Supporting methodic design practices with interactive organization and visualization of design artifacts

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1 Introduction

Designers are visual thinkers and work in an environment full of informative and creative design artifacts. This paper illustrates how designers work and defines the basis and activities for producing flourishing ideas. The goal is to find out how designers can be supported in the reuse, sharing, linking and capturing of design artifacts in order to speed up the design process and create a smarter way of handling prior design artifacts. In the first section, the phases of the design process and surfaces on which designers work are introduced. On the basis of this description, the second section clarifies the importance of design knowledge management, establishes a scaffolding of requirements that a tool should support for assisting designers in their work. Furthermore, an overview of existing tools and an analysis of the previously defined requirements are given. Finally, the last section points out the design goals for a promising tool and delivers insight into what a possible setup can look like.

1.1 Design process

The design process from the first idea to the design solution is like a flower during the process of growing. To reach the desired height, some time and some effort is necessary. Fertilizer can protect the flower from external influences and boost the growth. The appropriate ground, a friendly atmosphere and the right aids will lead the bud to bloom. After some time, the flower is getting older and needs a new magic bullet to bloom again.

The growth of the flower can be compared with the whole design process (Figure 1). The stem of the design process flower is something like the central of the designers and is responsible for processing the created ideas and the decisions designers made. The leaves are the different design phases with the design artifacts. The buds are possible design solutions as the result of the produced artifacts. Some of the buds begin to bloom and some will pause, before they begin to bloom. After a while, a design solution becomes stale and new design ideas have to be prepared to enthuse the target audience. If a prior design idea was good, the reuse of it in whole or the use of particular artifacts is a good basis to fuel a new blooming idea. Ideas that have not been used for one project can
be promising for other projects and consequently can provide a basis for new blooming flowers.

At least equally important is the ground in which the flower is growing. Resources can either be created by the designers themselves or ideas and solutions of colleagues and anonymous authors can be used [26]. Designers often use similar design ideas from competing designers to compare and analyze the features and choose those parts which can be transferred to the new design, because:

"'Without examples you are just running blindly [...] [12].""

Reflection. The involvement of several designers in the process of evaluation and reflection will multiply input to the design and add levels of material with which to have a reflective conversation that would normally be unavailable to the individual working alone [25]. During the whole process design ideas will be reflected and discussed. Reflection allows one to view an idea in more detail and to go into depth. Schön’s [20] method, Reflection-in-Action is the conversation of the designer with the situation. The designer critically reflects a main problem, then reframes it, tries to work out the consequences and runs through different ways to solve a problem. During the creation of possible solutions, the situation,
including the possible solution, is again reflected and some implications can be found. This findings are used to refine the solution, which is again reflected. The whole process of Reflection-in-Action is a fluent “back-talk” between the designer and the situation. Buxton [5] describes Prototyping as Iterative Incremental Refinement in Figure 2. This figure is also appropriate to Reflection-in-Action. The red arrow shows the enhancement of the situation and the spiral around is the process of Reflection-in-Action.

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\text{Fig. 2. Prototyping as Iterative Incremental Refinement [5].} \]

Farooq et al. [7] defines \textit{Group Reflectivity}, which consists of \textit{reflection, planning} and \textit{action}. First the ideas will be discussed, then a decision about the ongoing process of the idea in the project’s context will be made and finally the following actions will be defined.

\textbf{Convergent and divergent thinking}. As currently discussed, reflection is essential to the process and can be described as an instrument for making decisions for or against some design idea. Reflection is closely related to \textit{convergent} and \textit{divergent} thinking. As shown in Figure 3, in the early phases of design, numerous distinct branches will be created. According to Buxton [5], various design alternatives are more or less refined and can break up into new branches. At a certain point, designers start to choose the most promising ideas to go more into detail and refine them. What this Figure 3 shows on the left side is divergent thinking as the ability to generate a set of possible ideas, options and alternatives for a final design solution. This phase is followed by convergent thinking, which helps focus on one or more alternatives for the ongoing design process.

\textbf{Design is a choice}. Design is about exploring and comparing the created alternatives. According to Buxton [5], there is not just one right path, but rather there are several paths which can be taken into account at any given time, regardless of whether a special idea is realized in the final product or not. The point is, that making decisions matters for the progress of a design solution.
1.2 Design space

Designers work in an environment full of informative and creative design artifacts. Walls and surfaces enrich the atmosphere and help the designer to gain inspiration. In the following, the center shows the different types of surfaces in a creative environment, their classification, their purpose and lastly the activities in the design space.

Environment. According to Keller [14], the designer’s work environment can be classified in three ranges. The atmosphere is the large range and acts as a source of inspiration. The layout, as the medium range, is responsible for the organization and comparison of ideas and concepts on the desk. Finally, the precision is the small range in which the designer creates and explores concepts with sketches and models.

Surfaces. In the work environment, several surfaces enrich the design space. Vyas [27] focuses on the usage of a wide variety of desks and whiteboards and introduces a classification for surfaces in the design space considering the purpose, the number of projects for which they are used and the number of individuals making use of them. The four “artful surfaces” are:

- Personal,
- shared,
- project-specific and
- live-surfaces.

Personal surfaces are those, which are individually used by one designer. Artifacts include design sketches as well as ongoing project-related information,
physical models, prototypes and personal information. The functionalities range from consulting with colleagues about shared artifacts, organizing individual time and project management to supporting the individual’s creative thinking.

*Shared surfaces* assist a group of designers in sharing design knowledge related to specific projects. Usually the shared surfaces are created and used over a long time period and need a kind of formal organization as they are used by several users.

*Project-specific surfaces* are more related to a specific project than the other surfaces mentioned. Like the others, these surfaces gain a high degree of flexibility (e.g. movable whiteboards) and are frequently used for organization, management and reflection of a specific project. This type of surface is adapted for either synchronous or asynchronous tasks and acts as a mediator of social coordination.

*Live surfaces* support real-time collaborative group activities such as the variety of design techniques.

**Fig. 4.** Vyas artful surfaces arranged according the dimensions *number of persons* and *number of projects*.

Through arranging the different types of surfaces in a designer’s work environment, the atmosphere is something in between personal and shared, the
purpose of which is to put the designer in a creative mood. The layout can be mapped to shared and project-specific surfaces as its role is the organization and overview of one or several projects. Finally the precision is the place for the design tasks themselves and takes place in the live surface.

**Time and place.** Using Baecker’s CSCW-Matrix\(^1\) [2], which consists of four quadrants, the distinct surfaces can be arranged in relation to the dimensions of synchronous / asynchronous time and same / different place. Each of them describes whether the time is synchronous or asynchronous and the place is the same or is different.

![CSCW-Matrix Diagram](image)

**Fig. 5.** Vyas artful surfaces arranged in Baecker’s version of the CSCW-Matrix [2].

As Figure 5 shows, live surfaces act in face-to-face interactions, which means that these surfaces assist a group of individuals in working together at the same time, in contrast to personal surfaces, which support the individual in ongoing tasks. Personal surfaces are designers workplaces and so this place will mainly stay the same. Both, shared and project-specific surfaces are for individual and

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\(^1\) The CSCW Taxonomy was first presented by De Sanctis and Gallupe (1987) as a broad typology of group support systems. Johansen (1988) refined this work and introduced the 2-to-2 CSCW-Matrix with the differentiation between time and place. Baecker et al. [2] republished it in 1999.
collective purposes. Consequently the interaction can be synchronous and asynchronous. Concerning the place, project-specific surfaces are mostly more flexible than shared surfaces, but shared ones are being used over longer time periods as they are mostly for more than one project. The major difference between shared and project-specific surfaces is the purpose, as the latter ones have an organizational character and the first ones support the management of design artifacts.

As introduced in Section 1.1, the design process consists of different phases which can be broken down to two main activities, - the creation of design artifacts (*Action*) and the discussion of the solutions (*Reflection*). Design techniques such as Affinity Diagramming, Brainsketching or Storyboarding are mainly related to the first of the major activities and will mostly be executed on live surfaces. During the design phases of creation, designers begin to reflect on their work [20]. In this phase the whole project with all the produced design artifacts will be considered. Hence, the creation phase is asynchronous and takes place on project-specific surfaces.

In the following, the focus is especially on shared surfaces, as the work is concentrated on the support of Reflection-in-Action, which means the reflection of design artifacts in between the different design phases, through interactive organization and visualization.

**Activities.** The creative environment of a designer provides a place for social, organizational and individual activity [19]. This categorization has two components, that should be considered: the number of persons who are participating in a process and the kind of activity as organizational activities can be classifiled as social or individual. Vyas [29] takes another view on the executed activities:

- communicating and inspiring design ideas,
- exploring design solutions and
- managing design projects.

These types are more focused on the kind of activity. Surely, all of these are again either social or individual activities.

2 Analysis

The last section introduced the design process from the first idea to the design solution, the designer’s work environment and the various activities of designers. The terms convergent and divergent thinking as well as how design can be seen as an ongoing process of choice have been presented. Apart from that, the variety of artful surfaces has been analyzed and finally, a short overview regarding design space activities has concluded the previous section.
To focus more on the usage of design artifacts, this section introduces DKM (design knowledge management) and confines the term PIM (personal information management). Current strategies and methods for organizing design material are described and afterwards, the main activities of a design space were specified and the term collection will be introduced. The outcome of these activities leads, in the second part, to the definition of four requirements for supporting designers. To complete this section, several existing tools and concepts are presented and analyzed in the last part.

2.1 Design Knowledge Management

During design processes a large volume and diversity of design artifacts is created by designers. The design knowledge produced, consisting of a variety of design artifacts, is primarily used for a specific project, although, storing the created knowledge allows the designer to reuse the artifacts at a later time either to gain inspiration or just to generate new ideas for the same or for other projects. In addition, documenting dissenting views and then returning to these views during later consideration can also preserve a cognitive conflict and reflect on the minority dissent [7]. The storage and retrieval of design knowledge is called DKM.

The difference between DKM and PIM. In general, information management is defined as the process of capturing and organizing information in such a manner that it can be retrieved and reused at a later time [4]. But, contrary to the usual PIM, a system for DKM should address the designer’s need to share artifacts or capture the process and history. Overall, designers are visual thinkers and struggle with finding textual representations of their mental minds [21] that is another reason why traditional PIM is not appropriate to the needs designers have for managing their material.

Current organization strategies. In accordance with Sharmin et al. [21], designers currently have different strategies for organizing design artifacts: personal-physical such as personal paper notebooks for rapidly putting ideas to paper, shared-physical, for example storage rooms and large cabinets [14] accessible to all, and personal-electronic, for instance personal machines (e.g. computers, smartphones), blogs, e-mail or bookmarks. The major methods used by designers for regulating their design material are electronic folders on personal machines (personal-electronic) or central servers (shared-electronic) followed by physical folders and notebooks (personal- and shared-physical). Enterprise wikis are less important, and other websites, as well as blogs and version control software, which have gained less acceptance, are hardly ever used [21].

Due to the wide range of strategies and methods being applied, collections of materials are, in the majority of cases, chaotic. Furthermore, physical and digital, or tangible and intangible, artifacts complicate having a general survey of the materials. Relevant tangible examples are often flagged in books or magazines.
But designers forget that they flagged examples, why they flagged them, or forget to review them. The main question for the designer is "why did I flag it or what about it did I find particularly worth flagging?" [12]. As a result of using electronic strategies, the navigation through a mess of links and cryptic file names is complicated and the locating of items which are of interest is nearly impossible. If the collected material is used more as an inspirational source, the formulation of a specific search query is difficult.

In conclusion, a major challenge nowadays is not only to find a specific artifact again, but it is more to find the artifact in the medium in which it is stored. Generally, the DKM is brought to a more complex level as the variety of types of resources is increased.

Phases. To get an idea of what the support of designers in the creation and organization of collections can look like, the main activities during early DKM are now marked. Therefore, Sharmin et al. [21] structured this early process in four steps:

- Idea generation,
- collection of artifacts,
- storage and organization and
- retrieval.

Idea generation. In the early design process, the creation of a wide variety of design ideas is necessary (see Section 1.1). The generation of multiple ideas helps designers to understand a problem, prevents fixation, triggers new thought and creates "a rich landscape of possibility". As introduced in Section 1.1, designers should exploit their creative and divergent thinking in the very beginning of the design process. After the creation of numerous branches (see Figure 3), designers begin to think in a more convergent way and follow a few ideas. One idea is mostly a 'new direction' of an existing one.

Collection of artifacts. Produced artifacts, used as well as unused, can be the basis for new ideas and should therefore be stored. Moreover, designers not only take their own artifacts as a source of inspiration, they are additionally aware of current visual trends, product styles and new technologies. The sources of materials are the current project itself, external information sources and internal project repositories [21]. The stored artifacts can be described as a collection. Keller [14] mentions some key aspects which are relevant:

1. A collection is a whole which consists of multiple elements which share some characteristics.
2. Collections are dynamic objects created by somebody, over time, for an explicit or implicit purpose.
3. The growth of collections may not always be under conscious control of the user - like a garden.
The elements, contained in a typical designer’s collection, can be differentiated according to the media type, attributes (composition, detail, meaning, form, structure, emotion,...), modality (physical, digital), storage medium (computer, wall, shelf,...) or ownership (personal, shared). While reasons for keeping things are different, one common to many designers is that collections do not follow any structure and are a mess. Nevertheless, in order to use artifacts, designers have the need to interact with their collection. Main activities are adding, maintaining, organizing, selecting, categorizing, cross-referencing, throwing away, and so on... - The organization of artifacts is a fundamental aspect supporting the methodic design practices as it allows them to visualize the possibilities of their design artifacts. This process includes activities such as structuring, branching and sorting. As a consequence, these activities allow the designer to relocate the artifacts again.

In general, the primary activities of collecting are searching and browsing in digital libraries and visualizing data and processes [23]. In a designer’s context, the term digital libraries have to be extended to their tangible and intangible collections. But by and large, these two activities are only some of those which should be supported. It would seem that the goal of storing items in a collection is not to search but to find them again. However, Keller [14] argues that, the real reason for storing artifacts is the urge collect and the fear of throwing things away.

Storage and organization. Contrary to Keller, Sharmin et al. [21] finds several reasons for storing artifacts. After interviewing 28 designers, the biggest reasons identified for storing design artifacts are aiding idea generation, capturing the design process and sharing with, as well as helping, others. In Section 1.2, the design space is described as a space for social, organizational and individual activity. All of the formerly known reasons for storing artifacts belong to one of these activity categories. Table 1 shows the classification of all reasons designers have given for storing artifacts [21], according to the three activity groups. Only one of the activities, capturing the design process, has an organizational character. Most of them are social ones and some can additionally be categorized as individual activities. As a result, the design space provides a substantial ground for all these categories of activities. Consequently, the reasons fit to the definition of the design space.

Retrieval. Sharmin et al. [21] further identified the reasons for retrieving design artifacts. These are somewhat different from the reasons for storing artifacts. This depends upon to the different phases in which artifacts will be stored or retrieved. Considering the process, artifacts must first be stored, before a retrieval is possible. Hence, gaining inspiration, comparing ideas results from capturing the design process and searching for expertise follows capturing the design process and sharing with and helping others (see table 1 and table 2). But in general, the ranking of the reasons is, in both cases, nearly the same as aiding idea generation; gaining inspiration and sharing design information with others are the most crucial aspects. Furthermore, comparing ideas, reinterpreting past design
Table 1. Reasons for storing design artifacts ranged in the dimensions of the design space.  

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

Additional ideas and reflecting on the design process also gain some importance in retrieving design artifacts.

Table 2. Reasons for retrieving design artifacts ranged in the dimensions of the design space.  

<table>
<thead>
<tr>
<th>Activity</th>
<th>Responses</th>
<th>individual</th>
<th>organizational</th>
<th>social</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aid idea generation</td>
<td>22</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain inspiration</td>
<td>18</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share design information with others</td>
<td>16</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Compare ideas</td>
<td>14</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Reinterpret past design ideas</td>
<td>13</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Reflect on design process</td>
<td>10</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Search for expertise</td>
<td>7</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Facilitate story telling</td>
<td>7</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Other (e.g., business development)</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows that the retrieval of artifacts is executed in a more social context than the storage of artifacts. The reason for this may be that the capturing of the design process is a more organizational activity, which can be done alone or in a group. In a later phase, these artifacts can be discussed; new ideas will be generated and decisions will be made, all of which are social activities.

However, to provide a good base for these activities, the organization of design artifacts in an earlier phase is essential. If this earlier process of storing artifacts is executed in the group, it will be beneficial for the later phases as the designers have a common ground for further discussions. This helps to enhance the work flow and leads to substantial progress in designing.

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*Maximal number of responses: 28.*
2.2 Requirements

The previous section sheds light on the importance of various activities that support designers in their work. Additionally, Table 1 and Table 2 have shown the different reasons for storing and retrieving design artifacts in range and classified these according to the classes of activity in the design space. Now, the emphasis is on the activities which should be supported.

Supporting activities. In Section 2.1, the phases of the DKM process are shown and the different types of surfaces and their purposes are introduced. As a result of this analysis, four requirements for supporting the designer’s activities in DKM can be defined (see Figure 6):

- Support in capturing the design process,
- Support in linking related design knowledge,
- Support in sharing design knowledge,
- Support in reusing prior design artifacts.

Fig. 6. (a) Support of capturing, (b) support of linking, (c) support of sharing and (d) support of reuse.
To gain an understanding of why the support of these aspects in particular is relevant for DKM, Table 3 ranges the previously introduced reasons for retrieving design artifacts in the dimensions of the four requirements. This work is primarily focused on the design process of discussing and sharing design knowledge which takes place after the storage of artifacts, so Table 3 illustrates the reasons for retrieving design artifacts.

Table 3. Reasons for retrieving design artifacts and their requirements.\(^3\)

<table>
<thead>
<tr>
<th>Activity</th>
<th>capturing</th>
<th>linking</th>
<th>sharing</th>
<th>reusing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aid idea generation</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Gain inspiration</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share design information with others</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Compare ideas</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinterpret past design ideas</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Reflect on design process</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Search for expertise</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Facilitate story telling</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

As Table 3 shows, all of the requirements are important at least for one of the activities. The support of sharing and capturing has relevance for nearly every activity. In accordance with the ranking, aiding idea generation and gaining inspiration are the two most important reasons for designers in retrieving artifacts, and so the support of reuse is a constitutive requirement. Linking is rather fundamental as only the facilitation of story telling makes use of it.

Support in capturing the design process. During the different phases of a design process, lots of design artifacts are created. These artifacts give information about the result of the distinct phases and moreover the current status of a project. The availability of artifacts to others makes the process more transparent and promotes an awareness among others, whether they are directly involved or not [19], [29]. Furthermore, the clarity of group objectives and reflexivity enhances creativity, while a low awareness of what other group members are doing can lead to a slowdown in progress [25]. Besides, the capturing of data also demands knowledge about the process afterwards. In Section 2.1, the term DKM is introduced and the need for searchable design artifacts is pointed out. Designers often use cryptic filenames for design artifacts in their electronic collections, as certain projects may not feel immediately relevant [21]. Consequently, the need for proper DKM can not be seen. But, as a well-structured collection can facilitate a designers’ work, a system has to assist in that complex and extensive activity. Therefore, the system has to know the designer’s demands. The

\(^3\) The reasons are again ranked according their importance for the designers themselves.
right meta-data can foster searching for design artifacts and for that purpose, designers were asked for the attributes, which they would like to use for combing through their collections (see Table 4).

**Table 4. Attributes for searching past artifacts.**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name</td>
<td>23</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 Name</td>
<td>11</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>

In conclusion, it is necessary to provide a more or less structured overview of a design project. The reasons are *social* - raising the awareness of colleagues, *organizational* - personal or time management and *reflective* - seeing what is going on and reflecting the ideas during the process.

The big challenge in supporting the capture of the design process is providing the tools to create a clear overview of the produced material. *But how can design knowledge be presented such that the stories that have been created can be understood and, furthermore, can be found?* Does the designer need all artifacts produced during a given period of time? Should a tool make it possible to focus on some details?

**Support in linking related design knowledge.** Linking and building up a network of design artifacts assists in constructing a mental image of artifacts created during the design process. To understand one single artifact without the corresponding context can be hard and is sometimes impossible. Besides, the connections give the designer the path in which the artifacts should be read and convey the story associated with the artifacts [21] imagine, for example, reading the single images of a storyboard out of context.

In addition, consulting artifacts with their creator at early, middle and late phases assists in finding these again after some time. Two artifacts may or may not have a strong explicit connection to each other. In general, the network of artifacts and their links opens up the meaning and the importance of an artifact [29].

*But how can artifacts from one design phase be connected to artifacts from another design phase?*
Support in sharing design knowledge. Presenting design knowledge is also a conversational resource responsible for initiating and scaffolding conversations [19]. More designers have more ideas and so the sharing of one’s own ideas and discussion within a team is a promising way for getting a better outcome. According to Arias et al. [1], complex design problems require more knowledge than any single person possesses and bringing different and often controversial points of view together creates a shared understanding [...] and can lead to new insights, new ideas, and new artifacts. Vyas et al. [28] also describes this in the Resource Sharing Concept. In accordance with that, collaboration between individual designers is an essential aspect in designing and reflecting ideas. Sharing artifacts is an essential daily or at least weekly activity for the majority of designers [21] as it allows them to learn from one other, to compare ideas, to reinterpret and reflect design solutions, or to just tell a story.

In general, sharing ideas can be divided in two main activities: presentation and reflection. For presenting ideas, designers need an appropriate tool to assist them in sliding through the landscape of design ideas in a smart and proper way. Reflecting ideas in the group allows refining and writing it out in full [23]. Presentation is here the action of Reflection-in-Action [20] (cf. Section 1.1).

The main question is, how to provide a tool that gives an overview of the created design knowledge and assists in going into detail and modifying artifacts?

Support in reusing prior design artifacts. Prior design knowledge, whether produced by the designer himself, his colleagues or any anonymous designer, is extremely valued in early design activity. On the basis of this knowledge, designers’ gaining inspiration and reflecting of past processes is assisted and furthermore, designers will have an increased awareness of new trends [21].

The search for specific artifacts can be active - the designer knows exactly what he is looking for, or passive - he just wants to get some inspiration. Designers are not generally seeking specific solutions - they are seeking direction [21]. Some designers compare designing also with cooking and the design artifacts with the ingredients [12]:

"You may not like a recipe, but you like some of the ingredients in the recipe. So you take what you like, maybe add in some new ingredients and create a new recipe."

But only the appropriate combination of high-quality ingredients sets the stage for a promising design solution. Thus, the designer needs susceptibility to find the right proportion of design artifacts to let the user know the true promise of the design solution. The three factors, which should be considered, are:

- the ingredients themselves,
- the combination and
- the proportion between them.
The need for reusing artifacts in designing is indisputable. The main question is, **how to support designers in finding the right artifacts at the right time?** Is it possible to create a tool which allows the designer to be chaotic and to find artifacts in a shallow, unstructured system again anyway?

### 2.3 Tools

The last section shows an approach to how a tool can support the design process. The following descriptions demonstrate the tools and break down their functionalities and degrees of support. In the last decades, there has been a lot of research related to the support of designers in their work space. For the conception of a tool, the understanding of how designers work is essential. Several studies were engaged in the observation of the designer’s behavior in his workspace during the design process. The findings of these studies provide a basis for the tools that have been developed in the last ten years. Nevertheless, numerous tools provide a wide range of activities that can be brought to a higher level of how work can be done in a flexible, collaborative and productive manner.

**HeEditor and HeSketch.** Shirai et al. [22] presented two tools, which record the editing history throughout a design process. **HeEditor** is especially for text input, while **HeSketch** is intended for sketching. A time-slicing mechanism enables an interactive visualization of historical data in various levels of granularity. **HeSketch** offers, beside the main application window, a Canvas History Dialog window for showing the progress of the Canvas over time and a Stroke History Dialog window which stores the captured stroke data.

HistoryEnriched tools are primarily focused on capturing the history of one specific artifact e.g. text or sketches. Consequently, these tools will give additional support, particularly in creative live sessions. As the progress of design artifacts, from design ideas to design solutions, can be recorded over time, artifacts as well as ideas and whole solutions can be understood more easily.

**DEMAIS.** Bailey et al. [3] developed a sketch-based, interactive multimedia storyboard tool to support the multimedia designer in rapidly exploring and effectively communicating behavioral design ideas in the design process. This tool consists of four tool components: a storyboard editor, a narration editor, a multi-view editor and a content manager (see Figure 7). All of these components are especially conceived for the creation of interactive storyboards.

The DEMAIS' multi-view editor and the content manager support the designer in reusing earlier work. Thus, the storyboard editor assists in linking prior and current design artifacts.

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2 Multimedia Designers are those who create interactive applications for exploring multi-modal content.
Adaptive Ideas. Lee et al. [17] introduced a tool for the better usage of interactive example galleries which have been created in the wild. Adaptive Ideas is a web interface and augments a direct-manipulation Web page editor with a component for parametrically browsing a corpus of example pages (see Figure 8). The tool is composed of an editing pane, an examples gallery and a preview pane. Furthermore, it allows the user to select, present and browse design material. The pre-selection of the design material in the preview pane is based on a subset selection algorithm.

Adaptive Ideas is focused on collecting Web-content. The user is assisted in reusing artifacts mostly created by others and this implies that a sharing of artifacts in the Web-community is possible.
**IdeaSpaces.** Venkataswamy et al. [25] designed an early prototype for supporting designers in a collaborative setup for web site design. The generation and manipulation of several windowed themes allows the designer to get an overview of the design process from the very beginning to a special idea. The sample window concept consists of a research space for storing background information, a "'crazy'" idea space something like a scratch pad for fast scribbles that should not get lost, a moodboard for getting inspiration and the main idea space for creating and submitting solutions (see Figure 9). Furthermore a network view assists the designer in reflecting the generation process from some design artifacts to a final design idea (see Figure 9). Later in the design process, in the evaluation phase, IdeaSpaces supports the designer in commenting his or her own and other's ideas.

![Fig. 9. IdeaSpaces windowed themes sample: (a) moodboard (top left), "'crazy'" idea space (bottom left), research space (bottom right) and main idea space (top right). (b) Network view: capturing the design process to one specific idea.](image)

The idea behind this prototype is to create a universal concept, which can be used during the whole design process. The research space helps in reusing design artifacts, the network view allows one to link the produced material, as well as to capture the design process. Additionally, artifacts can be flagged and commented on, and states can be saved during the work.

**Quince.** Infragistics, a company creating user interface development tools, merchandises Quince, a design review tool, which helps multi-disciplined teams review, understand and collaborate [13]. The goal is to streamline the cooperating designers of their design intent. Quince consists of

- a pattern library, which allows to share UX and UI patterns including descriptions and examples with the online community,
- an example library, which provides an overview of already existing design artifacts, and
- a design board library, which gives an overview of several design concepts (e.g. several linked design artifacts with annotations).
Patterns can be explored by "user tasks", "tag relations", and in a "wire-frame" mode. Furthermore, each designer has his own corkboard for storing design artifacts and concepts, which can be shared again with colleagues. Each of them can be viewed in detail in a zoomable landscape. Here, artifacts can be moved, linked and annotated.

Fig. 10. Quince: (a) personal corkboard, (b) project-specific design library, (c) one design board and (d) a pattern description.

This tool is an example for Communication and Coordination, comparable with Adaptive Ideas and IdeaSpaces. Patterns, examples and design concepts can be shared with colleagues and the online community. Patterns can be reused and design artifacts can be linked and annotated. Quince is more to create a shared understanding of a current design problem than for capturing a whole design process.

**ConceptShare.** The web-based design tool ConceptShare from Thoughtballoons allows designers to gather feedback from colleagues and clients [24]. A concept can either be a design idea or a whole design project with several different design artifacts. ConceptShare provides an overview of the designer’s projects and some possibilities to review design ideas. New concepts including design artifacts can be added to the designer’s workspace. ConceptShare’s user interface allows to discuss ideas synchronous through chat and asynchronous through commenting, annotating and highlighting. Ideas can be compared in an alter-
nate view. Additionally, several project-specific functions such as assigning tasks to members, appointing deadlines make the coordination of projects much more easier.

![Fig. 11. ConceptShare: (a) overview of all concepts, (b) interface for discussing ideas and (c) alternate view for comparison of ideas.](image)

ConceptShare supports the synchronous and asynchronous discussion of design ideas in the web. Each designer has his own workspace and can share ideas with others. Design artifacts can only be attached to a project, linking of them is not possible. ConceptShare is a more project-specific tool, which supports the coordination of projects and their tasks.

**EDC.** The Envisionment and Discovery Collaboratory 3, developed by Arias et al. [1], is a system consisting of a table with tangible objects for urban transportation planning and community development and a horizontal electronic whiteboard for direct evaluation. The concept behind the EDC is Reflection-in-Action [20] to support users in creating a shared understanding of complex design problems (cf. Section 1.1). Fischer et al. [8] describes the EDC as an instrument for exploration of individual and social creativity through interaction and participation across a variety of dimensions. These dimensions include, for example,

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3 This prototype was applied in the context of supporting citizens in designing a transportation system for their neighborhood.
the individual and shared interaction in a face-to-face collaboration, as well as the opportunity to include people with different perspectives and from various backgrounds in the design process (see Figure 12).

![Fig. 12. Prototype of the EDC [1].](image)

The goal of EDC is to create a shared design space in which technology takes a back seat and collaboration comes to the fore. This prototype is a good example of a live surface and collaboration through new technologies.

**Caretta.** Similarly to EDC, Caretta is designed for face-to-face collaboration. The aim of this tool is to assist individual reflections and group discussions in parallel. A multiple-input sensing board is used as shared design space and several PDAs (Personal Digital Assistants) act as individual spaces. The personal space allows the user to concentrate on his own reflection without being disturbed by the others. Moreover, the flexible transition to the shared workspace offers the possibility to discuss ideas in the team immediately. Fischer [8] characterizes Caretta as an "'and'" and not a "'versus'" relationship between individual and social creativity.

The main advantage of Caretta is that personal and shared spaces are divided so that the user can act individually on his PDA, while discussions in the group are possible in the shared workspace. This enables the creation of individual ideas on the one hand, and the sharing of these those with others on the other hand. Thus, the support of sharing is given. In spite of the fact that the individual and the shared space are physically separate, the awareness of what others are doing can get lost. That is the price that has to be paid - depending on the users and the context in which it will be used, distinct design spaces can be beneficial or not.

**TEAM STORM.** Hailpern’s [11] sketching tool makes use of interactive 2D spatial maps for organizing design ideas and reflecting these. Similarly to Caretta, TEAM STORM provides an individual workspace in addition to the shared
workspace (see Figure 13). The idea behind this tool is to provide a place for collaboration and working with multiple ideas in parallel as designers have their own individual space.

![Fig. 13. TEAM STORM scenario with a shared workspace and some individual workspaces [11].](image)

TEAM STORM is another example for a supportive face-to-face collaboration tool and fosters sharing of ideas in the group.

**The Designers’ Outpost.** Klemmer et al. [16] designed a tangible interface for collaborative web site design which combines the affordances of paper and large physical workspaces (see Figure 14). The system allows the user to add notes to the digital space that have been written with a standard pen. Moreover, it supports digital ink annotations and the linking of digital artifacts. Two extended versions of the Designers’ Outpost give additional functionalities to the tool. One provides a timeline for accessing the design history [15], the other fits to the designers’ need for effective remote collaboration [6] and enables teamwork even if current location is not the same.

![Fig. 14. The Designers’ Outpost, a collaborative system for web site design [15].](image)
This tool is particularly designed for web site design in a collaborative setup. Similarly to Caretta and TEAM STORM, it provides a shared space as well as individual spaces, and thus allows users to share artifacts with the group and to discuss them. Moreover, one extended version of the Designers’ Outpost allows to capture the history of a live design session with highlighting of the modified artifacts.

**Face Poiesis.** Anzai and Nakamura [18] created a project called Face Poiesis. This interactive art project reuses numerous facial images for producing a new unique abstract face image. Figure 15 shows the design space and one result produced by using the tool.

This kind of work is different as it is more experience-oriented and playful. However, reusing prior artifacts remains of central importance. The combination of different artifacts opens an endless idea space - in this case, for the user. Hence, this project can also be seen as a meta-project of how the reuse of design artifacts can be described.

**Conclusion.** In the last section we present a variety of existing tools currently developed for supporting designers in their creative work. Each of the tools is mainly focused on a specific design space and specific activities. Table 5 shows that all of the tools support at least one of the requirements introduced in Section 2.2. Except DEMAIS and the HistoryEnhanced tools (HeEditor and HeSketch), all tools assist in sharing design artifacts and in supporting collaborative environments. The most powerful tools are the extended versions of the Designers’ Outpost and Quince. Compared with the requirements of Section 1.2, only the reuse of design artifacts is less maintained by the Designer’s Outpost and the capturing is missing in Quince. DEMAIS, Adaptive Ideas, Quince and Face Poiesis convey the reuse of prior artifacts. The first three tools are window-based and the last one is an impressive example of playful interactive art.
Table 5. Existing tools and their support of the requirements.

<table>
<thead>
<tr>
<th>Tool</th>
<th>capturing</th>
<th>linking</th>
<th>sharing</th>
<th>reusing</th>
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<tbody>
<tr>
<td>HeEditor and HeSketch</td>
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<tr>
<td>DEMAIS</td>
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<td>Adaptive Ideas</td>
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<td>Idea Spaces</td>
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<tr>
<td>Quince</td>
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<td>ConceptShare</td>
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<td>EDC</td>
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<tr>
<td>Caretta</td>
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<td>TEAM STORM</td>
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<td>The Designers’ Outpost</td>
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<td>Face Poiesis</td>
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Figure 16 shows that all of the existing tools, except Quince and ConceptShare, are developed for only one specific project or one live session. Quince and ConceptShare enable to manage several different projects.

![Diagram](image)

**Fig. 16.** Existing tools arranged in the dimensions *number of persons* to *number of projects*. 
According to Figure 17 Caretta, TEAM STORM, EDC, and Face Poiesis can be categorized as live surfaces. The Designers’ Outpost with the global timeline extension is an example of remote interactions. Other tools like HeSketch, HeEditor and DEMAIS are more appropriate for ongoing tasks which can be executed in the personal space. ConceptShare is in-between remote interaction and communication and coordination. IdeaSpaces, Adaptive Ideas and Quince, as asynchronous tools, are examples of communication and coordination.

The literature (see figure 17) shows that there is relatively little support of shared surfaces, especially for ongoing tasks. As shown in Table 5, most of the tools are more focused on supporting collaboration than on assisting the reuse of design artifacts. Section 2.2 introduced the three different sources of inspiration, artifacts created by the designers themselves, their colleagues or any anonymous designers. Therefore a comprehensive and consistent organization of design artifacts during the design process is the base for providing a fertile ground for the designer’s work.
3 Future Work

The last section gives an impression of what DKM is, which activities were done in early DKM, how these can be supported and how the current tools foster this. The focus of this section is to go from theory into practice and to give an idea of the potential for supporting designers in organizing design knowledge with the appropriate technologies.

3.1 Approach

Designers are known for being chaotic [14]. Keeping in mind that one of the main problems is remembering the location of design artifacts, structuring is necessary. Spatial grouping or categorization are some ways to give the chaotic design space some structure. But overall, the most important thing is to allow the designer to find his own transition between completely unstructured and strictly structured design space. Giving too much structure can inhibit some designers from working in their natural style [25].

The future work will be in the context of the project Blended Interaction Design [9] and is therefore concentrated on supporting interaction designers in their use of digital artifacts like post-its, sketches, sketchbooks images or videos. Geyer and Reiterer [10] presented an approach of a cross-device spatial workspace for supporting collaborative design. Therefore, four design principles have been defined - especially the first three will be important for the future work:

- Shared workspace as virtual pin board,
- Spatial visualization of artifacts,
- Cross-device interaction and
- Physical affordances.

Shared workspace as virtual pin board. According to Table 2, almost all of the reasons for retrieving artifacts are social activities. Therefore a setup has to fit the designers’ needs of working in a group to discuss and reflect ideas.

"[...] making creativity more open and social through participatory processes will increase positive outcomes while reducing negative and unanticipated side effects [23]."

Spatial visualization of artifacts. Providing interactive visualizations, which offer the designer the flexibility to make adjustments e.g. in the spatial location or the size of their artifacts will enrich the activity of exploration.

Cross-device interaction. A landscape of design artifacts can grow over time. A whole room with tabletops and displays can be adequate to the large amount of design artifacts.

In general, most promising for supporting the methodic design practices in a way appropriate to designers is to understand their motivations, rewards and needs.
References