Design, engineering design, creation, towards an interdisciplinary theory of design

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1. Introduction: creation, creativity, engineering design

The relationships between design and creation are both essential and the subject of great tension, both from the point of view of creation and creativity. To simplify, in this paper I will distinguish these ideas in the following way. On one hand, creation, referring to a specific profession in the context of a division of labour from engineering design to manufacturing, or corresponding to a sector of activity, what we call the ‘creative’ industries: audiovisual, music, publishing, fashion, design, architecture, advertising, live entertainment, visual arts, etc. (Paris 2007). On the other hand, creativity is an inventive aptitude, which is present to varying degrees in each individual and used in all professions when a problem arises requiring the development of an original solution.

Today, design is associated both with creation, especially author design, and creativity, notably in the implementation of design thinking or co-design approaches in innovation projects involving several stakeholders. There is often a tension between these two visions: the proponents of creation reproach those of creativity for ignoring the specific knowledge and expertise of the profession, while the advocates of creativity reproach those of creation for their distance from innovative projects in companies and the associated managerial issues.

To overcome this opposition, I will reaffirm certain points. I differentiate creation from the approaches that often only refer to author design and aesthetic design. To grasp the distinctive way in which design approaches creation, I will show how it is based on an original position in engineering design projects, between engineering and human sciences, by using its own tangible methods and realisation techniques.

When it comes to creativity, I will distance myself from other approaches that are essentially based on a list of psychological skills or personality traits. Without denying the fact that they can play a role, I will focus on analysing the conditions of stakeholders’ engagement in the process of generating ideas and sketches. What I call relationship design is the ability to bring together participants with complementary points of view into a suitable spatial and temporal environment that I consider to be driving creativity. Unlike artists, who often must cultivate a certain detachment, designers must include various stakeholders, at the forefront of which are users, to design creative solutions in often complex engineering design projects.

Whether regarding creation or creativity, I will focus on the way in which design sciences position themselves within engineering design sciences, also known as sciences of the artificial (Simon 69). Engineering design can be very broadly defined as an activity aiming at solving problems that are not well defined (see Visser 2009), but especially in which the client’s expectations interfere with the way the problem is addressed since the artefacts to be designed are intended for this client, whether private or public, or society as a whole in case of general interest issues (Simon 69). In engineering design sciences, one can distinguish upstream design phases (Bouchard 2011), devoted notably to the development of the concept, and downstream phases devoted to detailed design, testing and improvement. It is in the upstream phases, which are less formal and more strategic, that design sciences are most frequently called upon.
Engineering design sciences bring together a very large number of scientific or artistic disciplines, which have in common the creation of artefacts (Simon 69), not the discovery of general natural laws. These disciplines notably include engineering sciences, medicine, management sciences, artistic disciplines, architecture, education, ergonomics, sociology of usages, etc. and of course design sciences, which while relying on other disciplines, develop a specific approach that I will try to clarify.

Whether it is creation or creativity, I will focus on how design sciences bring together, to achieve its end, many disciplines, both humanities and engineering sciences, as well as realisation techniques that are traditionally found in applied arts. From this point of view, my vision of design sciences is similar to what is put forward, for example, in information and communication sciences or education sciences, which are defined as 'object-oriented' inter-disciplines combining different basic or specialised disciplinary skills to address the questions asked. This interdisciplinary approach to design, which is consistent with that of authors such as W. Jonas, who prefers the term transdisciplinarity (Jonas 2011, see also Findeli 2015), will allow me to offer an original classification of practices and design skills.

2. Distinction between author design and systemic design in engineering design sciences

It is common to distinguish between author design and industrial design. Although this distinction is sometimes debated, it makes it possible to roughly differentiate two main ways of doing things and to avoid certain ambiguities when one talks about roles and jobs in design. In the most traditional form of 'author design,' designers often even make several fully operational prototypes that bear their signature. Although the number is larger, and the designers do not produce the object itself, aesthetics are an essential component of artefacts that often belong to object design. The signature of the designer is an essential symbolic dimension of the work. This characteristic is rarer in interaction design or service design.

Conversely, in industrial design, designers do not usually participate directly in the material production of operational artefacts but contribute, in the early phases of engineering design, to the invention of some of its properties. This input takes place in the context of cooperative work with other designers and is not necessarily related to the aesthetic characteristics of the artefact.

From this point of view, the expression 'industrial design' does not seem relevant. It became widespread because designers were first employed by the industrial sector to design objects. At a time when the dominant trend was the growth of interaction, service and organisation design, the use of the term 'industrial' was misleading. For this reason, I propose replacing it with systemic design (see for example Jones 2014). This denomination therefore means that the value of the designer’s work is essentially independent from the handcrafted process and the creator’s signature on the object, as it can be in author design, but that it resides in the designer’s inventive contribution in the upstream phases of the engineering design work, in cooperation with other designers, without this input necessarily bearing the aesthetic characteristics of the object, interface or service. This contribution explicitly mobilizes the different dimensions of the artefact in engineering design, and engages a variety of contributors and stakeholders in relationship design.
The reputation of some systemic designers (in the sense of my definition) is of course also an important issue. But this reputation is not necessarily based on the ‘artistic’ dimension and the author’s signature. As in other areas such as consulting or architecture for example, it is based on the realisation of significant projects for well-known clients, on the prospective vision of the practice, its link with research, etc. If it can be embodied in the director’s name, it is actually carried by a team and the service dimension of the delivery may be as important as the object.

Although, to date, I cannot rely on empirical quantified data, my working hypothesis is that author design is now a reality that is marginal in terms of employment. For a few hundred author designers who put their name to artefacts by giving them a symbolic value, there are several thousand systemic designers engaged in industry or services as employees or service providers, designers whose creativity is equally remarkable and useful, but less visible than that of author designers. My attempt to classify them will therefore focus on systemic design which, according to my hypothesis, applies to most jobs. My argument will follow the three-dimensional classification of design practices, whose structure is detailed below.

3. Three-dimensional classification of design practices

In the rest of this paper, I will offer a multidimensional classification of systemic design practices of which I will discuss three approaches. The first, shown in Figure 1, corresponds to the type of artefact to be designed. The second (Fig. 2) refers to the dimensions of the artefact considered in the creative work, whatever its type, i.e. concept design. Finally, the third approach (Fig. 2) corresponds to the modalities in which engineering design players engage in the creative process, i.e. relationship design.

Designers’ input can be qualified through several approaches (Fig. 3): from the point of view of their competences relating to the type of artefact (object, interaction, service, etc.), from the point of view of their competences relating to concept design (form, function, experience, etc.) and finally from the point of view of their competences relating to relationship design (design thinking, co-design, etc.). Experienced designers have several competences in these different areas.

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**Fig. 1. Classification of design practices by type of artefact.**
Fig. 2. Breakdown of systemic design according to the approaches of concept design and relationship design (independent approaches).
4. First classification based on the type of artefact

If the role played by designers in engineering design projects is increasing, this extension of the field of design, to use Vial’s expression (2015), is mainly done by annexing existing professional practices that were so far differently named. This extension is due to current trends and encouraged by the business world’s unlimited love for Anglicisms, but it can also be considered from a different perspective, as an argument for the inclusive and interdisciplinary definition that I would like to give to this field. Among these extensions, let me quote, without being exhaustive, the fact that in certain contexts, Human-Computer Interaction (HCI) is replaced by ‘interaction design,’ scenography by ‘space design,’ certain computer graphic disciplines by ‘game design,’ animation by ‘motion design,’ interior architecture by ‘interior design,’ etc.

Faced with this proliferation of new names, I will use three dimensions to organise design practices. I will do this from a French-speaking perspective, in which the designer’s job is quite clearly separated from that of the engineer, a differentiation that is less clear in the English-speaking world. According to the first approach, the
classification is based on the type of artefact to be designed. According to the second and third approaches, on which I will focus in more detail, the classification is based on the type of activity carried out by the designer during an engineering design project. Regarding the classification based on the type of artefact, I think that it is possible to roughly group together the dozens of current names into five broad categories that partly overlap Buchanan’s four categories (1992): (1) visual and symbolic communication, (2) material objects, (3) organised activities and services, (4) complex systems or everyday life environment, games and learning.

The name of these categories can of course be discussed and amended, the main objective here being to produce a simple diagram, even if design schools themselves use dozens of different names for their training courses, without covering all the specialties that I mention here (for example, the ten departments of the Ecole nationale supérieure des Arts Décoratifs in Paris do not include service design).

- **Object design** refers to the engineering design of all tangible and non-digital artefacts (or non-digital components of these artefacts) including, for example, in addition to furniture and cars, textiles, materials, flower arranging, etc.
- **Visual and information design** includes graphic design, but also photography, video and animation, data visualization, etc.
- **Interaction design** refers to the upstream engineering design of human-computer interfaces through screens or other devices, i.e. the control systems of artefacts made interactive through digitalisation in everyday and professional life (Human-Computer Interaction).
- **Service and/or organisational design** in the very broad sense notably refers to the upstream engineering design of service processes including users in the private or public sectors through a variety of media, objects and spaces, which may include the social and political issues of social design.
- **Environmental design** includes, at very different spatiotemporal levels, urban design, space design, interior design or even scenography.

In the rest of this paper, I will use the term ‘artefact’ to describe ‘the engineering design object,’ whether it is a tangible object, a service, a Human-Computer Interface, a scenario or an organisation. The term ‘artefact’ therefore does not always refer to something ‘material’ but to an object ‘made by a human being,’ even when the medium used is purely gestural and ephemeral. Different design practices can be used in the upstream engineering design of a complex artefact (object, interaction, visual, etc.) and they may, if necessary, be entrusted to different specialists.

5. **Second classification based on the dimensions of the artefact (concept design)**

With the second approach, I considered the role of the designer in the design process, regardless of the type of artefact. Concept design refers to the practices and thinking that lead to ideas, sketches, diagrams and models that prefigure the artefact to be designed. The third approach, which I will highlight in the next section, focuses on relationship design and refers to practices driving the engineering design process that organises creativity and inventive cooperation. Within concept design, I will highlight four main dimensions for the artefacts associated with four types of design: form design, function design, experience design and symbolic design (Table 1).
Each dimension of concept design is linked to a specific point of view regarding the artefact being designed (purpose, function, architecture, form, focus on the artefact or on the environment, etc.), to its users’ specific point of view (cognition, affect, sociology, imaginary, etc.) and to the use of specific representation and modelling tools (texts, drawings, diagrams, objects, etc.). As, unlike engineers who focus on the technical specifications of the artefact or researchers on different disciplines of human and social sciences (ergonomists, sociologists, anthropologists, marketing experts, etc.), who focus on the characteristics of the user and the usage context, designers synthesize these points of view by using prototypes and mock-ups.

As pointed out by Dubuisson and Hennion (1996, 2013), designers’ proposals, compared to those of other specialists, give the same importance to both user and object. In my opinion, it is precisely to achieve this synthesis that they build mock-ups and prototypes using tangible representation systems that engage the various stakeholders, either through direct contribution, to participate in the construction of the prototypes, or through evaluation, to criticize them.

Most classifications of design practices tend to consider them as part of a process. There are phases of problem definition, exploration, architecture definition and analysis of aesthetic issues, following the same order as the chapters in Ulrich’s book (2011) for example. The field of ‘design management’ notably offers very sophisticated descriptions of this process. But in my opinion, this approach is more in line with relationship design (see below). My typology of concept design practices and skills relies instead on the identification of complementary points of view regarding artefacts and users who are equipped with different theories and skills.

In the case of a complex and highly innovative project, all these dimensions must of course be brought together. But designers’ input can be limited to a specific dimension in which their contribution will be no less decisive. It is also very rare for designers to be equally competent in all specialties. Even when they master the issues related to each of the main areas, experienced designers nonetheless call in other professionals specialised in form, usability, experience or symbolism, when and as needed.

Other authors (Vial 2010) have also tried to identify the different dimensions of design:

“Vial introduces the idea of three dimensions of design: 1) ‘the callimorphic effect’ related to the formal beauty of the object and which most designer manifestos advocate (p. 56); 2) ‘the socioplastic effect’, related to the social form, made necessary by the usage value of design and strongly linked to the idea of social sculpture, and thus to the moral ambition of design (p. 61); 3) the ‘effect of experience’ that combines the first and second effects, leading to ‘user experience’ (p. 62)’ (Alcade 2012).

This typology uses some notions of form and usage without identifying the specific functional and symbolic aspects, which would require a more in-depth comparison. This approach is also in line with Danielle Quarante’s design criteria (Quarante 2001, quoted by Elsen 2009), which differentiate cultural (which corresponds to the symbolic dimension), harmonic (form), functional (function), social (usage) and historical factors.
5.1 Form design

Form design refers to one of the designer’s traditional roles that define the shape of the artefacts to be designed (the ‘adornment’, Hatchuel 2005). This form is of course of considerable importance in a significant number of usage situations. It is directly related to the aesthetics, style and visual identity of the artefact and has many interactions with function and usage. Its importance is all the greater as the objective is to attract customers who are offered many equally functional alternatives. It is in this type of context that form makes even more difference.

Form design skills focus on aesthetics and the whole set of ‘realisation techniques’ that were traditionally grouped under ‘applied arts.’ Used by designers to create visuals and mock-ups, these realisation techniques cover areas as diverse as graphics, typography, photography, video and associated software, as well as textiles, woodworking, sound, etc. Form design is thus also linked to technology, whether rather basic, when an operational prototype of the artefact can be made, or more sophisticated, but mainly dedicated to representation and not production, although this distinction is sometimes more difficult to make with digital artefacts, especially in visual design. In object design, visual design or interaction design, form design always plays a major role in the project. But depending on the commissioner’s requirements, its importance can vary compared to other design specialties.

5.2 Function design

Function design differs from form design as inventiveness operates without any reference to aesthetic or stylistic issues, focussing on ‘what’ rather than ‘how.’ Strictly speaking, function design is first used when defining the issue without ‘interfering’ with the decisions on the technology and hardware architecture that will be used during the exploration phases of the solutions (see Ulrich 2005). But the functional approach is recursive compared to the dimensions of implementation (see Hoc 87; Zacklad 2003). It is thus possible to distinguish between functional goals (the ‘what’), abstract, general or even physical functions (see Rasmussen, 1985), each level distinguishing itself from the previous ones by its will to temporarily exempt itself from the decisions made at ‘lower’ levels: choice of technical components, details of the form, etc.
This distinction between semi-independent implementation levels does not mean there is a strict temporal organisation in the development of plans. As cognitive science research in engineering design processes has shown, engineering design thinking is opportunistic and multi-levelled (Stefik 1981, Hoc 1987). At a given phase of the project, drafts of different levels of abstraction, generic or physical functions, physical form, etc., can thus coexist, the process of selecting drafts being a constraint generating activity as important for solving the problem as the generation of proposals. As a result, collaboration between design specialists, as with other designers, is not necessarily linear but can be similar to a form of concurrent engineering.

When it focuses on the artefact, function design knowledge is close to engineering sciences, notably functional analysis. When it relates to the user, it relies on humanities and social sciences, especially ergonomics. Function design, like all systemic design approaches, often uses tangible mock-ups to illustrate new functions: diagrams, maps, Lego mock-ups, boxes, etc. But the use of these tangible tools does not aim at prefiguring the formal appearance of the artefact as does form design, but at engaging those who participate in the upstream engineering design process by making the functions of the artefact more understandable.
5.3 Experience design

Experience design (UX design in interaction design) or usage design aims at designing artefacts that provide good ‘user experience.’ This term is often traced back to the work of D. Norman (1998) who notably identified the need to raise ergonomists’ awareness on dimensions other than cognitive dimensions: affect, emotion, etc. In the domain of service, this meaning is similar to that of ‘customer experience,’ which refers to the whole set of dimensions to be integrated in a commercial process by integrating the ‘experience’ provided at the physical point of sale (light, comfort, atmosphere, sensory contact with the products, welcome, etc.) and by digital interfaces.

In line with Norman’s definition, and in keeping with the French-speaking tradition, I distinguish the issue of usage or usability, which refers to ergonomic criteria (perception, cognition, relevance and efficiency with regard to the task in a specific usage context), which belongs to function design, from the issue of usage that refers to a more global vision of practices, to the personal and professional environments in which the new artefact must be integrated, to the diversity of potential users and identity-centred brands: sociology, information and communication sciences and semiology, anthropology, marketing, industrial and organisational psychology... (see for example Mallein and Tarozzi 2002, Andonova 2004, Denis 2009, Proulx, 2015).

Usage design results from the broadening of the functional perspective to integrate the global environment of the artefact in an ecosystem approach engaging other stakeholders and artefacts into more complex processes than those of function design, whose objective is the in-depth identification of the interactions between artefact and user. The aim is to identify all the contexts of usage and all the ‘points of contact’ with the object, system or service, whether digital or provided by mediating agents in charge of promotion, customer relations or maintenance.

The point of view adopted by usage design somehow leads to the adoption of a ‘service-oriented’ perspective for all the artefacts to be designed, even when they are objects or software. This more comprehensive consideration of the environment also raises the question of the diversity of users, in relation with this environment and the variety of their interests and motivations, leading to the frequent use of the ‘persona’ methodology.

The point of view shifts from how easy it is to use an interface to achieve a given purpose to the perspective of usage functions within an integrated value chain. In the upstream engineering design of a ‘smart’ watch for example, the focus is not on the list of available technical functions or the usability of the interface aimed at enabling these functions, but, for a given technical function, on the access to e-mails for example, how it could be integrated globally with all media and communication devices that different types of users may possess. Usage design also frequently questions the new business models associated with the artefact depending on the ‘value proposition’ it can offer within the ecosystem considered.

Some professional authors specialising in interaction design consider that experience design encompasses the entire design process in a ‘user-centred’ approach (Garret, 2002). They thus define mandatory analysis plans:
strategy (the ‘what’), scope (functions), structure (architecture), backbone (components) and surface (form). But this approach seems both restrictive and confusing. Indeed, experience design shall not be limited to the field of interaction design, as service or object design also benefits from this approach. Moreover, defined in that way, the term experience design would be synonymous with design, full stop.

Conversely, human-centred design is not limited to experience design in the sense of a thorough consideration of usages. Some interactive design projects, revamping a website for example, thus use a user-centred engineering design approach by working with ergonomists then function and form designers without the role played by experience in the sociological and emotional sense being considered essential in this particular context, as the project is part of an incremental innovation that does not question the fundamental principles of usage. But with the term ‘user experience’ being particularly fashionable today, there is little doubt that the term design experience will be used incorrectly to describe projects that focus on the user, whatever the dimension considered.

5.4 Symbolic design

Symbolic design refers to the designer’s engagement in the most intangible and cultural aspects of products and services. The functional and experiential dimensions of artefacts partly derive from their effectiveness on a symbolic level. In addition to their usage value, artefacts are often a language that allows consumers to achieve a certain positioning within society (Veblen 1898, Bourdieu 1979) or creative community appropriation (De Certeau 1984). By choosing to use certain products and services, users/consumers also contribute to the definition of their social identity.

Through this symbolic dimension, the meaning of artefacts depends above all on recognition processes within social relationships that are diverse, conflictual and multi-cultural (Le Breton 2010, on Mauss’s symbolism) but also on a system of representation linked to the collective imaginary, based on myths or archetypes (see for example the diverse approaches adopted by C.G. Jung 1969, G. Durand 1960 or R. C. Castoriadis 1975). The importance of the imaginary is the subject of renewed interest in the field of innovation as evidenced by the work of P. Musso and his team (Musso 2005). Anthropology and history, as well as semiology and Roland Barthes’s famous studies on the mythology of consumer products (Barthes 1972) or more recently the work of Beyaert-Geslin (2012) contribute to both decipher and orientate the symbolic meaning of the artefacts.

One of the challenges is that this symbolic dimension is often driven by the brand that represents a company or a family of products. Researchers and designers can thus work either on a product within a brand or on the brand as a whole. One often speaks of ‘brand image,’ but it is rather a brand identity in which strictly formal dimensions, linked to graphics for example, are only one component. Brand identity may notably include a logo, a slogan, story-telling, graphic specifications, etc.

Symbolic design also combines different ‘communication media’ as it has a transmedia dimension from the outset. In addition to the artefact medium or media whose form is meaningful, the identity of the products and services can be conveyed through the packaging, paper and digital brochures, a supporting website, videos, etc. Recursively, each of these media is an artefact that can be the subject of a specific design sub-project.
These messages and supporting media, when they do not have an educational purpose, such as user manuals for example, most often have a promotional or advertising objective. This plays an even more important role when they are intended for media campaigns. The messages conveyed can sometimes be quite far removed from the functional and usage characteristics of the artefacts, but if they are misleading regarding these characteristics, the long-term effects are then counterproductive.

### Examples of the design of an educational digital service

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| Other skills | Anthropology, sociology, semiology, communication sciences | Sociology of usages, educational sciences, marketing, business models | Functional analysis, educational sciences and didactics, ergonomics, information architecture | Typography, photography, colorimetry, semiotics, aesthetics, styles of the interface… |

Table 2. Example of the contribution to the different dimensions of concept design in the field of interaction design when designing a digital educational service

### 5.5 Specificity of concept design

Beyond the terminological extension that may tend to include existing professions into the sphere of design, is there a specificity in the method function or experience designers adopt when they take the user’s point of view? In my opinion, if interaction or usage designers can sometimes use the knowledge of ergonomists and sociologists, they differ from these specialists through their use of tangible methods aimed at stimulating the creativity of the stakeholders by allowing them to project themselves into targeted situations. These complementary skills are at the centre of their approach, even when they do not work on the final shape of the object. Thus, when ergonomists resort to expertise, systematic observation and controlled experimentation and sociologists conduct interviews and ethnographic observations, experience designers create situations of engagement to simulate the usage of objects, systems and services through digital or physical mock-ups in order to foster inventiveness. When researchers in ergonomics and sociology highlight trends or systems’ cognitive, perceptual, emotional and social properties through analysis, designers focus on idea generation, assessments carried out by the various stakeholders and the identification of potential implementation, even if they are not always able to justify their recommendations other than by referring to the engagement situations they have envisaged.
6. Third classification based on the approach of relationship design

While concept design focuses on producing the characteristics of objects, systems, and services, relationship design aims specifically at designing the engagement conditions that will foster the subjects’ creativity, cooperation and acceptance of proposals (Table 3). As we have seen, the specificity of concept designers is the use of tangible methods that encourage the engagement and expression of the stakeholders. These methods are a way for them to progress in the specification of the objects. For relationship designers, engaging the stakeholders is the main purpose of the project. Indeed, whether they specialise in idea generation in the upstream phases of the project or whether their aim is to improve the collaboration of stakeholders who are not at first keen to share or have difficulty understanding each other, their input only plays a secondary role on the artefacts to be produced. Their criterion for success is the creativity of the stakeholders they put in touch with each other and to whom they entrust the task of preparing proposals. I will focus here on four modalities of relationship design: design in traditional projects, design thinking, participatory design and rhetorical design.

6.1 Design in traditional projects

I only refer to this form of relationship design for information purposes. All designers have been trained in the basic tasks of project management that are inherent in all engineering design activities. These tasks involve at least the identification of the stakeholders and their roles (customers, first-tier suppliers, subcontractors, users, etc.), the breakdown of tasks and deliverables, the temporal planning of the supply of these deliverables, a form of governance that results in hierarchical relationships and the implementation of bodies dedicated to project management. Within a project, the designer can work in a sequential process in a relatively isolated manner. The engagement of the other stakeholders is based on a set of specifications and the intermediate results are evaluated during traditional presentation meetings. In project mode, the relationship designer is mainly a project manager who understands the activities of engineering and design. All the other forms of relationship design that I will now address aim at going beyond this sequential process, the limits of which are well-known, by suggesting a teamwork approach that complements the creative processes implemented by the designers and stakeholders they work with.

6.2 Design thinking

Design thinking is the best known of relationship design specialties. The objective is to help groups produce new ideas by taking relevant spatiotemporal constraints into account. Design thinking could be called maieutic design in reference to Socrates’ idea generation process as maieutic designers are usually ignorant and seek to reveal latent knowledge through systematic exploration methods mainly based on the stakeholders’ experience. This elucidation of knowledge aims of course at finding creative ideas to solve the problem, the confrontation between points of view in order to make the generation of proposals even more productive. In some cases, design thinking may include surveys with users, but this approach is still rare. It is worth noting that design thinking has two meanings in specialised literature (Jonas 2011). The one advocated by N. Cross (2011) for example aims at translating the designers’ specific way of thinking by analysing their practices, which partly corresponds to the general objective that I set myself for this article. The other aims, in a normative way, at improving design and more generally innovation processes through IDEO (Brown & Wyatt, 2010). This meaning corresponds to relationship design which I am addressing in this section, by limiting the issue of design thinking
to the process of cooperative creativity without including all the survey phases that could potentially involve, in my opinion, other stakeholders in engineering design (see below).

Design thinking usually comprises of three main phases, although there are some alternatives, depending on the methods, by subdividing the canonical steps into subcategories: inspiration, ideation, implementation (Brown & Wyatt, 2010). The inspiration phase consists of identifying the issue through a brief, which, in the most sophisticated approaches, also aims at providing stakeholders with in-depth knowledge of the issues. In the ideation phase, stakeholders suggest solutions by exploring alternatives.

One must then be quite ‘divergent’ to generate as many options as possible, even by thinking ‘outside of the box.’ The ideation phase usually concludes with a ranking and a synthesis to retain only one or two options that will be explored further. In the implementation phase, a sketch of the solution is produced based on the selected options. In the time usually dedicated to design thinking, the implementation cannot be a detailed specification of the artefacts to be designed, but it can help build mock-ups illustrating the option that has been chosen.

Design thinking knowledge includes social psychology, cognitive psychology, knowledge engineering, communication sciences and semiotics, management sciences, etc. It is indeed in management sciences that the C&K (Concepts & Knowledge) theory has been developed in France (Hatchuel and Weil, 2002) to explain the logics of going back and forth between inspiration and ideation, knowledge research and concept production. Although this method does not claim to be design thinking, it has similar attributes. Here I would like to insist on the fact that the notion of ‘creating a relationship’ does not only concern stakeholders but also, from another point of view, ideas and knowledge.

Still in France, to take another example, semiotics and pragmatism are used in the development of the <Metabolism> method for ‘metabolism of thought’ inspired by the work of C. S. Pierce (Darras 2017a). Without explicitly claiming to be Design Thinking, this method allows an engineering design project manager to identify the cognitive, semiotic and pragmatic differences between the stakeholders in a project in reference to the cycle of thought in creative surveys: habitual action, doubt, inquiry, habit change, learning, new habit, etc.

Design thinking usually does not define the specific role that professional concept designers might have in relation to other stakeholders. These can have two statuses: they are either the commissioners or even the moderators of the design thinking session and do not feed the process with ideas, or participants in the process, but then they must not have any position of authority.

There is sometimes a tendency to extend design thinking to the entire upstream engineering design process, involving phases of user surveys and the evaluation of prototypes by users (see for example the online guide ‘An Introduction to Design Thinking, developed by Stanford’s D-School). This is a broad vision of design thinking that tends to be confused with human-centred design. Indeed, human-centred design often includes design thinking and co-design, but it also uses other observation and investigation approaches that are not inherently part of design knowledge. For example, Ideo’s guide ‘The Field guide to human-centred design,’ which focuses on experience design, contains a large number of design thinking techniques but also more traditional user survey techniques that do not necessarily require the input of professional designers.
6.3 Participatory design or co-design

Participatory design, also called cooperative design or co-design (Bodker et al., 2000), has many points in common with design thinking and these two approaches can be combined. But to be more precise, the aim of participatory design is partly dissociated from that of design thinking and they do not necessarily use the same techniques. In its original Scandinavian context related to participatory design, co-design claims to be a democratic form of engineering design that involves users in its process. The goal is to ensure that the engineers’ input can be controlled by end users. The work sessions are an opportunity to compare points of view based on sketches of the artefacts. The participation of users in design choices is legitimized by their knowledge of the work situations for which the new solutions are intended, but they are not necessarily consulted to suggest new ideas in the upstream phases. Users are supposed to be experts in utilization and usage and it is as such that they are consulted.

In current approaches, co-design retains the objective of confronting stakeholders who have heterogeneous points of view on an issue, but this confrontation can also be used to stimulate creativity in upstream phases by offering a symmetrical role to both users and professional designers. In some innovative approaches, the roles of the stakeholders may differ. Some are invited to working sessions to provide heterogeneous or disruptive knowledge and represent different points of view that are not necessarily those of usage. These contributions may not be included in the idea generation process, which is sometimes reserved for other stakeholders who are directly concerned by the artefacts to be designed (see the CoDesignIT approach). Various attempts at formalizing the stakeholders’ engagement have been made, notably by B. Darras and his new team (see Darras 2017b).

6.4 Rhetorical Design

Rhetorical design is not a traditional category of relationship design, but I nevertheless consider it as an essential component of the projects I have studied. The goal of rhetorical design is to better showcase the designers’ proposals during client briefings. But it would be restrictive to limit this specialty to the creation of slides, as suggested by certain meanings of ‘presentation design,’ unless one extends the meaning of ‘presentation’ to all types of expression. Rhetorical designers thus use all the resources of form design (graphics, typography, scenography, storytelling, etc.) but this use of tangible techniques is not intended to design the form of the targeted artefacts, as in concept design, but to contribute to the form of the intermediate presentations in order to win the support of the clients or, more generally, of the stakeholders. In certain cases, the experience provided by intermediate and final presentations and the shifts in perspective they may cause in recipients can be as important as the artefact to be designed.

This is why rhetorical design is above all based on relationship design and not concept design. Unlike design thinking or co-design, it is directly aimed at convincing clients or stakeholders about the design options chosen at the different stages of the project. Of course, especially in form design, the more aesthetic the work is, the easier it is for designers to present it, since they will be able to directly use in their presentation certain representations of the artefact to be designed. But efficient rhetorical design also highlights other elements than the dimensions related to the form of the artefact that can even be secondary to the project (function
design, experience design). Rhetorical design knowledge encompasses communication sciences, social psychology, semiotics, rhetoric, etc., as well as the whole set of skills associated with the realisation techniques used by designers to win the support of the recipient.

<table>
<thead>
<tr>
<th>Names of concept design specialties</th>
<th>Examples of design or other similar disciplines</th>
<th>Example of the knowledge and skills used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project-centred design</strong></td>
<td>Combined with traditional project management methods</td>
<td>Knowledge: project management. Skills: deadline and deliverable management, client relation management, etc.</td>
</tr>
<tr>
<td><strong>Design thinking</strong></td>
<td>Maieutic design (alternative name suggested in this article)</td>
<td>Knowledge: social psychology, cognitive psychology, knowledge engineering, communication sciences, engineering design management, etc. Skills: group moderation, graphic facilitation, etc.</td>
</tr>
<tr>
<td><strong>Participatory design</strong></td>
<td>Co-design (alternative term)</td>
<td>Knowledge: social psychology, communication sciences, engineering design management, sociology of organisations, sociology of sciences, etc. Skills: group moderation, surveying skills, graphic facilitation, etc.</td>
</tr>
<tr>
<td><strong>Rhetorical design</strong></td>
<td>Uses many types of design, notably graphic design but mainly focuses on project communication and not on the characteristics of the artefact to be designed</td>
<td>Knowledge: communication sciences, social psychology, semiotics, rhetoric, etc. Skills: the whole set of realisation techniques that can be used in form design…</td>
</tr>
</tbody>
</table>

Table 3. Dimensions of relationship design

7. Definition of design

The interdisciplinary and multidimensional approach that I have chosen here focuses on the diversity of knowledge that design uses, whether it is linked to the realisation techniques formerly grouped together in the field of applied arts, engineering sciences or human and social sciences. It also allows me to offer a definition of systemic design that leads to a better understanding of its specificity in engineering design projects:

Design is a discipline that belongs to engineering design sciences and has the specificity of using tangible methods allowing (1) to specify the different elements of the form, function, architecture, utilization or usage of an artefact and (2) to engage stakeholders in the engineering design process beyond the formal roles they play.

Designer have two specificities: (1) in concept design, they do not differentiate the challenges linked to the logical, material and formal specification of the artefacts from the challenges linked to utilization,
usage and symbolic value and (2) they do not differentiate those issues from those relating to the engagement of the stakeholders in relationship design, although more emphasis may be placed on one aspect or the other during the project.

Tangible methods make it possible to develop models and take steps that are part of a form of ‘semiotic formality’ (see Zacklad 2005, 2010), which is indispensable in the adjustment phases, leaving room for creativity. This formality differs, on one hand, from the logico-mathematical or computational formality that could prevail in the definition of the concept developed by engineers (strictly referential meaning) and, on the other, from the legal formality that could prevail in relationship management (strict compliance to formal roles).

By loosely drawing inspiration from Hjelmslev, one can consider semiotic formality as applying to representations of artefacts and situations in which several levels must be linked. For example, in a model of semiotic formality, the expression level (discourse, images, diagram, etc.) and the content level (the tangible and objective characteristics of the artefact for example) each have their own structure whose adjustment, allowing for understanding, is interpreted by the stakeholders depending on the context.

In contrast, the models used by engineers or lawyers in the downstream specification phases must be completely unambiguous, as is the precise geometric description that must serve as a plan for a robot, or the description in legal terms of a contract (although some legal aspects can also be subject to interpretation). Tangible models are thus more likely to play the role of ‘intermediate objects’ than formal logico-mathematical models (Jeantet 1998, Bassereau et al., 2015).

8. Conclusion: Design-specific knowledge

Does my interdisciplinary and multidimensional approach to design mean that there is no such thing as design-specific knowledge and that design is merely an opportunistic combination of techniques, methods and concepts that are external to it? I do not think so. In the same way as engineering or management sciences produce a type of knowledge that differs from that of the ‘fundamental’ disciplines on which they are based; design, through its specific approach of issues related to the upstream engineering design process, generates specific knowledge that neither ergonomics, sociology nor anthropology possess, taking examples only from social and human sciences.

Thus, when researchers in ergonomics, sociology or marketing conduct surveys and/or specific studies that provide information on cognitive, perceptual and identity processes, systemic designers translate this knowledge of the context into original and inventive models responding to the multiple constraints of the project, whether human-related, technical or economical. They produce these tangible models and mock-ups using concept design tools that allow stakeholders to project themselves into the future. Through relationship design, they collect inputs and evaluations, put stakeholders in action and ensure consistent support from commissioners. The role of the designers and of the interface skills that they produce and use are therefore quite unique.
But this interdisciplinary perspective also opens up several avenues for the development of design-specific knowledge and the collaboration with other stakeholders, in the domain of training and research. Beyond the traditional knowledge of the applied arts, which is essential to form design and can be used in the creation of models and mock-ups by all design specialties, many forms of knowledge related to engineering, human and social sciences can supplement design-specific knowledge and practices, some of which may even become compulsory during training.

In the field of engineering sciences, many areas come to mind: digital technology of course, but also, depending on the specialty, acoustics, electronics, chemistry, materials science, biology, etc. Regarding human and social sciences, I have already mentioned ergonomics, industrial and organisational psychology, sociology, communication sciences, semiology, anthropology, aesthetics, marketing, innovation management, etc. This broadening allows some designers to take on the role of engineers, interviewers, research managers or experts. In the same way, professionals wishing to vary their input during the upstream phases of engineering design can be trained in the skills and methods of concept or relationship design to work as designers on the project.

As you may have understood, I believe that a better comprehension of the knowledge used in upstream engineering design practices makes it possible to both better value the inputs of the different stakeholders in the project and to encourage collaboration and professional mobility. I also believe that such collaboration is the best way to ensure the relevance of the projects, and that designers, like other creators, always perform better when teamed-up with other specialists.

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