web and other sources (e.g., magazines) as these were immediately available. Several of the designers reported that their company had some form of a design knowledge repository, but they had no idea where it was!

The implication is that a DKMS should be integrated with commonly used tools for the particular design domain. For example, if a designer is creating a concept sketch with a design tool, other sketches from relevant or selected projects should be immediately accessible in the DKMS. Alternatively, a DKMS should provide an application-specific overview of related artifacts when invoked from the tool.

**DISCUSSION**

Design knowledge management is a very complex topic and studying it typically requires a narrowed lens. Our work is no exception. First, we studied a subset of design domains; including but not limited to graphics, Web, interaction, and industrial design. We chose these domains as they have been studied less in terms of knowledge management and reuse relative to the engineering design domains; but also produce large amounts of knowledge that must be managed. The domains studied are unique in the types of artifacts created (e.g., sketches rather than source code), but similar in that designers need to manage artifacts, processes, and decisions. Our findings and implications thus complement study results in other design domains, e.g., [22, 27, 37].

Second, our research focused on early design activity, when designers are striving to generate novel design ideas. The type of knowledge created, collected, and applied at this stage is informal, ad-hoc, and rapidly changing rather than captured in well defined specifications [8]. Our implications and systems derived from them are therefore most applicable for managing this type of early design knowledge. Such systems will likely differ from those used for managing knowledge related to detailed design and implementation (e.g., these would facilitate reuse of source code, artifacts, or physical components from prior projects). Further understanding is necessary to identify how such systems could be cross-referenced and integrated [27].

Third, we focused primarily on a particular form of design knowledge – ideas and representations expressed through all of the artifacts, examples, mockups, etc. created during early design. Though there was some intersection, our work did not explicitly investigate other forms of knowledge such as design rationale [6, 16] and communication [34]. Any design knowledge management system must also reflect lessons from studies of these other forms of knowledge.

Fourth, effective design knowledge management systems can encourage reuse [3, 27, 38] but it is important to point out that the ultimate benefit must come from designers’ willingness to contribute to and use such systems [14, 15]. For example, while almost all designers in our study expressed interest to review relevant prior designs during the conceptual stages, one designer considered this too constraining at this stage. Even if a DKMS can greatly reduce the effort of finding relevant prior knowledge, it is the designer who is responsible for deciding how and when to use such systems in practice.

Finally, our methodology utilized contextual interviews and surveys because this was most appropriate for meeting our goal of understanding practices of and attitudes towards managing knowledge in early design. Other methods such as in-situ observation could be employed to complement our results by providing more quantitative insights, e.g., which specific artifacts are accessed and how often.

**CONCLUSION**

Designers routinely draw upon prior knowledge to solve complex design problems. Such knowledge is often drawn from the ideas and representations captured in prior work. Unfortunately, traditional systems (e.g. case-based systems) have not been widely adopted, indicating that user’s needs have not been adequately recognized. It is also unclear how well emerging collaborative repositories such as Wikis will meet the specific needs of managing design knowledge.

The overarching contribution of this paper is that it offers further understanding of the practices of and attitudes toward knowledge management and reuse during the early stages of design in the creative domains. Our findings were distilled into actionable implications for the development of knowledge management systems. Though not exhaustive, applying these implications can move this class of system closer to real-world adoption. We believe such systems have immense potential for improving design efficiency and the quality of design outcomes.

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**REFERENCES**


