Reflections on designing in the wild: How Theories of Design Information Manifest in Practice

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ABSTRACT

Information acquisition, utilization and communication are integral to the design process, but systematic investigation of information behavior is complicated by its variety and the ways in which designers engage with information throughout the design process. Our previous work developed a theoretical framework to categorize the various types of information used during the design process, known as the Information Archetypes Framework. This paper explores how these information dimensions manifest in design practice, as reflected on by experienced practicing designers. Deep qualitative analysis of eight interviews with practicing designers revealed that the designers intentionally adapt their behavior to match situation specific needs, and navigate the tensions between information dimensions through trajectories and loops.

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INTRODUCTION

From early fundamental theories on how individuals generate creative thought (Wallas, 1926), to more recent explorations of how designers can use information technology to perform large-scale searches of the solution space (Martin, 2012), information has played a crucial role in how we understand the science of modern design. The very act of design itself is said to center around the transformation of information from the environment into actionable knowledge that drives the intent behind design activities (Mistree et al., 1990). The way that designers engage with information during the design process is as varied and dynamic as the process of design itself. Thus, we consider design information as content ranging from requirements, best practices, and designer experiences, to descriptions of technical and social systems (Heisig et al., 2010). All of these types of information are valued for their role in enabling designers to meet goals and consumer needs in their design endeavors (Ogot & Okudan-Kremer, 2004).

At the same time, technological advancements have led to an increased ability to develop and capture information from what was once a highly sought-after advantage, to a freely available commodity for innovation (Kalay, 2006). In addition, the complexities of modern design require designers to organize and share information more effectively because of trends towards life-long product support, products-as-services, efficiency improvements, and innovative solutions (Wong et al., 2008). Within these complex engagements, it remains unclear how designers navigate these rich sources of information and how this behavior might relate to the quality of design (Sio et al., 2015; Thekinen & Grogan, 2021; Viswanathan & Linsey, 2012; Youmans, 2011).

Further compounding this uncertainty is the fact that design is an increasingly social process due to the participation of many designers and stakeholders in collaborative design that enable designers to share expertise, ideas, resources, and responsibilities to improve design outcomes. Within these collaborative design engagements, designers must efficiently use and share information, coordinate tasks and resources (Chiu, 2002). However, collaborative design often requires a great deal of time and energy on information preparation and sharing, which may take even longer if the information is unstructured (Chiu, 2002). Thus, there is a need to improve understanding of what designers' information needs are in practice (Vijaykumar & Chakrabarti, 2008), specifically around its utilization and sharing practices (Heisig et al., 2010).

The realities of design practice have historically received very little attention in the research literature. The complexities of the types of information and activities used in design practice are not easily captured in highly controlled laboratory experiments, leading to the tendency for design research to happen in isolation, without detailed understanding of industrial practices and context (Stempfle & Badke-Schaub, 2002). Tools and methods developed in academic spaces often suffer from lack of adoption by practitioners. This is partly due to a fundamental lack of understanding what industrial demands are, and how these tools and methods will be applied in context (Alelyani et al., 2017; Birkhofer et al., 2005). Thus, academically created tools and methods face significant barriers to adoption by practitioners (Clarkson & Eckert, 2010; Gerrike et al., 2017). For example, a lack of contextual understanding by academics leads to the

development of tools and methods that lack integration into the organizational processes that practitioners operate in. Additionally, the presentation of tools and methods is often abstract and rigid, with unclear communication of the value that these formalized tools and methods can provide for the design process. Another major challenge to the transfer of knowledge from research into practice is our lack of consideration of the information needs, capabilities, and working styles of practicing designers (Albers et al., 2014). Thus, before research can prescribe methods to improve design practice, we must first systematically describe the behaviors, information needs, and context of use of these methods in practice.

Therefore, the overarching goal of this research is to develop a theoretical framework for adding to the understanding of what and how information is used during the design process. The specific focus of this paper is to draw on designers' experiences working with these information types in practice to further develop this framework. The following sections outline prior work conducted to develop this theoretical framework.

1.1 Prior Work On The Information Archetypes Framework Development

The previous section highlighted the importance of understanding designers' interactions with information. Our prior work has developed a foundation for addressing this knowledge gap through the development of a typological framework that captures the various types of information encountered by and used by designers during this process (Damen & Toh, 2020; Lumbard et al., 2018; Yi et al., 2019). The output of our prior work in this space has produced the Information Archetypes

Framework, and this current work builds on this framework for classifying information types found during the design process.

In sum, the Information Archetypes Framework is a theoretical framework to study information use in design through the lens of building typologies to develop a theoretical understanding of applied phenomena (Doty & Glick, 1994). This approach of using typologies to build theory has been applied in disciplines such as organizational science and social psychology (see (Brandtzæg, 2010; Büchel et al., 2016; O'Raghallaigh et al., 2010)), but is most strongly associated with the creation of taxonomies (a hierarchical typology) to describe the natural order of the animal kingdom (British Museum, 1933). Typologies in this research, similar to typologies of the animal kingdom, serve to provide a theoretical understanding of complex entities and their relationships to one another, but also provide pragmatic guidance to practitioners within that domain. In design, the stakeholders of typologies certainly include design researchers, but also those who practice design (individuals, organizations, funding sources), those who consume the end product of designs (customers, users), and those who teach design (educators, design methodologists) (Dorst & Overveld, 2009). While Dorst and van Overveld's work proposed a typology for describing the *practice* of design (Dorst & Overveld, 2009), in this work, we take a step back and instead advance a typology of the *information* used in design, recognizing that design practice must engage with information prior to acting on goals during the design process. Such a framework of design information can contribute to the understanding of how designers navigate complex design spaces using information and help to develop tangible guidelines for

designers and enhance design instruction.

This typological framework consists of *dimensions,* which themselves are found in unique combinations "in the wild", forming what are known as *Archetypes* (Doty & Glick, 1994) (see Figure 1).

These dimensions were developed through detailed analysis of the prior literature, reflections from field work with practicing designers, and rigorous qualitative coding procedures outlined in a prior publication (Lumbard et al., 2018). In all, five main dimensions with two corresponding levels each were identified. The details of each dimension are as follows:

Information Source: This investigates the origin of information with respect to the individual or organization that generated the idea of the design. Novel designs can be developed using external information such as new technology or trends in the market (López-Mesa & Bylund, 2011), but expert designers also rely on internal information such as their own past experiences and their ability to recognize design problem patterns (Akin, 1990).

Abstraction of Information: This focuses on the details provided by the information and the extent to which it deals with high-level concepts versus discrete real-life events. Designers engage with abstract information to maximize the effectiveness of their solutions (Ball et al., 1997), while concrete information can help in simplifying complex problems (Christensen & Schunn, 2009).

Generality of Information: This describes the extent to which information can be generalized to other design tasks, projects and areas. In contrast to such cross-cutting

features (Li et al., 2002), information can also capture core paradigms that are specific to a particular domain (Osman, 2015).

Effectuation of Information: This explores the varied thinking styles of designers or design teams when addressing design problems. Decision-makers can generate effective solutions to identified problems by either using existing resources such as their existing knowledge and network (effectuation), or by identifying a specific market need and working towards addressing that need by using and acquiring additional resources (causal) (Sarasvathy, 2001). Prior work stemming from this framework has shown that effectual and causal information play a complex role in influencing creativity in design (Abid et al., 2018).

Representation of Information: This revolves around the form of communication used to deliver information during the design process. Designers typically share their ideas with other designers through emails with links to examples and short descriptions (Herring et al., 2009). Some researchers have claimed that direct communication in the early stages has an impact on the creativity of the final product (Brown & Paulus, 2002). Others found a negative relationship between chat messages and design outcome performance (Thekinen & Grogan, 2021).

While this initial Design Information Archetypes Framework can be used to build a theory about how information is used in creative design and to allow researchers to empirically test the impact of specific types of information on design outcomes, empirical validation of this framework is still needed to advance its predictive and

166 explanatory capabilities. One important aspect of studying information utilization during
167 design is designers' own evaluations of relevant information early on during ideation.
168 Self-reflections are an important tool to gain insight into the cognitive processes that
169 designers employ during ideation. However, researchers have long noted discrepancies
170 between people's reported and actual behavior (Olson & Fazio, 2008).
171

172 *1.1 Research Objectives*

173 To further the development of a theoretical framework on information usage during the
174 design process, this paper explores the experiences of practicing designers to provide a
175 more applied context to Information Archetypes Framework. The specific research
176 objectives for this work are:
177 **RQ1: How do individual dimensions of information manifest in design practice?** The
178 information dimensions that make up the Information Archetypes Framework originate
179 from a combination of prior literature and reflections from fieldwork. The purpose of
180 this research objective is to investigate how these individual dimensions of information
181 take form and are used in design practice.
182 **RQ2: How are the information dimensions structured in design practice?** The
183 information dimensions are discrete but not disconnected from each other. This
184 research objective explores how the designers understand the relationship between
185 information dimensions and how the overall structure of the framework takes form in
186 design practice.
187

2 METHOD

To understand how practicing designers engage with different types of information found in our Information Archetypes Framework, eight practicing designers were invited to attend a 3-hour individual design session with the research team. All participants were identified using purposeful sampling through the authors' professional networks. Where probability sampling serves to select a "truly random and statistically representative sample that will permit confident generalization from the sample to a larger population" (Patton, 1990, p. 169), the goal of purposeful sampling is to select information-rich cases for an in-depth study to gain deeper insight into issues of central importance to the research (Patton, 1990). Purposeful sampling has been used in cognitive science (Chase & Simon, 1973; Morais et al., 2013) and engineering (Tomko et al., 2018) to uncover valuable insights on complex phenomena and human experience through a detailed analysis of in-depth protocol studies on behavioral patterns, performance, and reflections. In this study, specific cases (experienced designers) were chosen that intensely manifest the phenomenon of interest (routinely structuring information to facilitate the design process). Specifically, only designers who had obtained at least 3 years of software design experience (through educational training, certification, or job training) *and* currently engage in design activities as their primary function in their full-time jobs were recruited for this study. Consequently, each designer had between 3 to 17 years of experience. Six designers were employed by small to medium software design and development companies in a U.S. midwestern metropolitan area (see Table 1), while two also taught at the university (in a different

department) where the research took place. Reflecting the interdisciplinary nature of complex, real-world problems and following the notion of design as a discipline in itself rather than being unique to various domains such as Mechanical Engineering or Industrial Engineering (Cross, 1995; Daly, 2009), the participating designers come from a range of backgrounds varying from art and design to software development and engineering.

2.1 Procedure

The data used for this research was obtained from a larger dataset that was generated by a protocol study relating information categorization and idea generation. More details about this study procedure can be found in (Damen & Toh, 2020). In summary, each designer was asked to organize several information sheets that were provided to them and use these to engage with a hypothetical design challenge. The designers' resulting information organizations and rationale were analyzed to understand the cognitive organization strategies used by designers in the early stages of the design process. All participants received the same instructions, design challenge, and information sheets. This paper uses the data that resulted from the semi-structured interview that concluded the study session.

During this interview, participants were asked about their design practice and how they typically engage with information to address design problems. Since many of the cognitive processes affiliated with the design process rely on tacit knowledge, we used the theoretical framework described in Section 1.1. to provide designers a structured

232 approach to discuss these abstract concepts. We prompted the designers to critically
233 reflect on how this framework related to their own understanding of the types of
234 information used during their design activities. To do this, the participants were
235 provided with a brief explanation about each information dimension, similar to the
236 description provided in Section 1.1. Next, the participants were asked about their high-
237 level thoughts about the framework. Participants were specifically informed that the
238 framework only represents one perspective of design information, and a work in
239 progress, so their open and honest feedback was welcome. Once the framework and its
240 dimensions were described, the following semi-structured interview guide was used to
241 drive the conversation:

242 1. At first glance, what are your thoughts about the information dimensions?
243 2. To what extent are these dimensions representative of your work process?
244 3. How could the framework be helpful for you?
245 4. How could the framework be expanded upon?

246 On average, each interview lasted around 30 minutes, resulting in a total of 240 minutes
247 (around 4 hours) of recording that was transcribed and analyzed.
248

249 **2.2 Qualitative coding analysis**

250 The eight interviews were transcribed and analyzed for recurring patterns and themes
251 using deductive content analysis. In accordance with the research questions, the
252 material was analyzed for how the designers related their design practice to the
253 individual information dimensions and the framework as a whole, which were

developed in previous work (Lumbard et al., 2018). An iterative thematic analysis process was followed in which the participants' descriptions of how each of the information dimensions appeared in their design practice were iteratively extracted from the interview transcripts, and then used to construct emergent patterns across participants. The participants' discussion regarding the structure of the overall framework were captured and analyzed using a similar process. Analysis of the first few interviews revealed several rough themes, which became increasingly more nuanced and refined as additional interview data revealed similar or closely related codes. Once additional interview data no longer revealed new themes that were substantially different from themes that were already uncovered, the data was considered saturated and data collection was halted. The findings of these analyses are presented in the following sections and illustrated through the presentation of the most relevant or concise quotes.

3 RESULTS

A short summary of the findings of both research questions can be found in Table 2. Throughout the results section, participant quotes have been provided to increase transparency into the data. The quotes have been shortened and paraphrased where it was possible to do so without changing the speaker's intent. Longer quotes showcase the participants' chains of reasoning while shorter quotes illustrate how our interpretation and themes arose from the data.

3.1 RQ1: How do dimensions of information manifest in design practice?

3.1.1 Source (Internal & External)

The information dimension Source refers to the place that the information originates from. This can be internal when the information comes from within the individual, team, or organization, or external when it is acquired from outside the individual, team, or organization.

In literature, external information is often viewed as a source of inspiration (Eckert & Stacey, 2000; Song & Fu, 2019) and as a means of obtaining feedback on the design (Poltrock et al., 2003; Stobbeleir et al., 2011; Vredenburg et al., 2002). The designers in this study discussed the source of information largely in the context of acquiring and verifying information. One designer noted how essential acquiring external information is to the design process since "*design is not something I can do on my own*" (D8). In this sense, deliberately seeking out external information serves to fill in missing gaps in existing knowledge: "*I need a majority of external information to even internally create my own information. So it's externally collecting and then internally organizing and creating or designing*" (D8).

Another way that designers leveraged external information during the design process was to supplement or verify information that has already been obtained and internally curated: "*I don't trust my internal biases unless I'm meeting with an external source. So I constantly have to say: "this is where I'm at, right? This is where we're at together, right?" So I constantly need either to be researching to support myself or to have people that can confirm my intuition*" (D5). One designer remarked that rather than looking at

whether the information came from an internal or external source, they would break information into known or unknown. In other words, internal information was viewed as information that was readily available, or were "known quantities", whereas external information was used to supplement or validate internal information: "*What I'm doing in our process is determining the information that we have right away. If there's a gap in that information or we need to validate it more than it has been, then we go to known external. That's where we're doing some upfront customer interviews or more usability testing. I like to go into that with a very open mind, and then we're sort of relating that to the known information that we've gathered from previous relationships and customer analysis. So it's almost like I go directly to the known external, determine how to gather the unknown external, and then once we have all the information we need, we move to more ideation stage*" (D1).

3.1.2 Abstraction (Abstract & Concrete)

The information dimension Abstraction refers to the level of detail in the information. Information is abstract when it contains little detail, is more vague, and deals with concepts. Information is concrete when it is highly detailed, descriptive, and refers to specific events or activities.

The designers in this study showed familiarity with the use of abstract information in the design process. While a mix of concrete and abstract information was routinely used in their practice, they reflected that the early stages of the design process relied more on abstract information with concrete information being used in the later concept refinement phases: *"I think that abstract is maybe when it's starting as a vision and*

320 *concrete is when it's turning into a business"* (D3). Furthermore, participant D3 clearly
321 delineated between the abstract style of design thinking and inquiry early in problem
322 solving, from the more concrete solutions-focused activities in the design process: *"I*
323 *think I'm more of an abstract thinker up until I have to actually produce, but most of the*
324 *time what I produce is materialized. But as far as thinking through, I think I have more*
325 *questions than thoughts and ideas that are necessarily solutions".*
326 This affinity for operating with abstract information in design practice was reinforced by
327 another participant who commented that *"If you're a good designer, then you're always*
328 *thinking abstractly. I think that's the challenge of being a designer. Just being able to*
329 *look at concrete problems but then think abstractly as you're gathering more concrete*
330 *data*" (D1). These comments indicate that designers have a tendency to view much of
331 the design process as being abstract and conceptual. Indeed, prior work has shown how
332 abstract thinking is often used by expert designers to maximize solution finding (Ball et
333 al., 1997), particularly in the early stages of design (MacLellan et al., 2013). However,
334 the same designer acknowledged that it is likely that this may be different between
335 design teams: *"Product development [referring to the product actualization or product*
336 *refinement phase] is very concrete in a lot of teams where they have design handoffs*
337 *and they're essentially just meeting the requirements of the design. It's almost*
338 *mathematical in a way and there is some abstraction going on. But for designers, I feel*
339 *like half of your head space, it lives in the abstract*" (D1). Thus, while differences exist in
340 how designers engage with abstract information across different teams, abstract
341 information plays a prominent role in the practice of design.

342 *3.1.3 Generality (Cross-Cutting & Domain Specific)*

343 The information dimension Generality refers to how broadly applicable information is to
344 other areas. This can be cross-cutting when the information can be widely generalized
345 across various domains, or domain specific when it applies specifically to one domain of
346 interest.

347 The designers in this study related to the generality of information through their use of
348 cross-cutting sources of inspiration to increase creativity while generating ideas: "*When*
349 *you get too specific it's too narrow - I don't want blinders on. So I find more creative and*
350 *interesting solutions when I'm looking at other places that aren't direct resources*" (D5)
351 and "*I think that having a combination of these is what can really give an idea innovative*
352 *value, because I think the cross cutting is where it brings things into more of a unique*
353 *space at this point*" (D3). Our participants showed an appreciation for adapting ideas
354 across domains to address specific project requirements: "*I don't think enough time is*
355 *spent on cross-cutting. We had to look at a signature capture technology when we were*
356 *building the product that we built for the physicians. We had to look at what's currently*
357 *available for domain capture, what solutions are already in place, what those look like.*
358 *We looked at sign up documentations for businesses and legal tax documentation and*
359 *stuff like that. We brought in a lot of those findings and combined them with the domain*
360 *specific information to come up with the solution that's right for the scenario. This*
361 *solution had to be impersonal, for instance. Most signature capture software does not*
362 *have that requirement, that's the purpose of it [signature capture software]*" (D1). As
363 this participant described, existing solutions in a particular domain do not always fulfil

project requirements, necessitating inspiration from other domains.

On the other end of the spectrum, designers in our study also valued domain-specificity in an effort to develop a creative identity and focus their contributions to a specific area of design. One designer drew from the notion of the designer as an expert curator of information: "*There's this idea that a designer should do everything and be able to come up with any kind of solution, but the people who I see flourish the most are those who have a singular voice. There's a lot of variables in there, but if they have become a master of one or two styles, they seem to be the most successful because their work is really consistent and they become experts. It kind of reminds me of Italian Renaissance masters; they might experiment a little bit, but it's small shifts, not large ones. Our resources are just so abundant that it's easy to shift, but the people that I see whose work only moves a little bit are the people I've seen to be really, really successful*" (D5).

Across these two modes of relating to generality, the designers in this study showed a nuanced understanding of what it meant to be creative in their industries. The designers commented on the tension of drawing from interdisciplinary domains to broaden their base of knowledge while also maintaining enough focus to contribute specifically to a domain or to apply their knowledge to a specific application area (Fu et al., 2013).

3.1.4 Effectuation (Effectual & Causal)

The information dimension Effectuation refers to the approach taken when presented with a design problem. This can be effectual when the design is created with the available resources in mind, or causal when it is created with the end goals in mind.

The designers in this study understood causal information through the frame of project

386 goals and requirements, while they related to effectual information as the available
387 resources during a design project. Causal information could be used to drive the
388 direction and activities of a design project. One participant showed particular sensitivity
389 to the provenance of the causal information, paying attention to where the project
390 requirements originated from and questioning the relevance of the requirements and
391 the constraints surrounding the project: "*Now that I think about it, this [causal*
392 *information] is really critical. This is the requirements. Even this [referring to an*
393 *information sheet], I want to know what this is based on. On some executive who says*
394 *that they need something, or customers, feedback, data, or a problem within the*
395 *company that can be solved with a solution. Where is this information coming from?*
396 *Causal to me is related to some of the externals that we might be gathering. I think a lot*
397 *of designers blow past this. Like "these are the requirements of the process, but let's do*
398 *this" and then they'll start gathering information but they never really go back to check*
399 *if it's really the problem or the requirement that we need to address*" (D1). Indeed,
400 working with constraints, understanding the problem frame, and exploring the problem
401 space has long since been recognized as a crucial step in the design process (Dorst &
402 Cross, 2001; Harfield, 2007).
403 With regards to effectual information, another participant emphasized the importance
404 of other people's perspective to enhance the design process, highlighting the potential
405 of effectual information to shape the direction of a design project: "*I don't trust myself a*
406 *hundred percent to create something without bringing multiple people in and that's*
407 *something that, especially in the design community, people are very adamant about.*

Like one of my professors. Once you graduate she's like, "no, you graduated. I'm your colleague, I'm not your professor". So she really encourages it, and especially with design because collaboration is, you know, everyone has such different ideas and such a unique way to approach a design problem or design issue. It's almost a disservice to design to not bring multiple people in. Because my ideas for creating a design are specific to my experiences in life and everyone has completely different experiences, so those diverse ideas are really interesting, at least to me, to understand before designing something" (D8). Prior work has shown that effectual thinking is a hallmark of entrepreneurial thinking (Sarasvathy, 2001), involving the use of project resources (the means) to shape the goals of a project (ends).

3.1.5 Representation (Asynchronous & Synchronous)

The information dimension Representation refers to the way that information is delivered to the recipient. This can be asynchronous when the information is not delivered in person or in real-time, or synchronous when it is delivered in person or in real time.

Given the prevalence of digital tools and the importance of communication in design projects (Stempfle & Badke-Schaub, 2002), it is not surprising that researchers have looked into the effectiveness of computer mediated communication (Chiu, 2002; Kvan et al., 1998; Thekinen & Grogan, 2021). For the designers in this study, the representation of information was mainly interpreted as the communications between designers and clients, and between designers within an organization. Several themes emerged from the discussion, falling into three broad categories: 1) the ephemeral

nature of synchronous communication, 2) the functional benefit of synchronous communication for quickly resolving issues or conflicts, and 3) the role of synchronous communication for refining ideas and changing their own thinking. Generally, the designers expressed the sentiment that synchronous and asynchronous types of information had their own applications and were each better suited for different purposes. For example, asynchronous information was more suited for confirming decisions and record keeping, while synchronous information was more effective for conveying complex information: "*Representation of information, that's important to know because you need to know the limits of the information. For example, with emails you have a written record, which is helpful if you want to have a written record of someone approving either an estimate or the budget they provided. Emails are really poor in trying to get some more information. As in, it takes a lot of time to type something up. It's easier to get someone on the phone and ask what time does this package need to arrive at your destination?*" (D7). Additionally, designer D8 indicated that although design may be more skewed towards asynchronous information due to its convenience, the information that was conveyed synchronously was considered highly valuable information: "*For design, a lot of the time things tend to be asynchronous just because graphic designers are attracted to the idea of working remotely and working when you want to, how you want to, where you want to. So that convenience really facilitates more of an asynchronous representation of information just because it's convenient and you're not limited to reading information right now but you can come back later. So while the majority is asynchronous, there is also, that's why I meet with*

clients in person at the beginning, there is so much more, I think things get straighter into the point. There's more, I don't know if honesty is the right word, but people tend to give more real information. If you have however long to create a communication to somebody, you can really think it through. Whereas if you're forced to just give an answer right now, it's probably the most honest answer you're going to give. So I think sending emails and information that's not time sensitive is 95% of what designers deal with on a daily basis, but the 5% of communicating in person is extremely valuable. It expands your understanding quicker. And it's not just words on a page, it's in the moment and you have to focus on it. I think it's much more valuable."

3.2 RQ2: How are the information dimensions structured in design practice?

Our second research question sought to go beyond the ways that individual information dimensions appear in design practice by exploring the relationships between and surrounding these dimensions. To some extent, the presentation of the Information Archetypes Framework suggests a discrete distinction between information dimensions and a binary difference between the two levels that further specify each information dimension. Although they can be treated as such, and for data analysis purposes indeed have been, these boundaries are much less distinct in practice: "*I think that having a combination of these [cross-cutting and domain-specific] is what can really give an idea innovative value, because cross cutting is where it brings things into more of a unique space at this point" (D1).* The same designer drew a comparison using both causal and effectual information in the design process: "*When you're going through the design*

process, evaluating your problem's source is kind of effectual, and then your problem is causal. So I think both of those pieces of information are necessary to make a good judgment". In other words, the two different levels for each information dimension may not be mutually exclusive, and certain types of information may indeed contain multiplicities in each dimension such that a superposition of characteristics emerge in a single piece of information.

In some cases, the designers observed a directionality in the relationship between information dimensions and their levels. Regarding Abstraction, several designers noted that design activities move from the abstract conceptual design activities in the earlier stages of design, to more concrete forms in the later design stages of the process. For example, designer D5 remarked that "*when I think of the design process, at least what I've worked on, it goes from abstract to concrete in that order. Because everything creatively is extremely conceptual at early stages of design, and concrete isn't until some of the last couple steps or the last few stages of it*". Notably, this movement from abstract to concrete in the design process can manifest as a cycle in which one moves from abstract to concrete to abstract, etc.: "*I think that you're inevitably going to have a lot of abstract and concrete. I think that our clients usually start here [abstract] and we try and work them here [concrete]. Just because I think that abstract is maybe when it's starting as a vision and concrete is when it's turning into a business*. *I think that it happens consistently throughout, it's like a cyclical process. Because even at the start of a new design sprint you need to start with a vision and then get it to a concrete space. And that can go for information as well as the development process in general [referring*

to the overall design process]" (D3). This iterative structure of the design process has long been acknowledged by both formal design methodologies as well as informal observations of designers in practice (Wynn & Eckert, 2017). Perspectives on iteration in design describe how the discovery of new information influences the direction of project outcomes, which in turn modifies the search space that is considered relevant to the project, and so on until a final outcome is reached (Chiu, 2002).

This movement from one level of a dimension to another can also take place at a deeper, more personal level for the designer, as exemplified by one designers' reflection on inspiration gathering. Designer D5 described a pattern of appropriating external information to serve as personal and unique sources of internal inspiration: "*There was a typographic designer who was really, really talented and he said that he creates his own galleries using this metadata off of his iPhone images from his everyday life. So if he sees a cool bowling sign or "this sidewalk is kind of beautiful over here" then he just puts in the metadata something like "texture" or "old signage." So he's doing all this pattern categorizing to give himself things that he can pull up and bridge just by putting in the metadata and getting all of the urban textures, or something like that. So he's seeing how he views the world. It's like he's categorizing his references. He said "anybody can pull up Google and get the exact same results I do, or anybody is going to go to Pinterest to get the same first two pages, or any resource. So the solutions are going to be so similar unless you deep dive which just takes so much more time*".

In this example, while design inspiration was obtained externally, the process of categorizing inspiration and placing an interpretive lens on the stimuli transformed the

external information to highly personal internal information. As participant D5 explained: *"...by him making his own resources he's constantly tapping back into his own creativity and so no one has his solutions. So he's drawing very direct and very real creative stuff from his life, and his solutions are unique to him, and nobody else in his work is going to be like him".* This quote highlights the dynamic nature of information flow in design and demonstrates the utility of movement from one end of an information dimension spectrum to another.

While information plays an important role in the design process, other factors such as the designer's skills and expertise may affect how the information is interpreted and manipulated. This may apply to the Information Archetypes Framework as well, where individual differences between designers may affect how they engage with the information dimensions in the design practice. In our study, designer D6 observed that level of expertise plays a big role in a designers' ability to comfortably move between and utilize different types of information during the design process: "*Designers know the principles of design and they know the elements of design. So very foundational things, like shape, color, size, texture, movement. If you know those things then you have the playground to apply those things, but for students, they're still learning those skills, so they have to learn at the same that they're playing and so of course their creative output is not going to be as high as someone who's super comfortable with "I can do this with a line, I can do this with a shape, I can create this this kind of visual contrast to create this visual interest", and so on. You just have more freedom and play so you generate more unique solutions*".

Individual preferences or tendencies may also influence designers' behaviors as they engage with different information dimensions. Awareness of which type of information is being used frequently in their practice can reveal information deficiencies that may occur during this process. For example, designer D5 displayed a level of self-awareness for certain thinking patterns that drives their information seeking behavior: "*There are different thinking patterns that we've evolved as professionals that work for us. I already know that I love talking about abstract concepts, but I need concrete. I love getting concrete answers because I live in the abstract; I'm always trying to assess this, so I like to hear direct things from other people, and tell me if I'm interpreting it wrong*". In this way, the information dimensions also act as a kind of "compass" that designers use to calibrate their design efforts and ensure they are meeting design goals.

4 CONTRIBUTIONS TO DESIGN RESEARCH

The main goal of this study was to investigate how information dimensions manifest in design practice, as reflected on by experienced designers. The interview data was qualitatively analyzed, and the resulting themes were presented using participant quotes and descriptions where possible. The main findings are that:

- Designers display an awareness and understanding of their own thought and design process, and intentionally adapt their information usage according to their information needs, which varies throughout the design process.
- Designers recognize the inherent tension that exists between levels of dimensions, and deliberately and fluidly move between dimension levels through

562 1) trajectories and 2) loops.

563 The first contribution of our work brings the cognitive strategies used by designers
564 during their practice into focus. The designers' deliberate adoption of different
565 forms of information throughout the design process highlights that the Information
566 Archetypes Framework should not be taken as a prescriptive framework that
567 decrees a value judgment on information dimensions. Rather, it emphasizes how
568 each information dimension serves a different purpose at different points in the
569 design process. For example, in the generality information dimension, substantial
570 work has explored the cross-cutting level as a means of gaining inspiration (Fu et al.,
571 2013; Kaufman & Baer, 2005). On the other hand, the designers in this study
572 illustrated how a specialists' accumulation of domain-specific information can create
573 unique value through deep expertise, a notion that has received less attention in
574 design literature.

575 Throughout our study, our participants showed a nuanced understanding of the type
576 and purpose of different forms of information during design. While these reflections
577 can appear to be tacit, they mirror closely the "reflective practice" cognitive
578 processes discussed by Schon (1987), where expert designers demonstrate a
579 "knowing in practice" that guides their judgments and behaviors in highly uncertain
580 situations, as is common in design practice. Indeed, metacognition, defined as a
581 continual monitoring and control of cognition in the service of using effective
582 cognitive strategies, has been acknowledged as an important indicator of expertise
583 (Ackerman & Thompson, 2017), and plays an important role in a highly unstructured

584 and challenging environment such as design practice. Our work provides empirical
585 evidence of metacognitive strategies leveraged by designers in practice, and can
586 serve as a foundation for building tools and methods that support these
587 metacognitive strategies.
588 The second major contribution of this study is a conceptual understanding that
589 tensions exist between levels of an information dimension, and that designers move
590 between different forms of information during the design process. First, setting up
591 the dimension levels as two opposite ends on a spectrum creates an inherent
592 tension in each dimension that the designers treated as a natural part of the design
593 process. The following sections illustrate how these tensions manifest in the
594 designers' own work practice:
595 **Information Source:** The designers in our study circumvented the tension between
596 information that is already available (internal) versus acquiring additional
597 information (external) by approaching external information as a way to supplement
598 and verify already existing internal information. This finding provides nuance to the
599 generally accepted notion that designers are blank slates seeking inspiration from
600 external sources early in the design process (López-Mesa & Bylund, 2011). Instead,
601 designers in our study described a rich and complex network of internal inspiration
602 sources, sophisticated methods for curating their inspiration, and a critical approach
603 to modifying and updating their internal network with relevant external information.
604 **Abstraction of Information:** The designers in our study navigated the tension
605 between utilizing broader concepts (abstract) versus specific details (concrete) by

606 counterbalancing them throughout the design process, such as by advocating for
607 concretization of abstract ideas and keeping the abstract in mind when collecting
608 concrete information like user data. This finding extends previous literature by
609 showing how the complementary relationship between abstract information (used
610 to maximize the effectiveness of solutions (Ball et al., 1997)) and concrete
611 information (used to reduce complexity (Christensen & Schunn, 2009)) can be
612 tapped into continuously and concurrently, rather than across design phases or
613 activities.

614 **Generality of Information:** The designers in our study indicated that the desire to
615 draw from different disciplines (cross-cutting) is opposed by the desire to become an
616 expert in their specialization (domain specific). One designer emphasized the
617 importance of seeking input from other designers while another highlighted the role
618 of curating expertise as a means to providing unique value. The designers diverging
619 experiences are in line with previous literature which similarly argues that value can
620 come from deep, domain specific information (Osman, 2015) as well as from
621 conceptually distant information (Fu et al., 2013).

622 **Effectuation of Information:** The designers in our study moderated the tension
623 between leveraging existing resources (effectuation) versus focusing on the end-goal
624 (causal) by interpreting existing resources as the network of people that they could
625 tap into for additional expertise and different view-points to complement their own
626 as they sought to fulfil the causal project requirements and goals. This finding is
627 somewhat in line with previous work in the sense that people are considered as

628 resources that can be leveraged (effectual). However, the designers did not view
629 effectuation as an independent thinking style, but rather as a means to achieving
630 end-goals (causal) (Sarasvathy, 2001).
631 **Representation of Information:** The designers in our study indicated that the
632 tension between the desire to resolve conflict and quick passing of ideas
633 (synchronous) versus the need to record information (asynchronous) was inherent
634 to the nature of their work. The designers experiences regarding which channels
635 were used to communicate what kind of information was very much in line with
636 previous work, with the designers echoing previous literature by affirming that
637 although the majority of design work is done through asynchronous emails (Herring
638 et al., 2009), synchronous face-to-face communication is especially valuable in the
639 early stages of the design process (Brown & Paulus, 2002).
640

641 **4.1 Traversing Information Dimensions**

642 In considering the inherent tension that exists in these information dimensions,
643 designers described several ways that they moved within each dimension during
644 their design practice, as illustrated in Figure 2. Consider a hypothetical situation: A
645 client comes to a designer to develop a software product. *Path A* illustrates how the
646 designer loops through various modes of communication; The client will most likely
647 have reached out to the designer using asynchronous email, after which the
648 designer may set up a synchronous meeting in person. As the project continues, the
649 designer may use emails to update the client with progress (asynchronous), or call

650 them for additional clarification or questions (synchronous). Throughout the
651 process, the designer makes use of asynchronous information more frequently due
652 to its speed and convenience, but these asynchronous communication methods are
653 punctuated by synchronous meetings with the client to delve deeper into issues that
654 necessitate a face-to-face meeting. *Path B* illustrates how a designer may bring in
655 external information to verify existing internal information, for example by
656 conducting user studies and checking in with the client. The designer relies on
657 external information earlier in the design process, and then turns inward towards
658 the later stages of the design process to synthesize findings, reflect on their
659 knowledge, and generate innovative solutions to the design problem. Lastly, *Path C*
660 illustrates the overall directionality of the design process in which a client's abstract
661 ideas become a concrete solution. However this process is not linear, as the designer
662 must keep these abstract goals in mind as they evaluate concrete information and
663 make concrete design decisions. Ultimately, the generated solution is a concrete
664 manifestation of abstract concepts that the designer has kept in mind during the
665 design process, such as design principles and heuristics, desired messaging or
666 branding around the solution, and even design philosophies or approaches that they
667 are trying to advance (e.g., sustainable design, ethical design).
668 In the illustrative examples provided in Figure 2, designers described a general
669 movement over the course the design process towards a specific end of the
670 information dimension (e.g., moving from abstract to concrete in *Path A*). We call
671 these general movements over time *Trajectories* in the design process. In addition,

designers show a tendency to move back and forth between different levels of an information dimension throughout the design process, either through periodic cycles (e.g., asynchronous punctuated with synchronous in *Path B*) or through tightening iterations (e.g., increasing reliance on internal information towards the end in *Path C*). We call these iterative movements *Loops*.

5 LIMITATIONS & FUTURE WORK

The information dimensions that make up the Information Archetypes Framework were developed through a combination of literature and field work (Lumbard et al., 2018). By focusing on the ways in which information can be present in the design process and how it varies, the framework is primarily descriptive in nature. This study contributes to the Information Archetypes Framework by exploring how and when designers might use the information dimensions. Although it has provided some insight into this matter, several limitations must be noted. Firstly, although the designers who participated in this study were experienced designers, future work should look into validating their responses with a larger number of participants to investigate the generalizability of their claims. For example, even though all eight designers provided valuable input for the results, not all designers were equally represented in the quotes provided in this paper. To some extent this can be attributed to the appropriateness of the quotes with the research question, as well as differences in how eloquently people verbalized their thoughts and how much people have reflected about their practice. Additionally, some dimensions may be more relevant, less complex to understand, or more consciously accessible to

694 designers during an interview study.

695 Secondly, the designers in this study operate in different fields that could be viewed as
696 more technical (software design) and more visual (graphic design) areas. While this
697 study did not specifically sample from mechanical engineers, this broader definition of
698 design more accurately reflects the interdisciplinary realities of complex, real-world
699 problems that engineers in practice face (Roy & Roy, 2021). The growing need for
700 engineers to work beyond disciplinary boundaries has become integrated in engineering
701 education, as evidenced by the courses and learning outcomes that are prioritized in
702 major engineering institutions (Harrison et al., 2007; Lam et al., 2014) and the inclusion
703 of multidisciplinary skills as a necessary accreditation criterion for the ABET Engineering
704 Accreditation Commission (ABET, 2021). While the designers did provide responses that
705 spoke to the specifics of their respective fields (such as the examples they provided),
706 overall, there was substantial overlap in the participants' experiences as designers,
707 especially in the general approaches and processes that they employ. For example, the
708 inclusion of user-experience designers was particularly helpful for studying how
709 information is organized and structured around a wide variety of design projects due to
710 their focus on the holistic aspects of a users' experience (Hassenzahl, 2006), which was
711 used in this study to represent the range of considerations that may influence design
712 decision making in disciplines such as Mechanical Engineering design. Still, it is possible
713 that a more narrowly defined sample of designers may reveal specific insights,
714 constraints and considerations that may be unique to the engineering discipline. Thus,
715 further research exploring the practical context of mechanical engineering projects is

necessary.

Thirdly, the interview format enabled the designers to select experiences that they deemed most relevant and generalize across multiple experiences. While interviews provide insight into the participants' thoughts and feelings, they are less suitable for determining what participants would actually do in a situation. The benefits of self-reflections are often disputed with reliability concerns (Bennett-Levy, 2003), so future work that observes in-situ could provide insight into how designers actually engage with information throughout the design process versus how they think they do. Lastly, although this work does not intend to make claims about when which information dimension is more useful, relevant or important, such prescriptive statements could be useful guidelines for ensuring that information is not unintentionally overlooked or disproportionally favored over other information.

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944 **Figure Captions List**
945

Fig. 1 Doty and Glick's approach for building archetypes from unique combinations of dimensions to understand applied phenomena (Doty & Glick, 1994).

Fig. 2 Illustration of how designers may move more towards one information level or the other depending on their existing needs at that time. These charts are illustrative and do not represent actual data, rather, they exemplify how the need for an information dimension might fluctuate throughout the design process.

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948 **Table Caption List**
949

Table 1 Relevant designer characteristics

Table 2 Summary of study findings

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951

952 **Figure 1**

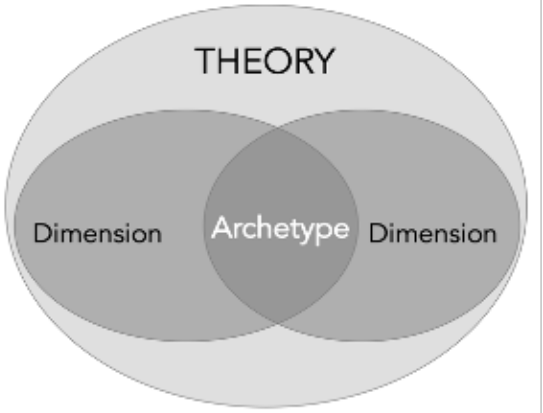

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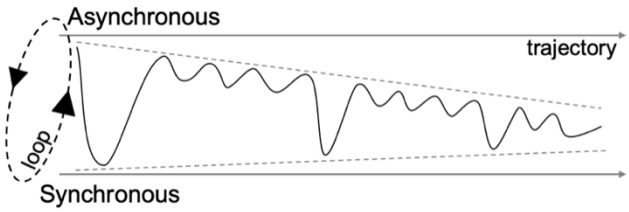
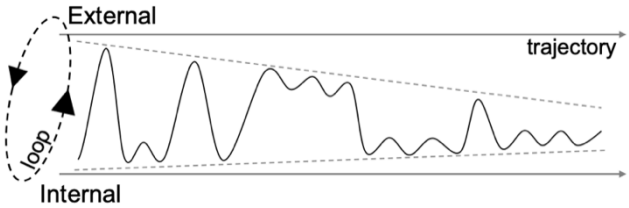
Figure 2

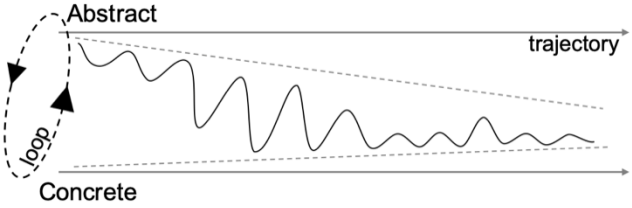
Path A: Asynchronous communication with client punctuated by face-to-face meetings for deeper discussions.



Path B: Designer relies on external information early on but then turns inward to generate solutions to the design problem.



Path C: The generated solution is a concrete manifestation of abstract concepts that the designer is trying to advance.



967 **Table 1**
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Designer, ~years design experience	Title, ~years in current position	Organization size & sector
D1, 8 yrs	User experience lead, 3 yrs	~ 51-200, mobile development & integration
D2, 7 yrs	Product designer, <1 yr	~51-200, managed hosting & web design
D3, 3 yrs	CTO, <1 yr	~1-50, custom software development & design
D4, 6 yrs	CEO, 3 yrs	~1-50, custom software development & design
D5, 17 yrs	Graphic design instructor, 7 yrs	~1000-5000, educational institution
D6, 15 yrs	Graphic design assistant professor, 14 yrs	~1000-5000, educational institution
D7, 5 yrs	Graphic designer, 3 yrs	~1-50, print, signage & marketing services
D8, 8 yrs	E-learning designer, <1 yr	~1-50, digital marketing solutions

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970 **Table 2**
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Information dimension (section)	**Description**	**Summary of RQ1: information dimension usage in practice**	**Summary of RQ2: manifestation of tensions between dimension levels**
Source (3.1.1)	Where information originates from (internal vs external).	Mainly used to acquire and verify information.	Rather than relying on external information for inspiration, designers use external information to augment and verify internal information.
Abstraction (3.1.2)	How detailed the information is (high-abstract vs low-concrete).	Abstract is more a style of design thinking and inquiry than information itself.	To benefit from the complementary relationship between abstract and concrete information, designers draw from both continuously and concurrently.
Generality (3.1.3)	How applicable information is in other contexts (high-cross-	Mainly used cross-cutting for inspiration and creativity during idea generation. Deep domain information can foster a creative identity.	While inspiration from cross-cutting information is more common, inspiration and value can also come from deep domain specific information.

	cutting vs low-domain specific).		
Effectuation (3.1.4)	What information is focused on (resources-effectual vs end goals-causal).	Causal drives project direction and activities through framing of project goals, requirements, and constraints. Effectual can also guide project direction through available resources such as access to other people('s knowledge).	Designers view people and other resources (effectual) as a means of achieving their goals (causal).
Representation (3.1.5)	How information is delivered (in-person or real time-asynchronous vs not in-person or real time-synchronous).	Mainly understood as communication between designers and clients, and between designers within an organization. The more ephemeral synchronous information is mainly used to reduce complexity, such as quickly resolving issues or conflicts and refining ideas	The majority of design work is done through asynchronous information, although synchronous face-to-face communication is especially valuable in the early phases of the design process.

		and changing thoughts. Asynchronous is mostly convenient and used for confirming decisions and record keeping.	