

Idea Generation Techniques among Creative Professionals

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Abstract

The creative process has been a key topic research over the past century, but it wasn't until the last decade that creativity became a hot topic of research in the HCI. It is an important commodity to businesses and individuals alike spawning numerous research studies in business, psychology and design. However, it wasn't until recently that researchers became interested in developing technologies to support creative behavior. This article outlines the role of creativity in design from the designer's perspective, provides a model for the creative process and provides a foundation and direction for future creativity support research by identifying nineteen idea generation techniques utilized by creative professionals.

1. Introduction

Creativity is an extremely important facet of life and is a feature of many of the tasks we do every day. It can occur in a multitude of situations ranging from work to pleasure, from artistic portrayals (music compositions, new media art) to technological innovation [1]. Most texts regard creativity as a beneficial process in an organization and it has been said to offer a competitive advantage in the design processes [2]. Although creativity can be hard to measure, it is understood as a vital area of research in a wide variety of disciplines [3].

Creativity and cognition research has focused upon issues such as creative cognition, creative media and technology, and the impact of technology on practice [4]. Specifically, Human Computer Interaction research has focused on developing technologies to better support the cognitive process of creativity. Much of the research in the field has been focused on highly formalized idea generation practices during group design sessions, without placing these sessions within the larger context of design [5; 6; 7; 8]. The main focus of these studies was on brainstorming techniques; often used to increase creativity in a product development environment.

Brainstorming is an important idea generation technique, however many other strategies have been identified. These include, but are not limited to: free association, mind-mapping, divergent thinking and

sketching. While many idea generation techniques have been identified, there have been few studies to date that have analyzed the frequency and motivation of use of idea generation techniques as a whole [5; 9]. It is also unclear what techniques designers, in particular, deem most important in their overall design process.

The purpose of this study was to understand the creative process as viewed from the design community, understand how technologies can assist these processes, develop a model for the idea generation process, gain insights on current strategies used to generate ideas and establish a research initiative for future creativity research. This study resulted in greater knowledge of the design process, a new design focused idea generation model and a total of nineteen different research directions that need to be explored in order to fully support the creative processes of the design community.

2. Related Work

2.1. Creativity Models

Creativity research has long tried to synthesize its results through the elaboration of models of creativity. These models attempt to provide a common framework for further empirical research and aid in the design of creativity support tools [10].

One of the most influential early models of creativity was proposed by Wallas [11]. He divided the creative process into the four distinct phases of *Preparation, Incubation, Illumination and Verification*. *Preparation* involves gathering knowledge and understanding the problem. In the *Incubation* phase, the subconscious takes over, mulling over the problem without deliberate concentration. *Illumination* occurs as a sudden flash of light, when the solution has been discovered. *Verification* consists of evaluation of the newly formed idea.

From this four stage creative process model, a wealth of new models was born. Osborn broke the creative processes into two main phases of *Idea Generation* and *Idea Evaluation*, decreasing the emphasis on incubation [12]. Amabile decided to add a step with the five stages of *Problem and Task Presentation, Preparation, Response Generation, Response Validation and Outcome* [13].

Shneiderman took a different approach classifying the types of creativity, and the creators, into the divisions of *Inspirationalist*, *Structuralist* and *Situationalist* [10]. Arguing that creativity support tools should provide support for the different processes resulting from differing creative personality types. He also developed a four stage model of *Collect*, *Relate*, *Create* and *Donate*; placing a large emphasis on contributing the results of a creative act to the larger community.

Warr and O'Neill synthesized the main creativity models into a unified model of *Idea Generation*, *Problem Preparation* and *Idea Evaluation* [14]. This *Generic Creative Process* model stressed the similarities of all previous models and attempted to reach a uniform consensus.

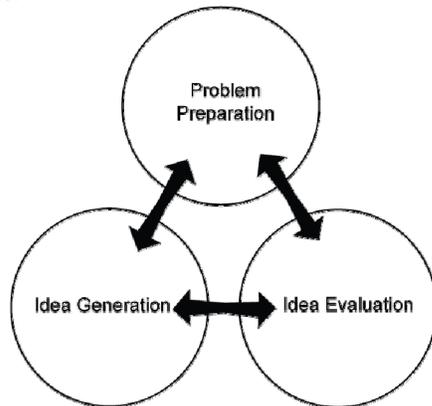


Figure 1: Generic Creative Process Model
Adapted from Warr and O'Neill [14]

While these models have been largely adopted and used in the creation of creativity support tools, there is some skepticism regarding the simplicity of current creativity models. Most of these models note that they are not intended to be followed in a discrete linear fashion [14]. However the representations are always portrayed in a static, linear fashion cycling through distinct stages of the creative process. Many authors have rejected this distinct and limited representation [15; 16; 17]; arguing that creativity is a “dynamic blend of processes that co-occur, in a recursive way throughout the work” [15]. These same authors call for a better understanding of the creative process, and a better representative model. While this paper does not attempt the rigor of a cognitive process model, an understanding of existing models is useful.

2.2 Cognitive Process Models

During Guilford’s address to the American Psychological Association in 1950 he noted the four important steps of the creative process. However, he felt the analysis was superficial from a psychological point of view because these models did not explain the mental operations that occur [18]. He proposed a new program of research focusing on the identification, measurement and validation of creativity-relevant abilities [19].

From this research, many new models were developed, stepping away from the basic four process model to more

complex models involving sub-processes [20; 21; 22]. These models include such sub-processes as: the investigation of problem finding, problem formation and problem redefinition [21; 23], sub-processes involving the dissemination or combination of information or even the process of generating ideas through a random process [24]. Some authors have proposed models that organize the sub-processes involved. Mumford and colleagues [25] specified a dynamic model based off of a specified set of core processes (problem construction, information encoding (and retrieval), category search, specification of best fitting categories, combination and reorganization of category information to find new solutions, idea evaluation, implementation of ideas and monitoring. The dynamic model allowed for cycling between different processes as deemed necessary during the creative process.

These models address the complexity involved in the creative process. However, the complexity of these models makes them difficult for wide spread use and particularly difficult to explain to software developers. Although these models provide a good theoretical background and a deeper understanding of the cognitive mechanisms underlying creativity, they do not necessarily aide in the understanding of how technologies can be developed to better support the creative process due to their complexities.

2.3 Idea generation and creativity

Idea generation, or the act of generating novel, applicable ideas, is the activity most frequently associated with creative problem solving (CPS) [26]. As the ideas generated in this stage are used throughout the creative process, taking the idea generation phase seriously is crucial to the success of the CPS process [27; 28; 29; 30]. Research has attempted to increase the number of ideas produced by creative professionals because a direct relationship between the number of initial ideas produced and the quality of the final idea has been established [12].

Osborn stated that out of the entire CPS process, individuals are likely to experience the greatest difficulty during idea generation [12]. This is partly due to the fact that it is difficult for individuals to suspend judgment when formulating ideas. Individuals tend to focus more on the quality of the idea and the practicality, as opposed to focusing on generating as many ideas as possible [13].

The creative process is also inhibited by people’s inability to entertain ideas that violate previously held assumptions, rules, and conventions [31; 32]. In other words, individuals must be able to break associations and patterns of thoughts in order to create new relationships that didn’t previously exist. Additionally, the idea generation process is heavily influenced by intrinsic motivation [13; 33]. This implies that creative professional must be given both the tools and the incentives to produce creative works.

2.4 Idea Generation Techniques

In order to help individuals in the idea generation process, researchers have identified methods to stimulate creative thought, generate more ideas, and expand on the solution space [34; 35; 36]. These techniques categorize the methods used by creative professionals in pursuit of the creative end product. Idea generation techniques consist of a mixture of artificial formal techniques and classifications of naturally occurring design practices.

Smith [37] identified 172 idea generating techniques such as Osborn's [12] Brainstorming and SCAMPER (substitute, combine, adapt, modify, put to other use, eliminate, rearrange). Smith then distilled these techniques into a smaller set of *active ingredients* that represent the core functionality behind each technique, similar to active ingredients in pharmaceuticals.

Although many techniques have been identified, there are a limited number of studies that have addressed the frequency of use of idea generation techniques and their applicability during constrained situations, namely Lin and colleagues [5]. Knowledge of the relative importance of these techniques is crucial for creativity support tool design, as only a few of the techniques are used frequently in practical design situations.

2.5 Technology for idea generation

The aspiration of most creativity research is to inform the creation of tools to improve the efficiency of the creative process and the quality of the creative results [10]. A number of researchers have proposed standards and implications for the design of creativity support tools [38]. Researchers have suggested implications for the design of creative support systems. For example, tools have been developed to aid: fine arts collaboration [39], sketching [40], creative problem solving environments [41], and distributed scientific communities [42].

Along these lines, Shneiderman built upon his three categories of creativity by recommending ways in which technology can enhance the creative process of the individual [10]. For example, he suggested that *Inspirationalists* would benefit from technology that emphasizes free association, helps the user understand previous work and orients the user to visual techniques. *Structuralists* are aided by standard software packages that allow for the organization and structuring of existing ideas and benefit from repositories of previous work. *Situationalists* could be aided by advanced communication mechanisms, allowing them to share ideas and design documents freely.

Going beyond implications for design, a number of tools have been constructed with the goal of improving the creative process. The Electronic Paper Napkin helps designers retain the ambiguity in their designs and attempts to intelligently recognize what is being drawn [40]., SILK is an interactive idea capture tool designed to facilitate rapid prototyping. This tool aids designers in building rapid prototypes of interfaces through a unique sketching

interface [43]. Tools such as IdeaTree and IdeaFisher provide the user with associative linking; however a study of these tools found them insufficient for practical use [9]. While a wealth of these tools has been developed, at present they are not utilized within industry and the current study is focused on inefficiencies in current practices in design.

3. Description of study

The purpose of this study was not to determine what was unique to product design but rather to learn about current practices in the field to guide and develop tools to better support those practices. We interviewed 10 designers involved in the product design process. Nine of these designers were from three different companies and one was a freelance designer. Seven of the interviews were conducted in the designers' project space, which facilitated the observations of artifacts and allowed us to observe their working environment. The other three interviews were conducted over the phone due to geographical constraints.

3.1. Who was interviewed

Two of the three companies we observed were large corporations with internal product development groups. These two companies were situated in the service and electronics industries. The other company we observed was a design firm that is typically contracted by outside clients to design end consumer products.

Years of Experience in Design	# of participants
Less than 5 years	2
Between 5 and 10	3
Between 10 and 15	3
Between 15 and 20	1
More than 20	1

Table 1: Designers' Professional Experience

Educational Background	# of participants
Engineer	5
Industrial Design	4
Product Design	3
Occupational Health	1
Architectural design	1
Graphic design	1

Table 2: Designers' Educational Background

The designers interviewed represented a range of professional design experience levels (Table 1) and came from diverse backgrounds (Table 2). Some of the designers had professional background in many industries such as product design and occupational health or engineering and industrial design. Therefore, the background of the participants in Table 2 do not add up to the number of designers that actually participated in this study.

Due to the diverse background of our participants, much of what was observed during this study is not necessarily unique to product design but probably draws from the broader traditions of design including (but not necessarily limited to): architectural design, industrial design, graphic design and engineering design.

3.2. What was asked

After inquiring about the participant's design experience and professional background, the participant described their creative process from project definition to project completion, explaining what happened at each stage of the process. The participant was then asked to provide the interviewer with an example of a recent project. Examples of the projects discussed include next generation lawn sprayers, automobile interiors, household appliances, computer input devices and consumer packaging.

The participant was then asked to describe techniques that were used to generate the initial design concepts for that project, or techniques that they prefer to use in general. After the techniques had been identified, the participant was asked about the benefits and limitations of each technique. The participant was then asked to show any relevant examples that he or she produced during the process and explain its significance.

4. Design cycle model

One of the first questions participants were asked was to describe their creative process. In reply, almost every one of the designers described their *entire* product development cycle from idea creation to client presentation. In other words, the designers viewed their overall design process as a creative process, referencing how it is important to be creative throughout the entire cycle.

Previous models of creativity focus mainly on the idea generation process and do not differentiate ideas from final product solutions (see the Creative Models and Cognitive Process Model sections). Following the responses from designers, the following model makes the distinction between the design cycle and the idea generation process. This model aimed to merge the simplicity of the creativity models with the dynamic attributes of the cognitive process models developed by Mumford and associates [25].

The design cycle consists of three phases: *idea generation*, *implementation* and *evaluation*. These phases are represented as distinct circles due to the deliberate separation of the design cycle by time management practices. Under a strict deadline, designers must ensure that they place clear boundaries between the phases in the cycle, ensuring that the product is delivered to the client on schedule. When the designer leaves the idea generation circle he or she has an idea that she is ready to implement. Following the completion of the solution, the designer evaluates the solution and its representation. This evaluation leads to a new insights utilized in the next iteration of the design cycle.

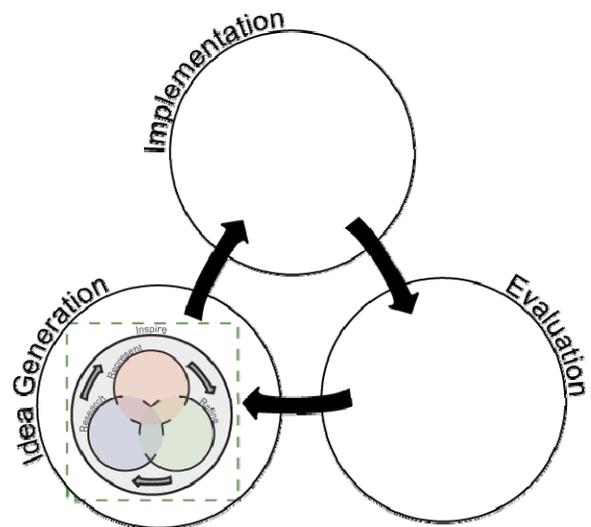


Figure 2: The Design Cycle (for inset see Figure 3)

4.1. IR³ Idea Generation Model

Focusing on the idea generation phase we discover the IR³ Idea Generation Model (Figure 3). This model describes the fluid cycle of idea generation utilized by designers during the conceptual stage of the design cycle. Within this model the designer generates and refines ideas, eventually leaving the circle with an idea that is ready to implement and moving to the next cycle in the overarching design cycle.

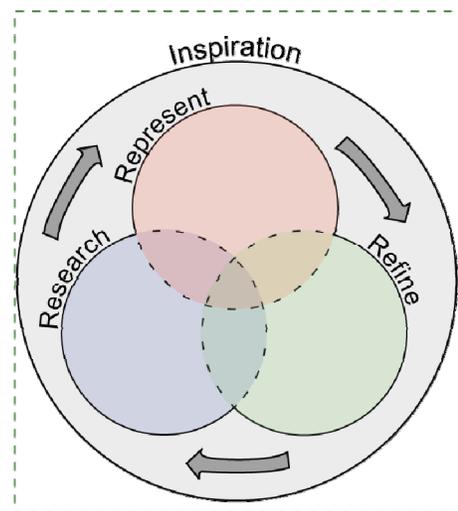


Figure 3: IR³ Idea Generation Process Model

The model consists of three non-distinct categories: *research*, *represent* and *refine* all encompassed by the category of *inspiration*. Designers search for *inspiration* throughout the idea generation process in order to spark the formation of creative solutions. The process begins with *research* into the problem domain which will generate a multitude of diverging concepts. Once initial concepts are formed in the research phase they are physically *represented* in an externalized form. When the representations are solidified the designer begins to

evaluate and *refine* the concepts eventually leading to a convergence of concepts. The refined, validated concepts then guide further research and knowledge acquisition starting the process anew. The cycle by no means maintains a constant speed of rotation. During the idea generation process a concept may be *represented* by a quick sketch or may be discarded during a split second *refine* cycle. (A detailed explanation of each stage occurs in the Categorization of Techniques section.)

This model depicts the transference of concepts and not ideas. This subtle distinction is emphasized to explain the initial problem finding exploration, within which the designers attempt to solidify an ill-defined problem. Thus a concept represents either a working definition of the problem or a potential solution.

5. Idea generation techniques

The interviews were analyzed by the authors and every reference to a distinct idea generation technique was documented. This extensive list was then condensed by conglomerating similar ideas into broader categories. For example all references to emailing, instant messaging or asking someone a specific question were grouped into the *consultation* category. These categories were carefully refined until agreement was met between the authors.

The list of idea generation techniques was condensed in order to facilitate ease of comprehension and application among creative cognition professionals. In contrast, Smith's research [37] resulted in the identification of 172 idea generation techniques. Due to the exhaustive, meticulous nature of the list it is difficult to apply during the development of creativity support tools.

The idea generation techniques identified are briefly introduced as follows:

1. Role Playing: Role playing involves designers acting out scenarios. These scenarios are often ones that the designers observed during the research phase of the design process when they participated in user research. This technique is a tool for both team-based ideation and communication to users and/or clients [44; 45].
2. Active Search: Active search refers to designers hunting for a particular solution. This hunt could range from a web search for images of current vacuum cleaners to searching through books, magazines, newspapers, etc. to find the demographics of a particular population [46].
3. Attribute List: Attribute listing refers to taking an existing product or system, breaking it into parts and then recombining these to identify new forms of the product or system [47; 48].
4. Brainstorm: Brainstorming involves generating a large number of solutions to a problem (idea) with a focus on the quantity of ideas. During this process, no ideas are evaluated; in fact unusual ideas are welcomed. Ideas are often combined to form a single good idea as suggested by the slogan "1+1=3" [12]. Brainstorming can be used by groups as well as individuals [49].
5. Collaborate: Collaboration refers to two or more people working together towards a common goal [51]. Designers often work in groups and co-create during the entire creative process.
6. Concrete Stimuli: Concrete stimuli are used when designers want to gain new perspectives on a problem by manipulating physical materials. This could be looking at paint chips, feeling different material textures or physically maneuvering objects.
7. Critique: Critique refers to receiving input on current design ideas. This could be collaborative such as receiving a design critique from a colleague or individuals critiquing their own ideas (either systematically or intrinsically). This technique often spurs new thought by finding solutions to design flaws within current concepts.
8. Documenting: Documenting refers to designers writing down ideas (physically or electronically). This includes journaling, writing stories, and taking notes.
9. Expert Opinion: Designers often elicit opinions from experts to identify potential problems with products or services before more comprehensive evaluations. This occurs when they are looking for an answer to a problem that is outside their domain knowledge or when they want to test a new idea [52; 53].
10. Empathy/User Research: User research requires the designer to observe people in everyday situations in order to develop empathy for them. The methods used to conduct this type of research is founded in ethnographic research methods such as observations, field studies and rapid ethnography [44; 54].
11. Encompass: Encompassing is an inspirational technique which involves designers immersing themselves in information relevant to the current project.
12. Forced Analogy: Forced analogy involves comparing the current problem with something else that has little or nothing in common in order to gain new insights and results. This technique often generates ideas for new areas of research. [55; 56]
13. Incubate: Incubation refers to stepping back from the problem to let the subconscious mind work [11].
14. Passive Searching: Passive searching refers to designers looking through material (web, magazines, books) for inspiration without searching for a particular solution to a problem. They are simply looking for inspiration.
15. Prototyping: Prototyping, in this study, refers to a low-fidelity model of an idea. These models can be created with any type of material (paper, clay, etc.) as they are only used to conceptualize a thought.
16. Reflect: Reflection occurs when designers review their previous work (sketches, documents, prototypes, etc.)
17. Sketching: Sketching refers to a rough drawing of an idea.
18. Socializing: Socializing refers to talking with others about topics unrelated to the current project.

19. Storyboards: Storyboards are a way for designers to represent information gained in the research phase of the design process. Quotes from the user, pictures, and other relative information are placed on cork board, or a similar surface, to represent a scenario and to help understand the relationships between design ideas. Designers often post information about users using as little detail as possible to allow for interpretation of information [57; 58].

Technique (% Referenced)	Research	Represent	Refine	Inspire
Active Search (100)	x		X	x
Attribute List (40)		x		x
Brainstorm (80)	x	x	X	x
Collaborate (60)	x	x	X	x
Concrete Stimuli (2)	x			x
Critique (90)			X	x
Documenting (60)	x	x		x
Expert Opinion(90)		x	X	x
Empathy/ User Research (80)	x			x
Encompass (50)				x
Forced Analogy (5)	x			x
Incubate (30)				x
Passive Searching (60)				x
Prototyping (70)		x		x
Reflect (60)	x		X	x
Role Playing (10)		x		x
Sketching (100)	x	x		x
Socialize (30)				x
Storyboarding (40)		x		x

Table 3: Categorization of idea generation techniques

5.1. Categorization of techniques

After the 19 idea generation techniques were identified, they were categorized and placed into the IR³ model according to what the technique was used for (inspiration, research, representation or refinement). The techniques were placed into the boundary areas of the model if the technique served many purposes. Therefore some techniques are placed on the boundaries between two categories or in the middle of the model if they encompass all aspects of the ideation process, see Table 3. A detailed description of the categories and the explanations of technique placement are described below.

5.2. Inspiration

As previously mentioned, inspiration can occur at any stage within the idea generation process. Many designers mentioned solely inspirational idea generation techniques such as: *passive searching*, *encompassing* themselves in the material, *socializing*, and *incubating*. Passive searching refers to searching without a particular concept in mind. In particular they search to, “Get inspiration, (when you) don't even know what you are looking for”. Many designers reported searching through magazines, web sites, and

books. Designers reported checking web blogs on a daily basis. Many designers also said they frequently search on the internet, “The internet is obviously a god-send. There are a few good websites that people frequent around here. (We) Spend time just looking through ideas.”

Designers also reported immersing themselves in information relevant to the current project, “It helps me to be really physical. You took photos, you took video. Maybe you built some prototypes. But you try to get it up in your space and spread it all out.” Designers reported going into their project space and reflecting, looking at all of the information and “finding out what is really important”.

Another method designer's use is to *socialize*. Socializing refers to talking to someone about anything unrelated to the project at hand such as the weather, sports or politics. This allows them to clear their mind for new ideas to immerge.

Finally, designers *incubate* to find inspiration or let information ‘sink in; Some incubation methods mentioned by designers were taking showers and going on walks.

5.3. Research

During the research phase of the idea generation process, designers try to gain additional knowledge to help them identify potential solutions. This acquisition of knowledge could include anything from user research, to active web searches, to reflecting on previous work.

In this investigation, designers reported the necessity to have upfront *empathy* with the users. In order for designers to achieve empathy with their users, they must conduct *user research*. Although designers might have a clear audience in mind, they often use *forced analogies* to develop a larger research area. For example, one designer was developing a new interior cab design for a commercial truck. In order to develop empathy for the user, the designer interviewed people who lived in small spaces such as small houses and semi sleepers. This forced analogy allows designers to research a broader area and gain additional knowledge.

In addition to the upfront user research, designers often *reflect* on their previous work. This work often comes in the form of pictures, physical prototypes, reports, sketches, etc. Designers can also perform an *active search* where they search for particular information. For example, if a designer is designing a new water bottle they could perform a web search for relevant pictures of water bottles or names of manufacturing companies. Although this type of search could take place in the web, it could also be performed by looking through books, magazines, newspapers, etc.

Sketches or *documentation* (physical or electronic) is also utilized during the research phase. The designer sketches possible solutions as well as documents his or her journey by journaling (writing stories/ notes), “Sometimes the best way for me to think is to sketch... to sketch and to write.... 90% of my notebooks is stuff I'm thinking... (it helps me) organize my thoughts.” Designers often use these sketches and document to generate ideas in the next phase

(represent), “Sometimes I get to the best sketch by writing, sometimes I get to the best story by sketching”.

5.4. Represent

During this represent phase of the idea generation process, designers use physical objects to represent their design ideas. As previously stated, *sketching* and *documenting* are both used during the representation phase of the idea generation process. However, in this phase the designers use sketching and documenting as a way to conceptualize their idea, “It helps other people understand your idea. It gives them something to react to”. Another designer stated that they liked to communicate their ideas through *acting* them out. This allows designers to properly communicate an idea to others when they cannot explain it by sketching and writing. *Word lists* also provide a way for designers to illustrate their ideas. When using word lists, designers list important features that should be included in the design. Word lists can include aesthetic as well as functional elements of a product.

Storyboards are also used by designers as a way of displaying knowledge gained during the research phase. Storyboards usually include information about users researched in the research phase. The designers represent these individuals by including pictures and a few key pieces of information that they learned during their visit

“Quick and dirty” *prototypes* are also created in this phase to manifest their ideas by using materials such as foam core, paper, Legos™, and Play-Doh™. Prototyping in the representation phase should not be confused with prototyping in the later phases of the design process as it is only used to represent a rough idea and not a finalized product (low versus high fidelity prototypes).

When designers need to develop a product outside their area of expertise they often *elicit expertise* from others. The designers usually either search for an answer to the problem or a “spark that helps them form the answer”.

5.5. Refine

The final phase in the idea generation process is the refine phase. In this phase, designers converge ideas based on evaluation of the concepts. This evaluation could be a formal process through such as a design *critiques* from another individuals, or they could be informal critique from the individual such as having the notion that, “this idea won’t work”. The number of ideas is normally reduced in this phase as they weed out ideas, but by critiquing these alternatives they gain new insight. Additionally, designers often *reflect* on previous designs, and *actively search* for comparisons during critiques.

5.6. Co-Creation

There are two idea generation techniques that have yet to be discussed, *collaboration* and *brainstorming*. These two techniques appear in the middle of Figure 3 because

they occur in all areas of the idea generation process: research, representation and refine. *Collaboration* refers to working with another individual to actively generate ideas. One designer described collaboration as, “sitting down and talking about it, seeing what seems to resonate, creating a loose construction of ideas in an informal setting.” This could occur during research by trying to identify possible research paths, discussing the ideas generated during the representation phase or by reflecting on the concepts created with another person.

Brainstorming is one of the most popular techniques used by designers. This is directly reflected by the 80 percent of the designers in our study who mentioned brainstorming as an idea generation technique. In a brainstorming session, designers create as many ideas as possible in about an hour session. Within these sessions the individuals go through many cycles of the idea generation process by researching what others have presented, representing their own ideas, intrinsically critiquing the ideas in order to develop new ideas.

6. Design Implications

Designers were not only asked to mention the techniques they use, but also discuss the limitations of these techniques. The rest of this section will discuss these limitations and offer implications for future creativity support tools.

6.1. Support Group Collaboration

“A lot of what we do is co-creation, (we are) building things together”

Most of the designers interviewed worked in a corporate setting, so they were almost always co-located with their affiliates. This is often useful as they critique colleagues design ideas, collaborate on products and socialize to inspire new thoughts. Although these things are easy to do when people are in the same location, it is difficult to replicate this type of community when people are distributed or have unusually busy schedules. Designers mentioned struggling to communicate design ideas when they were working with team members that were dispersed throughout the city, state, country and world. Although briefly mentioning collaborative tools such as wiki’s and video conferencing, they immediately dismissed these technologies because their needs were never met. For example, one designer complained that sometimes files would be saved over on a wiki because no one knew who had the most up-to-date file or who made the last revisions. They also complained that video conferencing was inefficient, they liked the privacy of telephones (people couldn’t see what they were doing).

Due to the technology-designer mismatch, designers often revert back to old technologies such as emailing and telephones. They feel these metrics are more effective at communicating and sharing ideas. Software is needed that enables people that are distributed to have the same

resources as those that are co-located (automated design critique, built in social channels, and collaboration tools that allow easy exchange of both ideas and file sharing).

6.2. Elicit expertise

Almost all of the designers that were interviewed mentioned eliciting expertise at some point during the design process. They claimed to utilize this technique when the problem was outside of their domain knowledge, when they were looking for a spark for an answer, and when they wanted to test a new idea. Although designers established the necessity of eliciting expertise, they outlined the difficulties of finding the right person to contact. One designer stated, "we have internet tools that are internal, you can go to people pages and see things about a person and read up on them, but in my experience the most useful thing is just word of mouth." This shows there is some added benefits (both trust in the system (person) and ease of information access (who to contact)) of addressing individuals you know as opposed to using these online information pages.

Although in most cases asking a colleague first hand is convenient, it is often difficult as designers work odd hours and are constantly traveling. When one designer was asked how he/she determines who to contact when expertise is needed they replied, "more often than not the first thing you want to do is just email the whole office, or the whole company. You say, 'Has anyone worked on a project about open carousels or on a project that has to deal with injectable devices.' You want to throw that out there so you can get names of people in the company to talk to them face-to-face." When another designer was asked how they elicit expertise they stated, "I don't like sending out general emails because there are so many general emails and there is a lot of time wasted so if I can avoid it, I do."

Software needs to be developed that aids designers in finding the expertise they need for a particular design problem. Future research should focus on understanding the problems with current online, internal, tools and the information cues used by contacting a colleague face-to-face (how they know the expert, what projects they have worked on together in the past, etc).

6.3. Re-use design knowledge

During the interview process, 60% of the designers queried mentioned reflecting on their previous work. Since all of the designers mentioned sketching, 60% mentioned documenting, 80% mentioned user research (including taking photos, videos and notes) and 70% mentioned making low fidelity prototypes, the need for a proper storage and retrieval system of design knowledge, at both the individual and group level, is greatly needed. Designers often cited the poor structure of their current electronic storage devices. At the individual level, designers need to have a proper filing system that allows them to reflect on previous work without any limitations. Although this is

already a challenge at the individual level (creating key words, making information readily accessible) it becomes even harder at a group level.

Designers often mentioned titling files with ambiguous names such as CellPhoneModel2.sldprt. The problem with this type of filing system is it makes file recognition from other colleagues incredible difficult. In addition, designers not only want to have design knowledge of ideas generated, they want to know about deliverables and about company expectations. When asked about what types of information they reflect on during design, one designer stated, "In the early stage it could be trying to figure out the right avenues to do research in. In the later stages it is more important to learn about deliverables and how they can be communicated. (For instance) what tools were used... what obstacles had to be overcome..."

New technologies are needed to aid in design knowledge reuse. The system should be easy to implement (aka not having to scan in all sketches) and should be easy to search. Not only should generated ideas be stored, but also deliverables. The information should have several keyword search mechanisms such as by company, product designed, colleagues who worked on the project, etc.

6.4. Supporting active search

There were two types of search tasks mentioned during the interviews: active and passive. Designers mentioned using active search when they were looking for a particular solution. However, one designer summed up active search problems best when they said, "I find the internet really hard to use from a design standpoint. (AKA) Find the answer to our design problem through Google™." For example, "If what you are after is not necessarily about bathroom soap products, it is hard to find the keywords to define the projects that are relevant for the content, for the types of deliverables. You never really find easily what you are looking for. You have to already know what to look for."

There are two types of problems associated with active searching: the user cannot find the information or the information is simply not available. Not being able to find the information is a problem that can be addressed in part by encouraging designers to participate in embedding semantic knowledge on the web, for example by tagging information sources with relevant (design) keywords. For example, designers mentioned they frequently visited blogging sites. If the designers found a blog that would be interesting for someone working on a cleaning product, they could tag the blog with the appropriate key words. This type of methods could be used not only on blogs but websites, pictures, magazines, books and other documents. Although seemingly simple, this type of group tagging activity could greatly benefit the design community.

The second problem with active search is if the information is not available. Often times designers search for design solutions to a particular problem and are unable to find an answer. It is not necessarily the case that no one has ever tackled the problem, but the information is not

readily accessible. This type of problem could be addressed by an expertise search engine. If someone had worked on a similar problem they could offer new insights.

6.5. Supporting passive inspiration

Inspirational techniques are often times very insightful for designers. Half of the designers mentioned encompassing themselves in material that is related to the project such as pictures, notes, similar products etc. There are many benefits to these techniques. One designer stated that it helps them “be really physical. You took photos, you took video. Maybe you built some prototype. But you try to get it up in your space and spread it all out.”

When working on a design team that is co-located, this activity is extremely easy; there is one project space where the information is stored. On the individual level this is also easy, as long as the designer is in the same location as the design material. However, if the designer leaves to travel or the group is dispersed, this space is no longer useful.

Software that supports the replication of these project spaces is needed. A dynamic digital picture frame could be displayed in each of the dispersed groups work space as a means of replicating this concept. As designer members added new pictures to the design folder, the picture frame would automatically update. This would allow design team members to see new pictures, notes and ideas easily.

7. Conclusion

Creativity research has been conducted for almost a century and yet new findings are still being reported. This study has attempted to better understand the creative process of professional designers in order to improve creativity support tools. The authors realized the importance of creativity throughout the design cycle and reflected this in the creative model of design. Additionally, in order to deepen the understanding of the idea generation process among creativity support tools designers, the IR³ model of idea generation was developed, emphasizing the importance of non-distinct phases and the cycle within a cycle concept. The authors also expanded the creativity literature base by providing new insights on the idea generation techniques used by designers. Finally, a research initiative for future creativity support tools was established based on the limitations of current instruments. Although only a small sample was surveyed, inferences can still be made to lead the design of future creativity support tools.

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