Knowing and Designing: Understanding Information Use in Open Source Design Through the Lens of Information Archetypes

Abstract

The early phases of the product design process are crucial to the success of design outcomes. While information utilized during idea development has tremendous potential to impact the final design, there is a lack of understanding about the types of information utilized in industry, making it challenging to develop and teach methodologies that support the design of competitive products. As a first step in understanding this process, this study focuses on developing and empirically testing a framework of Information Archetypes utilized by designers in industry. This was accomplished through in-depth qualitative interviews with large software engineering companies, and analysis using the principles of inductive content analysis. The results reveal two archetypes of information utilized by decision-makers within these companies during the development of new products and services. The findings of this study allow for future research that investigates the role of information during the product design process.

1. Introduction

In today's constantly shifting technology landscape, companies are required to generate innovative solutions quickly and effectively to respond to rapid changes in customer needs, new market opportunities, and emerging technologies [1]. This link between innovation and long-term economic success has been widely acknowledged [2], leading to substantial investments in increasing the innovation capabilities of the United States [3]. Therefore, research focus has been on improving the practice and education of design to meet these growing needs.

Within the field of design, the availability of information is crucial to the success of many stages of the design process since design is viewed as an 'information-centric' enterprise [4, 5]. In fact, researchers have argued that the very act of design is the process of transforming information gathered from the environment to actionable knowledge that can be used to make decisions during the design process [6]. While information has traditionally been highly valued during the product design process, the increasing availability of information due to recent information technology trends are transforming information from a highly coveted advantage to a freely accessible commodity for innovation [5]. As an example, significant changes have taken place in industry with the inclusion and integration of open source software into commercial design processes [7-9]. These studies show that new access to information has the potential to play a crucial role in shaping the field of design and creativity, but it is still not clear how designers in industry are navigating these abundant streams of information during design. This knowledge gap poses challenges to design research and education since we do not yet know how to best leverage these information sources to increase the quality of design outcomes, or how to best train the next generation of designers to operate effectively in this environment.

Therefore, this exploratory study focuses on developing a new typological framework for understanding the information utilized by designers in industry. This was accomplished with in-depth qualitative interviews of designers from software engineering organizations, through the lens of engagement with open source communities.

1.1 Design in Open Source Communities

The investigation of open source communities has a long research history, set against lenses of innovation [10], fluidity [11] and social structures [12]. Such research has traditionally focused on the internal dynamics of open source communities, considering complex questions of how social networks are comprised and evolve within these communities [11], evident governance structures [13], and the nature of information exchange within these communities [14]. While the investigation of the internal dynamics of open source communities has been critical in advancing our understanding of open source communities, new structures for engagement with open source communities reveal that open source is moving beyond its egalitarian roots and becoming a critical component of for-profit design streams [15].

Since the early 2000s open source communities have served as a key component of for-profit organizational design streams. Companies such as Hewlett Packard, Tesla, and Google leverage open source communities for a variety of reasons including lowered internal development costs and increased

corporate product time-to-market. In these arrangements, corporations engage with open source communities because they provide a platform where shared and non-differentiating practices or technologies (those practices or technologies not unique to an organization's design stream) can be collaborated on. Namely, for-profit companies engage with open source communities because they provide low-cost solutions to universally shared problems.

Open source has become such a pervasive part of how for-profit corporations perform software development, non-profit and trade organizations, such as the Linux Foundation, have grown to house these corporately important open source projects. Foundations provide these communities with brokerage services to help manage and stabilize open source communities for reasons of long term health and sustainability [16]. From a corporate perspective, if an open source community that is being leveraged as part of a corporate design stream becomes stagnant or unsupported, any benefit of engaging with open source becomes hindered. Foundations exist, in large part, to ensure that communities with broad interest and reach remain stable over time for all involved.

In these complicated contexts of communities, corporations, and foundations, research has found design to be a dynamic and responsive activity that is subject to the many engaged members, environmental contexts, and stabilizing structures [7]. Members navigate an open source environment that is comprised of other participants (some corporate, others volunteer) where each participant can engage with the community in ways that are relevant to their own interests.

In this paper, we explore design as rooted in the Information Archetypes that exist in these dynamic design environments. While prior research has identified many information sources that designers engage in [17], there is a lack of data on what types of information is utilized when making design decisions in organizations. Thus, this study aims to investigate the nature of information influencing design directions in the dynamic context of corporate engagement with open source communities. Lahkani and Von Hippel [14] premise that information is an exchange between suppliers and providers. We too believe this and further explore the depth to which information exists within these complex design environments.

1.2 Information in Design Decision-making

Researchers and practitioners recognize the importance of information in influencing the direction of the design process. From the information-gathering stage of customer needs, assessment to the design embodiment, and realization stages, the success of design efforts hinges on the identification of key pieces of information that will help designers develop products and services that successfully addresses design goals [18]. Furthermore, fundamental research has argued that the acquisition and transformation of information is integral to the design and development of creative ideas [19]. However, research has also shown that certain forms of information can be detrimental to the creative process by fixating the designer on a set of ideas or concepts regardless of their potential for innovation or success [20]. These contrasting findings highlight the complex nature of information availability, quality, and timing on design creativity, and necessitate an in-depth exploration of what information impacts the design process as it occurs in practice.

Researchers have begun to explore information usage, organization, and impact in design practice to shed light on design creation and decision-making in industry. These studies highlight the varied characteristics, dimensions, and forms that information is utilized during the design process. For example, studies that have explored the process in which new products are developed in industry have identified external sources of information, such as new technologies, as key drivers of decision-making during the design process [21]. Similarly, studies into the conceptual design phase in the product design industry have shown that teams tend to focus on the end goals of the design, such as the needs of the customer, as the key source of information for design activities [22].

Protocol studies investigating expert designers also show that designers frequently engage with abstract levels of information while problem solving in order to maximize the effectiveness of solution finding [23]. Other research has revealed that design exemplars, both within and beyond the domain of the design, and using varied forms of representation, are used by professionals in the creative design process [17]. Such research in software engineering has explored the use of cross-cutting features to streamline the development process [24]. Finally, research has focused on effectively utilizing guidelines across entire product families to analyze commonality across domains and increase the effectiveness of product design [25, 26].

While these studies highlight the wide variety of information used during the design process, there is a lack of a comprehensive framework for characterizing these types of information impacting the design process. In addition, the types of information evident during the design process in corporate engagement with open source artifacts is still largely unknown. Prior work in this area has identified that compliance information defines communal design obligations [27], historical information defines design trajectories [28],

and shared information defines cooperative design activities [15]. Building from this prior work, our study aims to develop evident information within design processes by identifying and building a foundational framework for characterizing the types of information used during the design process found in the context of corporate engagement with open source communities.

1.3 Research Objectives

The objective of this study is to advance a framework of design information dimensions and archetypes. While prior research has explored important types of information relevant to design practice in industry, no studies have advanced a typological framework for capturing the types of information used by designers to make decisions during the design process. This was accomplished through in-depth interviews with designers from large software development companies regarding their engagement with open source communities during design. Inductive content analysis was performed on the interviews to capture the types of information used to make decisions during design. From this analysis, five major dimensions of information and two information archetypes were identified. A discussion of the implications and contributions of this research are then presented.

2. Methodology

To advance an Information Archetype framework of design information, we explored select interviews conducted as part of an on-going six-year qualitative field study. The field study is broadly aimed at exploring corporate engagement with open source communities. During the field study, we conducted over 100 interviews and three focus groups with managers and developers, participated in nine different Linux Foundation conferences, directly participated in open source communities, and contributed to both open source technologies and standards.

As engaged field researchers, we treated ourselves as an "instrument of knowing" (p. 3, [29] in [30]), providing grounded interpretation of design information. Deep field engagement also allowed us to generate significantly more data and understand that data in more detail than if we simply acted as external observers. This also allowed us to build from our own reflective experiences, and as a sense-making experience, to understand the cognitive, social, and technological structures of the field, constructing a "system of meaning within which our experience is embedded" p. 7, [30]. It is through this lens of engaged field research, that the data was analyzed to identify the dimensions and archetypes of information used to make decisions during the design process.

2.1 Participants

This study examined a subset of the collected field study data. The data used in this study consisted of interviews and focus groups conducted across ten organizations (six of which are Fortune 1000 companies) actively engaged in open source development. These ten organizations were chosen for this study since the interviews conducted with these companies specifically focused on artifacts derived from open source software, and they were mature open source contributing organizations who would be able to draw from rich experiences regarding their design process. In total, the interviews included 17 individuals (2 females, 15 male). Participants were managers and developers working for corporations actively engaged in open source design and development. As part of their employment, these individuals were tasked and remunerated to directly participate with open source communities in the design and development of both corporate and communal outcomes.

2.2 Qualitative Data Coding Procedure

The selected data consisted of 11 one-hour interviews with individuals from nine organizations and one three-hour focus group interview with an additional organization, totaling 242 pages of transcribed text. During the study, participants were asked a series of semi-structured interview questions aimed at assessing their process of engaging with open source communities during design activities. The questions covered areas such as, information gathering, contributions, risk, and organizational structure.

To capture the various forms of information utilized by designers during the design process, a framework of Information Archetypes was advanced. The typological approach of building theories was used, as discussed by Doty and Glick [31]. According to this framework, a theoretical understanding of applied phenomena can be captured through the development of dimensions and archetypes that build on the dimensions. The approach of using typologies to build theory has been applied in disciplines such as organizational science and social psychology (see [32, 33]). In design, Dorst and Overveld [34] developed typologies of design practice that describe the type of activities typically conducted in the product design process. Thus, this typological approach can be used to describe the types of information utilized in design.

In order to build theory based on typologies, Doty and Glick [31] first recommend that dimensions are

built that capture specific aspects of an entity. Next, archetypes are understood as complex phenomena that are described in terms of multiple dimensions. Thus, each ideal-type "represents a unique combination of dimensions used to describe the set of ideal types" p. 233 [31]. Archetypes, or ideal types, represent a pure conceptualization of entities, and are expected to be very rare, or non-existent in empirical data. Through the act of developing ideal types, a deeper understanding of the observed space is obtained, and a theory-based framework of the phenomena can be used for further research. Therefore, this approach of building typologies was used to analyze the interviews and build a theoretical framework of information use in design.

Closely following this framework, we first developed a handbook of design information dimensions through a series of five one-hour exploratory analyses of the interview transcripts with all four authors. The dimensions were the result of discussions, preliminary analysis of the transcribed interviews, reflective experiences gained during the field study, and review of related work. These meetings led to the creation of an Information Dimensions Handbook containing descriptions and examples of each dimension. The handbook is available at: https://github.com/InformationArchetypes/Dimensions.

The dimensions were further considered beyond the initial one-hour analysis sessions. Using the handbook, the first and second authors refined the design information dimensions in the 242 pages of transcribed text using the principles of inductive content analysis [35] using NVivo v.11 [36]. Over the course of the coding process, the first and second authors met 12 times, for a total of over 33 hours. During these meetings, a deep shared understanding of the design dimensions was built collaboratively.

The first and second authors first independently coded one transcript using the handbook and met to discuss the results and build similar mental models about the design dimensions. This recursive process was repeated for all remaining transcripts. During this process, the first and second author aligned understanding of dimensions, edited the handbook to merge or refine dimensions, and reached agreement on specific sections of interview text to code. These specific sections of text were organized into blocks approximately four to five sentences in length.

Following this initial analysis and discussions, all transcripts were independently coded. The first and second authors coded the agreed upon blocks of text across the 242 pages of transcribed interview text. The inter-rater reliability (Cohen's Kappa) of all five dimensions showed an acceptable level agreement for an exploratory study [37] as seen in Table 1. After the independent coding sessions were complete, consensus across all dimensions was reached through pair coding and discussion of disagreements to resolve differences.

Table 1: Inter-reliability statistics for the five information dimensions and levels.

Dimension	Level	Cohen's Kappa
1 Information Source	External	0.60
	Internal	0.75
2 Abstraction of Information	Abstract	0.83
	Concrete	0.52
3 Generality of Information	Cross-Cutting	0.71
	Domain Specific	0.59
4 Effectuation of Information	Casual	0.61
	Effectual	0.63
5 Representation of Information	Asynchronous	0.74
	Synchronous	0.84
	Average	0.68

In the next section, we detail these dimensions and highlight their linguistic proximity to each other. In doing so, we provide a view into the evident information dimensions as well as their inductive role in advancing an Information Archetype framework.

3. Information Dimensions

Our research objective sought to investigate the dimensions of information used by designers during the decision-making process in design. Specifically, content analysis was conducted on the interview transcripts to uncover these information dimensions and their corresponding levels. In all, five main dimensions with two corresponding levels each were identified; see Figure 1. The following sections present descriptions and examples of each dimension and their levels as they occurred during the interviews.
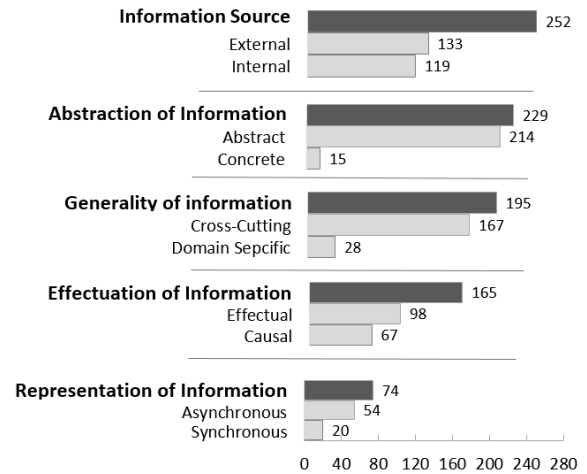

Figure 1: Number of times each information dimension (dark gray), and their levels (light gray), were found in the interviews.

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3.1 Information Source

The first dimension identified was Information Source (f=252). This dimension focuses on exploring the origin of information with respect to the individual or organization that generated the idea of the design. Thus, this dimension was broken down into two levels: Internal (f=119) and External (f=133) information. Specifically, information coming from an individual or their organization was considered Internal. For example, one participant described utilizing internal software resources in a project: "Well, with [open source OS] we've had to build it from scratch because it's brand new, so there is a lot of code in there that was originally proprietary… We do start a lot of projects where some of the code is internal, and we think that we get some advantage from making it open".

Information originating from outside the organization during the information gathering or idea generation phase is considered as External. For example, one participant described obtaining software from outside the organization during their design process: "We took the Linux kernel code and we decided that we were going to make all of these modifications to it for the [our 64-bit processor] we were working on". This result is supported by prior work that has shown that information relevant to the design process is obtained from a variety of sources, both internal and external. For example, new products in industry are routinely developed using external sources of information, such as new technologies or trends [38]. Designers rely on external sources of information to guide and inform their design efforts and ensure competitiveness in increasingly crowded markets. Interestingly, researchers have also shown that designers' own cognition is equally critical to the development and assessment of design ideas. Seminal work on design cognition has shown that design experts rely heavily on past experiences and pattern recognition in design problems to generate the most innovative and effective solutions to problems [39].

3.2 Abstraction of Information

The second dimension that was identified was Abstraction of Information (f=229). This dimension was defined as the level of detail included in the information and the extent to which the information dealt with concepts versus discrete real-life events. This dimension was divided into two levels: Abstract (f=214) and Concrete (f=15) information. Information that was theoretical in nature, or did not deal with specific instances in time were considered Abstract. For example, one participant described hypothetical and generalized information about their design process:

"And some of the code is directly related to the work that [our company] does and the hardware drivers. But we also do a lot of work that helps us in a more indirect way. We have a guy who's done a whole bunch of power optimizations in the Linux kernel... whose job is completely dedicated to that and to making things faster and more efficient and a few other things really around power consumption".

Concrete information dealt with specific details and events. For example, other participants described information related to a specific product: "If we're doing massive audio processing, low latency audio processing requires a couple gigaflops of CPU and we're talking low latency in terms of 166 microseconds, it's not going to happen in a user task, at least not with Xenomai". As seen below in Figure 2, most information found in this dimension was considered abstract. This result is supported by prior work that show that designers frequently engage with abstract levels of information while problem solving in order to maximize the effectiveness of solution finding [23]. In a sense, abstract levels of information are more easily recalled in contrast with specific instances or examples, and serve to help the designer cope with high levels of complexity in design problems [40]. However, researchers have also uncovered evidence that the ability to use concrete representations can aid in decision-making when there is a high level of uncertainty in the design [41].

3.3 Generality of Information

The third dimension that was identified was Generality of Information (f=195). Two levels were developed for this dimension: Domain Specific (f=28) and Cross-cutting (f=167) information. This dimension describes the generalizability of the information to other design tasks and projects. Domain Specific means information used is directly related to the domain of the current product. For example, one participant described software design in a specific software domain: "To provide a graphics driver for Linux, we chose to leverage the same graphics driver code base – the core code base that's used on all the other platforms. So, the core of our code for [our open driver] for kernel-level support, you know, all these different components is common across [multiple platforms]".

Cross-cutting refers to information used in the design process that is relevant across many design domains. For example, a participant described common processes used for projects across multiple domains: "Translation is big for a lot of projects. You know, it's written in English, and people everywhere else want to use it. And so, translating is a good way to contribute to projects". The results showed that designers in open

source development use both Cross-cutting and Domain Specific information in the design process, however they are primarily concerned with Cross-cutting types of information. Prior literature supports designer's usage of Cross-cutting features to streamline the development process [24] as well as the use of information and heuristics to apply generality across instances and to improve the design process [25, 26].

3.4 Effectuation of Information

The fourth dimension that was identified was Effectuation of Information (f=165). This dimension was broken down into two levels: Effectual (f=98) and Causal (f=67) information. Effectuation of Information explores the varied thinking styles of designers or design teams in addressing the design problem. Prior work in entrepreneurship judgment has shown that there are two distinct approaches to solving a problem: using existing resources to generate effective solutions to problems found in the market (effectuation), or starting with identifying a specific market need and working towards addressing that need using any resources necessary, whether available or not (causal) [42]. Information was coded as Effectual if it described how design goals are identified and pursued based on available means. For example, one participant described leveraging existing open source resources to reduce development burden on the corporation: "What we get is 90% of the system, so [we] do less than 10% of the work. We then leverage that investment to provide client value. If we were doing Linux on our own, we would have to do that other 90% instead of doing other things for our clients and stockholders".

Causal was defined as information that focused on addressing a specific goal using any kind of resource, immediately available or not. For example, one participant discussed making design decisions based solely on customer needs: "It had to be based on circumstances that were involved and you just needed to solve that customer's mission. If that was the piece of code you needed, you'll come up with the right way to do it". The results show that designers utilize both effectual and causal modes of thinking. While prior work has argued that effectual modes of thinking tend to lead to more successful creative endeavors [43], and are more frequently used by experts [42], others argue that the integration of both effectual and causal thinking are integral to strategic decision-making [44].

3.5 Representation of Information

The final dimension that was identified was Representation of Information (f=74). This dimension was broken down into two levels: Asynchronous (f=54) and Synchronous (f=20) information. Representation of Information revolves around the form of communication used to deliver information during the design process. Asynchronous is defined as information acquired using virtual tools such as email, chat, blogs, bug trackers, digital documents, and comments in code. For example, one participant described using online collaboration tools in the design process: "We've had some requests for people to use software that they found in a blog posting. And without a license attached to it, you just didn't know where it came from".

Synchronous is defined as information acquired in-person through meetings and conferences or using real-time communication tools such as phone calls and video conferences. For example, one participant discussed using communication face-to-face meetings to share information: "We invite a bunch of people who are working on key components of the Linux kernel and we bring them in and we talk and tell them exactly what [our company] is doing, why, and what we'd like to see in the kernel and how we can work better together to do that". These results are echoed by prior research that has identified the channels through which designers obtain information for inspiration during the design process [17]. In conducting research on the design space, designers may share example products with their peers through email, with a link to the example and a brief description of the product [17], while other research has shown that direct communication in the early stages of design is crucial to the creativity of the final solution [45].

4. Information Archetypes

Once the key dimensions of information were identified in this study, information archetypes were developed to capture the main groups of information found in design decision-making in open-source engagement. In advancing a typological framework on Information Archetypes, preliminary analyses were conducted on the results of the information dimensions found in the interviews. A frequency matrix was created to identify frequent overlap where dimensions tended to occur concurrently in the data. We defined these overlaps as Information Archetypes. We observed many relationships between dimensions but for the purposes of this study, we explicate Information Archetypes as combinations of information dimensions that occur at least 70% of the time on the same coding block (4-5 sentences). Figure 2 shows that while 70% was chosen as the cut-off point, relationships among other dimensions were observed less frequently. The two Information Archetypes observed at 70% were named Domain Specific & Abstract (Engaging Differences) and Concrete & Cross-cutting (Managing Complexity).
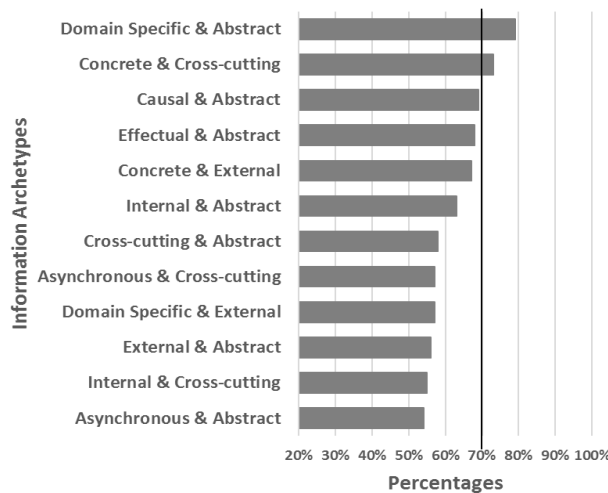
Domain Specific & Abstract
Concrete & Cross-cutting
Causal & Abstract
Effectual & Abstract
Concrete & External
Internal & Abstract
Cross-cutting & Abstract
Asynchronous & Cross-cutting
Domain Specific & External
External & Abstract
Internal & Cross-cutting
Asynchronous & Abstract

Information Archetypes

20% 30% 40% 50% 60% 70% 80% 90% 100%

Percentages

Figure 2: The top 12 co-occurring information dimensions.

4.1 Engaging Differences: Domain Specific & Abstract

This archetype was identified as information that was both Domain Specific and Abstract. Specifically, of the 28 times that Domain Specific information was identified in the interviews, Abstract information was also present 79% of the time. Thus, this was considered an Information Archetype. We further observed tertiary relationships between the Engaging Differences archetype and the External (50%), Internal (36%), Effectual (27%), Causal (23%) and Asynchronous (9%) dimensions. However, for the purposes of this study, relationships between three information dimensions was not explored due to the lower number of co-occurring 3-way relationships.

The Engaging Differences Information Archetype was observed when comparing systems to one another in relation to product differentiation. In the following example, the archetype is represented in conversations about the process of identifying and adding missing components to projects by comparing them to proprietary systems: "At the moment, [we have] a project to improve the Linux kernel and what we'll be doing is to look at [our internal operating system] and compare Linux and say, 'Well, those are the things that [our internal operating system] has which Linux is not for the moment'". The archetype is also represented in discussions where participants discuss differentiation strategies, whether the product has "a bit of differentiation in terms of features", or if "there's not much point in differentiating in them".

Prior research has shown that corporations utilize open source communities for the development of non-differentiating technologies [46] and can influence the direction of the open source community by comparing and aligning the firm's strategy with that of the community [47]. Likewise, researchers and practitioners in design theory have long since investigated the impact of product differentiation in developing effective product families [47] and increasing customer satisfaction [48].

4.1 Managing Complexity: Concrete and Cross-cutting

This archetype was identified as information that was both Concrete and Cross-cutting. Specifically, of the 15 times that Concrete information was identified in the interviews, Cross-cutting information was also present 73% of the time. Thus, this was considered an Information Archetype. We further observed tertiary relationships between the Managing Complexity archetype and the External (64%), Effectual (27%), and Asynchronous (9%) dimensions.

The Managing Complexity Information Archetype is often related to scaling systems, compliance, and optimizing shared resources. In the following example, the archetype is represented in conversations about scaling standard open source systems to improve efficiency: "We integrated the first Linux based supercomputer for a large public organization... To be able to do that you had to do some changes in the operating system to make that possible because you were running Linux on much larger systems than had been used before". The archetype is further represented in the following example, where a participant discusses open source license compliance and community standards: "We forked Memcached and Memcached is licensed under BSD so like we have to – we generally go Apache 2.0 by default but if we're working with a community, we'll go with what the community generally uses as kind of our baseline position policy".

The strength of open source software development is often attributed to the speed of development, reliability, portability, and scalability of the resulting software [49, 50] Open source software development incorporates many of the same licensing practices as the free software movement from which it evolved from. These "copyleft" licenses are integral to the open source community and a requirement to participate [51]. Prior research in open source development has shown that compliance information defines community design obligations [27] or generally speaking, the role of designers in complex design projects is evolving since designers in these complex environments are being asked to be mediators, facilitators, teachers and directors in these collaborative and often distributed design projects [52]. Research in design theory has explored product complexity and variability by

identifying and verifying cross-cutting features of systems [24] and proposing methodologies and architectures for managing and designing these complex systems [53].

5. Impetus for Design Research

The purpose of this study was to advance archetypes in an information typology framework for understanding the types of information utilized by designers in the design process. This was addressed by observing designers engaged in open source communities and exploring information usage in design. The main contributions of this study are:

- Information dimensions used to characterize the open-source design process.
- Information Archetypes identified from relationships between information dimensions.
- An emerging typological framework that integrates information dimensions and archetypes for understanding the types of information utilized by designers in industry for making design decisions.

One of the main goals of this study was to identify the dimensions of information utilized in the design decision-making process. Our results showed that five key dimensions of information emerged from the empirical data, each with two corresponding levels. The presence of these dimensions in the design process is supported by previous literature as discussed earlier. Furthermore, our analysis revealed that Abstract and Cross-cutting information types were heavily used in open source development. This finding is supported by prior literature that has also explored these issues [24, 39]. In contrast, other concepts highlighted in previous research such as the use of analogies as an information type was not identified in the interviews. The use of analogies in design is supported by prior literature that has shown that creative insights may originate from analogical comparisons of two or more very distant domains [54]. However, the lack of strong evidence of analogical reasoning in the interviews points to potential differences in decision-making when reflecting about design retrospectively in the current study, compared to during design activities.

We found too that the dimensions of information have a distinct pattern of co-occurrence in the in-depth interviews. These patterns of co-occurrences were identified as Information Archetypes, and fall into one of two "ideal types" of information: Engaging Differences and Managing Complexity. This finding has implications for understanding design decision-making. Since these archetypes were formed from co-occurring information dimensions, it suggests that

potentially meaningful patterns of information usage exist in design decision-making. This finding builds on prior research in design that shows that designers interact with a variety of information sources, types, and activities during the design process [17, 55], and goes one step further by advancing a framework that structures these information types. Additionally, the resulting framework of Information Archetypes in design advances our understanding of design cognition as it occurs in industry, explicating systematic information use in complex design environments.

6. Limitations and Future Work

While this exploratory study was successful in advancing a typological framework of Information Archetypes, there are several important limitations that should be noted. First, the use of the typological framework for theory building as developed by Doty and Glick [31] has limitations, which also apply to this study. Specifically, the "ideal types" identified through empirical work may not necessarily predict any outcomes, and may not be constant in different research contexts. Therefore, further work is needed to investigate the use of these Information Archetypes as they occur in design activities and discussions, beyond retrospective interviews with designers. Another important limitation of this study is the limited number of interviews utilized for analysis. Therefore, future work should expand the analysis of information use using a larger corpus of interviews with designers in industry. Lastly, the interviews analyzed in this study were conducted with high-level managers and supervising developers involved in large-scale corporate environments. Therefore, it is not clear how non-managerial developers utilize information during their design process, or how these archetypes translate to different levels of personnel. More work is needed to identify potential differences in information usage depending on organizational role.

7. Conclusions

The main goal of this study was to advance and empirically test a typological framework of Information Archetypes. By understanding the types of information utilized during the design process and their relation to one another, we contribute to fundamental theory on design practices. This was accomplished through in-depth qualitative interviews with large software engineering companies actively engaged in open source development, and analysis using the principles of inductive content analysis. The result of this exploratory study reveals five Information Dimensions that constitute two distinct Information Archetypes

utilized by decision-makers within these companies during the development of new products and services. Further research into the nature of these archetypes will contribute to the quality of design outcomes and training of the next generation of and designers.

8. Acknowledgements

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