RE-THINKING DESIGN REPRESENTATIONS IN DESIGN EDUCATION: AN INTERVIEW STUDY WITH PROFESSIONAL DESIGNERS

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ABSTRACT

Design representations are important tools for designers in the design process. To help designers choose the appropriate representation, taxonomies have been proposed based on type, degree of fidelity, and when to use them. However, Design representations may also play an important role in designers' communication with users and enabling users as co-designers. Therefore, new taxonomies, focusing on design representations' potential mediating roles in collaborative design processes with users, have been developed. The purpose of this interview study, with twelve designers within Swedish industry, was thus to investigate how designers use design representations in communication with users in the design process. The study indicates that the designers mainly interacted with users in order for them to answer specific design questions or to evaluate design solutions. If design representations' value for facilitating communication and collaboration with users should be emphasized, we need to shift from teaching mainly taxonomies related to fidelity levels or when to use them in the design process, and rather educate future designers about design representations inherent potential to mediate and enhance the dialogue with users.

Keywords: Design representation, Collaborative design, Design education, User centred design, Representation TaxonomiesTax

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1   INTRODUCTION

Design representations are important tools in the design process and "critical to design thinking and practices required in an activity aimed at exploring preferred futures" (Pei and Self, 2022). Accordingly, they have received considerable interest from design researchers.

A common theme in design studies has been designers use of design representations as means to support their own thought processes (e.g. Goldschmidt, 1991; Lim et al., 2008), externalise mental concepts (Schön 1983; Goel, 1995), explore ill-defined design problems (Visser, 2006) and transition from conceptual to more detailed designs (ibid.). Several studies have over time focused on the role of traditional media. For example, Goldschmidt (2014) analysed the role of sketching to develop a deeper understanding of the nature of design problems, and Do et al. (2000) interpreted designers' thinking as part of an investigation that focused on design drawings. Other research has been concerned with the impact of digital media, for example, Bilda and Demirkan (2003) compared the effects of using CAD and sketching in the early conceptual design phase.

Design representations are also essential tools for designers in communicating and sharing their intentions, ideas, and solutions with other members of the design team. Design research on how different representations enhance collaboration between the different disciplines includes, for example, Stompff and Smulders (2014), who observed the boundary spanning capabilities of different representations in multi-disciplinary development. In another study, Buskermolen and Terken (2012) investigated how and why designers choose certain design representations for discussing and collaborating with internal stakeholders.

A third context where design representations play an important role is designers' communication with users. Some efforts have been made to understand if and how representations may facilitate the dialogue between designers and users, (e.g., Engelbrektsson, 2004). The role that design representations may play in supporting users as co-designers in design projects has also been addressed, for example, by Cain (2005), Dorta et al. (2019) and Eriksson et al. (2021), but considerable emphasis has also been placed on which design representation to choose in supporting users in their role as evaluators, including what reactions different types of representations evoke (e.g. Reid et al., 2013) or what level of fidelity is appropriate for valid evaluations, not least in usability testing (e.g., Walker et al., 2002; Sauer et al., 2010).

In a parallel stream, different taxonomies have been proposed to describe the types of representations used by designers in different situations and support designers in their choice of representation. Pei (2011) proposed a taxonomy for visual design representations according to their type, while other taxonomies are based on the design process and the stage in which the representation is or should be used (Ullman, 2002). An often-mentioned classification is expressed in terms of levels of fidelity and how closely the representation represents the final product (e.g. Preece et al., 2002; Ulrich and Eppinger 2012). However, other approaches have been suggested, one such example is Houde and Hill (1997), who proposed a classification based on the purpose of the representation in evaluations, and another is Petrakis et al. (2019), who also presented a taxonomy based on the purpose of the prototypes. Eriksson (2014) proposed instead a taxonomy based neither on the types of representation, nor their place in the design process, but on the different mediating roles that design representations are given (in the specific case) in multi-disciplinary co-design.

This paper is concerned with the latter themes: firstly, professional designers' choice and use of design representations in their dialogue with users, and secondly, whether professional designers share a taxonomy by which they describe the representations used and on which basis their taxonomy is shaped (e.g., type or purpose). The findings carry implications for design education as future designers must learn not only to produce design representations but also choose, create and use the best option for a defined purpose.

2   THE STUDY

The study consisted of semi-structured, in-depth interviews with twelve professional Swedish designers (D1-D12), six men and six women. After six interviews, a saturation of information was reached; however, six additional interviews were conducted to elicit potentially new, additional information.

2.1 Participants

The designers were active in different industrial domains, ranging from medical applications and protective equipment, to automotive, furniture and interior design, or were employed by design firms undertaking assignments for a diverse range of products. The companies differed in size, ranging from large enterprises (with between 1500-1700 employees) to micro companies (with 5 employees or less). Some of the participants were trained in industrial design engineering with a specialisation in design and human factors from different universities in Sweden, while others had a university degree in industrial design, product design, product development or fine art.

2.2 Procedure

Prior to the interview, the designers received written information about the topic of the study in order to sensitise them to the topic, (cf. Sleeswijk-Visser et al. 2005). All interviews followed the same interview guide and lasted between 40 and 75 minutes. The participants were first asked to describe their company's design process, their role at the company, and tasks performed on a daily basis. In a second step, they were asked about their interaction with users to explain if and how they used different representations in this process, and more specifically about their view of physical versus digital representations. They were probed to convey their own taxonomy of design representations, and finally, to consider the taxonomy proposed by Eriksson (2014) (see Table 1). The taxonomy was presented in tabular form, and the participants had an opportunity to consider the content for a while before being asked questions about their own experiences related to the proposed roles.

Table 1. Roles and explanations

Category	Description
Visualiser	Facilitates the externalisation of mental images; concretises mental representations and aids recalling or adapting mental images to make them more comprehensible for others
Verbaliser	Fills in where words are missing; supports explanations of the meaning of words when words (terminology) are not understood; helps to put words to a problem
Demonstrator	Is concrete to its nature and provides evidence of the existence of 'something'; provides practical explanations or shows the operation or use of something
Stimulator	Encourages the process whereby an individual becomes inspired and supports the generation of new ideas and a sudden insight of 'something'
Integrator	Facilitates the integration of different perspectives, supports the internalisation of new knowledge; facilitates unification of different perspectives

The majority of the interviews took place face-to-face in the designers' respective work environments, but two were conducted over Skype. All interviews were recorded with the consent of the participants, and the recordings were later transcribed verbatim for analysis.

In order to search for patterns in the empirical data, a thematic content analysis was carried out, following the process recommended by, for example, Elo and Kyngäs (2008) and Miles et al. (2014). This meant reading through the transcripts, identifying, coding and reviewing relevant themes. The interview questions formed initial themes, but in the coding/reviewing process, iterating between the specific and the general, other themes were allowed to emerge. Examples of themes are: Which representations are used? With what purpose(s)? Which factors guide the designers' choices of design representations? Do they share a common taxonomy? On what basis does the designers' taxonomy/-ies appear to be shaped? Do they recognise a taxonomy based on mediating roles? The analysis was performed by the first author but was regularly reviewed in discussions with the co-authors.

3 FINDINGS

In the following section, the findings are presented under headings, which follow the identified themes of relevance for the paper.

3.1 Use of design representations

All participants created and used various kinds of design representation in their daily work, including "handmade sketchy sketches", card-board models, physical mock-ups, digitally created images and CAD drawings. However, there were also those who described other types of representations such as samples of material (e.g., fabrics, pieces of metal or plastics) and existing physical products.

The designers were all well aware of the potential of design representations to communicate design intents and design solutions and extensively described how they used the specific characteristics of different representations, partly for themselves to explore ideas and potential solutions, and partly to communicate their ideas and design solutions to users. They emphasised that they considered users' knowledge and experiences in relation to the intended product and its use in context as "... extremely valuable" (D6), and to facilitate their interaction with users, they brought design representations of various kinds to meetings: "If you need to find out some details like ... in a handle... then it may not necessarily be the product itself, it can be other representations of, for instance existing handles ... so we get as much input as possible which we can relate to..."(D6).

The designers used representations with various levels of fidelity to explore and identify design elements and their potential to be included (or not) in the intended design: "…then you design something ... a prototype, they [users] could have a look and were invited come up with reactions and then they can make a ranking of different things – 'do you want this or this'?" (D8).

A few described that, if they had the opportunity to meet users early in the design process, their ambition was to keep the representations "open" to facilitate idea generation for the intended product and avoid "... steer[ing] the users in a certain direction towards a solution" (D8; D9; D10). However, others had experienced that such open representations could give an unprofessional impression and therefore hinder the intention to ideate with users (or other stakeholders). One designer described such a situation: "It was too sketchy, and a bit sloppy-like when we presented the concepts, and it didn't turn out so well I think" (D5).

The most common approach was to use the representations to communicate and evaluate design solutions fairly late in the design process. Consequently, the representations used were most often physical representations with a high level of fidelity, and the dialogue with users focused on getting feedback on the design ideas – not generating new ideas – and acquiring input to reduce the designers' uncertainty regarding specific design solutions, not co-creating solutions per se: "I had developed a few new prototypes, and I showed them [users] the prototypes, and they evaluated them, and we went through them [the prototypes] and their respective pros and cons, from a user perspective, from their side, but also from a patient perspective…everything from handling to the CE marking process" (D12). It did not appear as though the designers used representations early in the process to facilitate the elicitation of information on users' knowledge, experience of usage, use situation and use context (cf. Engelbrektsson 2004).

Earlier research has emphasised that product representations, besides being used to provide feedback and confirmation concerning whether requirements have been correctly understood, may possess a much broader and more diverse capacity to act as mediating tools in different collaboration contexts (Buur and Bødker, 2000). The designers' viewpoint was, in line with Brandt (2001; 2007), that design representation could bridge language barriers between users and designers. However, they seemed less aware of design representations' potential function as mediating tools to facilitate, not only the design process, but also a dialogue beyond design solutions and design perspective. This was exemplified by one of the designers: "Mmm, it's easier to communicate when you have things /.../but I never thought of that myself, that it can create such a ripple effect [for communication]" (D1).

3.2 Choice of design representation

Although the importance of using design representations was generally acknowledged by the participants, many of them expressed difficulties in selecting the appropriate representation for the intended purpose, as potential mistakes could result in irrelevant feedback from users. The designers emphasised that the level of fidelity had to be carefully considered in relation to the intended purpose of the design representation but underlined at the same time that they faced a dilemma when choosing the representation. It was "... difficult to determine and balance which level you should go for with different types of representations – customers expect a "WOW!" effect when something is shown to them" (D5).

Examples were provided of "unsuccessful" strategies. One designer described, for example, a project where the intention was to explore users' ideas for new applications regarding an emerging generic technology and how this technology could contribute to and affect the user's work and/or home environment. The choice was to use a design representation where the technology had been embedded in well-known and familiar everyday products as the designer believed it would facilitate users' understanding of the inherent potentials of the technology. However, the strategy of creating these high-fidelity product concepts became instead a barrier to the intended exploration and ideation; the representations appeared to preclude further exploration since it was "too close to the finished product" (D4).

Over the years, industries have promoted and invested profoundly in digital tools, with the aim to streamline the development process, and it has been argued that digital tools and virtual representations will replace physical representations in the design process (e.g. Gupta et al., 1997; Kuutti et al., 1997). It was therefore of particular interest to hear the designers' views on the matter.

Many of the designers confirmed that such a strategy seems to be in line with their respective organisation's intention. Digital representations are, according to the participants, often considered more attractive and stand higher in the 'hierarchy' compared to physical representations from a management perspective. However, this conflicted with the designer's opinion about their needs in their daily work. Despite the designers agreeing that digital tools are supportive and critical to their exploration of design ideas, they argued that physical representations 'stand above' digital ones in creating an understanding of the design and are essential for ensuring the design quality in the design process: "You can discover mismatches and problems earlier in the design process – you don't see that in a digital representation in a preferred way" (D1).

Overall, the designers showed a greater awareness of differences between the potential of digital and physical representations to communicate design solutions or future design ideas with users than they did differences between physical prototypes of different levels of fidelity. However, regarding physical design representations, the designers stressed the importance of tangibility, of being able to interact physically with the representation to explore design attributes and create a common understanding of 'something'– for the designer themselves but also equally for users. This was expressed as: "With an image you can visualise an idea, but it creates no understanding or sensation of the product like a physical (representation) does" (D6) and "With the physical representation I can make people understand the design" (D2). In this case, the designer described a mediating effect where the representation was "... a door opener, as people can interact with the representation, which can stimulate new ideas to emerge" (D2).

Digital representations were, on the other hand, described as something that do not fully support the understanding of the design: "It is almost impossible to validate anything else than the colour and shape of the product" (D3). They could can have a seductive quality which the participants thought may result in invalid evaluation results: "It [the digital representation] can look too good; and later when they [clients or users] see the physical model they do not understand that this is how it will be in real life – the digital version looks too good, and they wonder if it is the same product, and I have to say that, yes this is how it will be in real life" (D1). Nevertheless, all informants shared the view that digital and physical design representations need to co-exist during the design process.

3.3 Understanding and taxonomy

Regarding a shared taxonomy of design representations, the majority of the participants shared the same understanding of, and referred to, the term 'design representation' as "something that embodies something" in the forthcoming product. As regards the word 'prototype', the designers had different interpretations. Some of them used the term in relation to a more traditional taxonomy (cf. Ulrich and Eppinger, 2012), which one informant explained: "Prototype is a word used improperly. At that moment, everything should be ready – no more searching, it's about checking if your theories [design solution] is correct" (D3); others referred to 'prototype' in ways comparable to the definition by Houde and Hill (1997), that is, that "anything that represents a design idea can be referred to as prototype".

As already pointed out, all interviewed designers created and used various types of design representations. The physical representations were referred to as 'models' or 'prototypes' and differed in the described level of fidelity depending on the designers' perception of the taxonomy. Those with industrial design educations, employed in domains characterised by more traditional product design,

often described the physical representations used as 'functioning models' (to explore or test a specific function), 'design models' (to explore shapes and the interaction of components and structures) or 'appearance models' (to communicate the appearance of attributes). The designers from more specialised industries, such as the automotive and textile sectors, seemed to have adopted a more domain-specific terminology. For instance, the designers employed in the automotive industry also used models with different levels of fidelity, in this case 'clay models', which were most often used to communicate shapes and aesthetics; 'plastic models', which referred to mock-ups that could communicate visual design and/or test functional design; and 'plastic car', which referred to prototypes with a high level of fidelity. The designers from the textile domain referred instead merely to materials or models. Materials ranged from pieces of yarn to manufactured sample fabrics, typically used early in the design process to explore, test and communicate certain properties of materials, while the term 'prototype' implied a later stage in the design process and indicated that "something" was made of the material by combining different materials to reflect the intended future product.

The designers primarily used design representations for different evaluation purposes, and their taxonomy reflected this type of use. Nevertheless, their reactions to the taxonomy proposed by Eriksson (2014) were in most cases recognition and acknowledgement. They recognised and had, in different ways, experienced or could see the need for the different mediating roles in different situations (see Table 2), but at the same time they seemed more familiar with roles as Demonstrator, Visualiser and Verbaliser than the other roles.

Table 2. An excerpt of designers' comments on the taxonomy proposed by Eriksson (2014)

Category	Comment
Visualiser	"There is a big need to visualise things when you talk to people" (D9).
Verbaliser	"[It is] needed all the time ... It is so difficult to find a common language, especially in new innovation projects" (D4). "You do not have the same words for what you want to achieve..." (D9).
Demonstrator	"Useful to illustrate something very concrete" (D7). "Something that could facilitate building trust between users and designers" (D11).
Stimulator	"Just the thought of a stimulator, it really helps" (D5). "It becomes a stepping-stone for new ideas" (D5). "As a stimulus to get people to talk to each other" (D10).
Integrator	"It helps to increase the understanding between different perspectives" (D8). "It facilitates the integration of different perspectives which in turn may generate new ideas for the product" (D12).

The majority were of the opinion that the proposed taxonomy had potential, and could be, "... an important tool to remind designers of how to facilitate communication" (D6), as well as a tool that could help them "... move away from choosing A or B and rather become more aware of how to use design representations to support collaboration" (D5). Moreover, they suggested that the taxonomy could "create awareness of the potential functions of design representations in communication" (D4) and support designers in "more consciously support[ing] dialogues and understand[ing] that you can use different ways to clarify something" (D9).

In contrast to taxonomies based on level of fidelity and/or when using the design representation in the design process, the proposed taxonomy extends beyond embodied aspects of design per se. Instead, the taxonomy builds on the function of design representations in mediating the dialogue between designers and users, with the aim to enable a shift from users primarily (or merely) providing feedback on something proposed to them to users participating in the design process with their knowledge and experiences of use and use domains. Even though a few participants (two) thought that the proposed taxonomy was somewhat abstract, it was by mostly perceived as liberating: "it is so good that the roles have been abstracted into functions for communication rather than focusing on the design attributes" (D9) and "this is the first step to understand how we can concretize design representations' function for facilitating communication" (D8).

4   DISCUSSION AND IMPLICATIONS

According to the interviews, the designers frequently used different design representations, but for user involvement they used primarily high-level fidelity representations in evaluations where they wanted to attain feedback on specific design-related questions and design solutions. It is also evident that, even if they did not share a common taxonomy, their (explicit or implicit) taxonomy was primarily based on level of fidelity. They were aware of the importance of design representation and equally that one should choose an appropriate representation. However, in line with findings by Buskermolen and Terken (2012), they also showed uncertainty about what representations to choose in different situations. In particular, their concerns appeared to centre around the representations' readiness or similarity with the final product in eliciting valid evaluation results.

This probably reflects the amount of debate on the topic (Ulrich and Eppinger, 2012; Pei, 2011). There is, for example, an abundance of advice on which prototypes or prototyping tool to choose for validation purposes in the academic literature (Houde and Hill, 1997; Ullman, 2002; Stompff and Smulders, 2015), but even more so on different Internet sites and fora, compared to a rather limited discussion on representations as mediating tools to enable users to communicate their needs and requirements, as described by Karlsson (1996), Engelbrektsson (2004) and Brandt (2007). Even less importance appears to be placed on how to create and choose product representations in order to shape the best enabling conditions for co-creation (exceptions being, e.g., Cain, (2005); Eriksson, (2014)), although the importance of, for example, prototyping is acknowledged as it makes it "...easier to share and develop knowledge in a common language, unbounded by barriers between disciplines or hierarchies" (Sheard et al. 2019) (interpretation of prototype as proposed by Houde and Hill (1997)).

A specific theme in the interviews was digital design representations and their role in the designers' process. The justification for introducing and expanding the use of digital tools in product development is that they can contribute to reducing project lead time as well as increase cost efficiency in product development, but from a designer's perspective, the argument is that they can aid designers to visualise ideas and communicate design attributes (Bailey et al., 2012).

It was apparent that the designers had faced the rhetoric connected with digital tools but also that their relationship to these tools and digital representations was bifurcated. On the one hand, they embraced the benefits of visualisation design attributes or the simulation of functions with digital tools. On the other hand, they often felt squeezed between the organisation's emphasis on the digital tools as masters and prevailing over the physical when they themselves felt that the physical representations were directly decisive in their design process for understanding and communicating the design. The digital representations were perceived more as tools that supported their process. Similar experiences have been described by Bailey et al., (2012).

The are several implications from the interview study for design education. The importance of teaching designers how to produce design representations is generally acknowledged in different papers on design and engineering education. Berglund and Grimheden (2011), as well as Berglund and Leifer (2013), have argued the value of teaching prototyping for increasing students' creativity and innovation. However, if the results from the interviews are representative of professional designers' knowledge (and the lack thereof), design education must also be more concerned with the role of design representations in communication with external actors, as well as how to choose the most appropriate design representation for a specific purpose, how to make use of design representations and other mediating tools in different contexts, and the mediating roles that design representations could have in order to facilitate, for example, user involvement in the design process.

Furthermore, the use of digital tools in companies will evidently mean that students must also learn the production of digital representations. However, the professional designers that took part in the interviews emphasised the importance of the traditional, physical, representations – for their own design process as well as for their dialogue with users and other external stakeholders. However, the designers also mentioned how the visual qualities of digital product representations in some cases resulted in exaggerated, positive responses by external actors. It is possible that the representations in these cases were not produced with sufficient knowledge about what is required from such representation in order to persuade, compared to trigger, feedback on the overall design or elicit new design ideas in co-creative processes. The experiences described indicate that future designers need to become more aware of potential obstacles and/or dilemmas related to the use of digital and physical design representations, respectively, and how the different media could complement each other.

Teaching activities on how to make use of digital representations, their pros and cons and the challenges associated with their use (Soderman, 2005; Tiainen et al., 2014), must also be part of the design education curriculum.

Design representations are important in most user studies, but the increasing emphasis on co-design with users makes understanding how design representations can facilitate communication and collaboration between designers and users more important than ever. The taxonomy proposed by Eriksson (2014) could, as suggested by the designers who participated in the interviews, be a tool in this process, for a more thought-through choice of physical and/or digital design representations, but it could also encourage the use of other representations in terms of, for example, pieces of materials, etc. (as also described in the interviews). As the taxonomy does not refer specifically to fidelity levels or media, the taxonomy could support designers to change their focus on a choice based on the type of representation in order to focus on a purpose. The proposed different roles have specific mediating functions (i.e., demonstrators, verbalisers, visualisers, stimulators, and integrators), and the embodiment, that is, the physical or digital form that the representation takes, is decided with the specific mediating function in mind. This means that they can be requested and appear at any time throughout the design process.

However, for the taxonomy to become a tool, and a complement to existing taxonomies, it must be placed in a learning context. In the master level course 'Advanced User Study and Co-Creation' at Chalmers University of Technology, Gothenburg, Sweden, the authors (first and second) have adopted a new teaching approach with the purpose to enable design students to become more aware of the mediating functions of design representations in co-designing with users. At the start of their co-design projects, the students have lectures about co-designing with users and the importance of mediating this activity to facilitate communication and collaboration cross-borders with people not trained in design. Initially, the students most often confirm the findings of the present study, namely that the design representations are seldom consciously used to specifically enhance the dialogue with the users but rather facilitate users in expressing ideas or requirements. However, there is a shift when lecturers meet students in teaching seminars for collective reflection of their experiences in co-creation activities. During these sessions, the students show progress from having expectations and collecting new design ideas and solutions, or information on users' immediate needs and requirements for the future product, to having a greater awareness of the need to facilitate the dialogue with users in order to externalise and incorporate their specific knowledge and experiences in the design work. The students thus become increasingly aware of the need to consider, not only how design representations are used to create such mediation, but also what they may mediate to bridge perspectives and support knowledge transfer in complex design situations.

5 CONCLUSIONS

In summary, the interviews shed light on designers' choice and use of design representations in design and product development.

- The interviewed designers frequently used a range of design representations, such as sketches, physical models, or digitally created visualisations in their daily creative work – to support their own design process as well as when interacting with users.
- They showed awareness of the potential of design representations to communicate design intents to different actors, including users, project members, managers, and other stakeholders. However, they seemed less aware of the potential of design representations to facilitate communication and collaboration with users, support designer-user dialogue and co-design activities.
- When interacting with end-users, the designers chose high-level fidelity design representations in order for users to provide feedback on specific design-related questions and design solutions. At the same time, they expressed uncertainty regarding what type of representations to choose in different situations and for what purposes. The designers' taxonomy of design representations appeared to be based on the level of fidelity, and their concerns centred around the representations' readiness or similarity with the final product to elicit valid evaluation results.
- The designers acknowledged the benefits of digital tools but had concerns about their organisation's (over)emphasis on digitally created design representations as they found physical representations to be superior to digital representations in communicating design solutions.

- The increasing importance of co-creating with users and enabling a shift from users providing feedback on something proposed to them to users participating in the design process with their knowledge and experiences, makes understanding how design representations can facilitate communication and collaboration between designers and users more important than ever.
- The proposed taxonomy could be an important tool in this process for designers to make more informed choices of representations for communication as the taxonomy does not specifically refer to any levels of fidelity or types of media. Rather, it focuses on the mediating roles of representations.
- However, for the taxonomy to complement existing taxonomies and become an efficient tool for designers, and for representations to be used accordingly in mediating communication and co-creation with users, these matters must become part of design education curricula.

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