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Designing Disruptive Innovative Systems, Products and Services: RTD Process

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1. Introduction

There are well over hundred design processes described in literature, so why invent a new one? Over the last decade we have observed a need in our department for a process that emphasises different values than most current processes highlight. To start, we have seen a desire for a process that supports design-driven innovation, that is, we step away from incremental innovation in favour of disruptive innovation, in which disruptive refers to the absence of a well-established frame of reference for users or the market. Not only the product as such is new, but it also enables the creation of radical new meaning for the user, the market and society. We have seen a desire for design processes that can deal with this openness and complexity, in order to design open and intelligent systems that evolve during use, and which have a high level of complexity due to their adaptive, context-dependent and highly dynamic character. Next to this, the role of the designer is changing. More and more we see open platforms and design projects in which a variety of people and experts create products. We believe this has implications for the design processes used. Finally, we have seen the desire for a design process that fits self-directed learning instead of teacher-directed learning, which corresponds with educational theories like social constructivist learning.

Based on these observations on the changing face of design we present the Reflective Transformative Design process (RTD process). It is a design process, particularly aimed to support the design of disruptive innovative and/or intelligent systems, products and services, that emphasises values like openness, context- and person dependency, envisioning a new society, intuition, craftsmanship and development through reflection.

In this chapter, firstly, we elaborate on the changing field of the Industrial Design and the implications this has for design processes. Subsequently, we explain the rationale behind influential paradigms of design methodology and a variety of design processes, and show why they do not match the abovementioned changes and needs. Thereupon we introduce the Reflective Transformative Design process (RTD process) in detail. We explain how it works and elaborate on the rationale behind the model. We present the design processes of two projects, Other Brother and Ennea, to elucidate and discuss the possibilities of the RTD process to design disruptive innovative systems. We conclude the chapter by demarcating the position of the RTD process in comparison to existing processes and by explaining our plans for further development of the RTD process.

2. The changing field of Industrial Design

The field of Industrial Design is changing. At least that is the message when going to conferences like TED, the World Design Forum (WDF), ICSID World Design Congress and CHI. According to Stefano Marzano, CEO of Philips Design, we are moving towards an intellectual new renaissance based on humanistic values. Designers are catalysts for change and raise large societal questions. They are creating a vision in the first place and concrete ideas in the second (Marzano's presentation at WDF '10). Consequently the scope of design is changing. It is expanding towards all kind of systems: education, health-care, economic growth, transportation, defence, and political representation. Moreover, the role of designers is changing. Designers are dealing with a creative society in which we are all producers and consumers of value (Nussbaum, 2008). These changes have implications for educating future designers who can anticipate this changing design profession and their envisioned role, and who can even enhance these changes.

In this chapter, we describe four developments in the field of industrial design and design education, which in our opinion ask for a new view on design processes: disruptive innovation for societal transformation, intelligent systems, open design and self-directed competency-centred learning.

2.1 Disruptive innovation for societal transformation

The first development that asks for a new view on design processes is disruptive innovation, in which disruptive refers to the absence of a well-established frame of reference. Not only the product as such is new, but it also enables the creation of radical new meaning for the user, the market and society. Especially nowadays, when technology is so rapidly and innovatively created by the technology providers of the world, and at the same time when we are facing large societal challenges like healthy living and aging, sustainability and mobility, there is a need for a new type of innovation that can transform the lives of people, the way they experience and act in the world, and consequently transform society.

All designed artefacts, be it systems, products or related services, are inextricably intertwined with society; they will have a social impact as soon as they enter society. Products arise in a social context, and consequently, are a reflection of that society. Moreover, a product is a vehicle to steer society implicitly as well as explicitly; it influences the behaviour and experiences of users (Hummels, 2000; Verbeek, 2006). For example, open office layout and furnishing, which originated in the 1920s, enabled the ideas of scientific management, such as efficiency, introduced by Frederick Taylor (Forty, 1986). Designing for disruptive innovation is a way of explicitly steering society, a way of actively exploring the possibilities for social and societal transformation.

At the department of Industrial Design we are employing and researching disruptive innovation for societal transformation and we are not alone in this focus. In 2004 the British Design Council set up RED, a 'do tank' that uses transformation design to tackle social and economic issues (Burns et al., 2006). Robert Fabricant, Vice President of Creative at Frog Design, sees a shift towards 'design with intent' that has an immediate impact on user behaviour through direct social engagement (Fabricant, 2009). Bruce Nussbaum, editor of the innovation and design coverage of Business Week, states that transformation takes the best of design thinking and innovation, and integrates them into a strategic guide for the unknowable and uncertain years ahead (Nussbaum, 2008). Also Roberto Verganti (2009), professor of Management of Innovation at Politecnico di Milano, shows that we are moving

towards disruptive innovation, or to put it in his words, we are moving towards design-driven innovation, that is based on a strong vision to create new markets. This type of innovation is not obtained by scrutinising user needs, which generally leads to incremental development, but by developing a strong vision that can guide disruptive innovation.

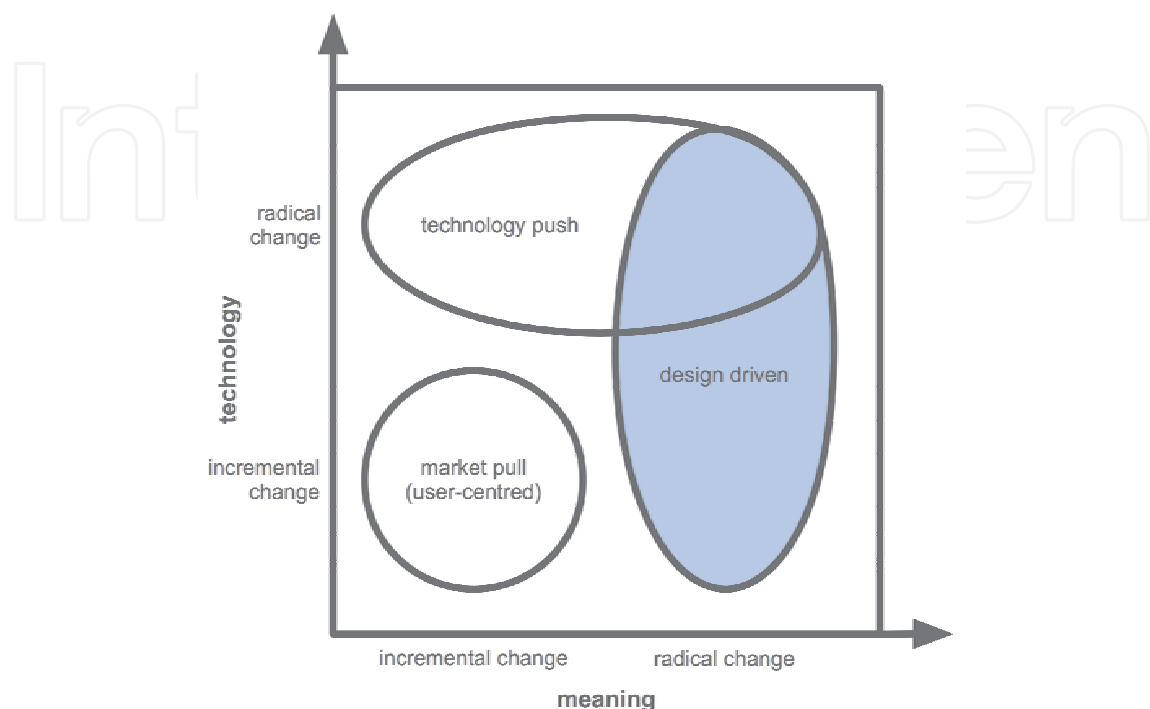


Fig. 1. The strategy of design-driven innovation through a radical change of meaning

Verganti shows that in order to realise such leaps, industry must build upon so-called interpreters, i.e. "the community of players - from artists to technology suppliers to design schools - that surround every product and deeply understand and influence how people give meaning to things." (cover, Verganti 2009). So, design schools are challenged to educate students as interpreters, with visionary design skills who can advance disruptive innovation in order to enable societal transformation. They are challenged to educate designers who are able to apply new technologies in ways that are new and daring, driven by a design vision of how our world could be, and validated by solid user research. So, educate designers who are able to transform our world, preferably in beautiful ways, instead of solving problems.

Designing disruptive innovations and envisioning societal transformation, is based on the concept of meaning, as is also indicated by Verganti. But what do we define as meaning? We adopt the phenomenological perspective in which meaning arises in interaction: *"How we think about the world is ... rooted in how we interact with it before we think, and so our intellectual thoughts cannot be used to explain away that pre-reflective experience. We move about the world, make use of the objects in it, respond to situations emotionally, act in order to change it, and so on. All these and other ways of interacting with the world give rise to its meaningfulness, so that the meaning of things in a sense, exist neither 'inside' our minds nor in the world itself, but in the space between us and the world, in the interaction"* (Matthews, 2006, p.33).

The core of phenomenology as Merleau-Ponty (2002) describes it is *'être au monde'*, which means not only being in the world but also belonging to it, having a relationship with it, interacting with it and perceiving it in all dimensions. We perceive the world in terms of

what we can do with it, and by physically interacting with it we access and express this meaning. Moreover, we do not perceive ourselves as one more object in the world; we perceive ourselves as the point of view from which we perceive other objects. Disruptive innovation extends our current interaction with the world and its consequential meaning for us in ways that are new to us.

What is important for designers to realise is that arising of meaning occurs during the design process too. And because designers perceive themselves as the point of view from which they perceive systems and products, they are a part of their designs. They are designing from a first person perspective while intermittently taking a third person perspective. Therefore, their designs will be meaningful for them in a different way than for someone else (Trotto et al., 2011).

Designing disruptive innovative products provides challenges for designers and industry. Designing products that do not have a well-established frame of reference for users, the market and society, requires a different design process than is often used up till now. Both Roberto Verganti (2009) and Donald Norman (2010) indicate that the classic form of human/user-centred design is not suitable for designing large radical transformations. Since users have no frame of reference, it is not possible to ask them using traditional market and user research techniques, for their needs for and requirements of these future products. The actual added value of these products becomes only clear after a certain amount of time in which users have created in interaction meaning and added value of (the services provided by) these new products (Gent van et al., 2011). Therefore, the design process needs to stimulate the development of experienceable prototypes throughout the process, also at the early start, that enable potential users to create meaning in interaction.

A second consequence of taking a phenomenological approach towards disruptive innovation and a radical shift of meaning is the importance of intuition and design action during the design process. Making enables designers to explore the unknown by trusting their senses, exploring resistance and ambiguity, and by tapping into their intuition. Dijksterhuis & Nordgren (2006) show that intuition, or unconscious thought as they call it, is better suited for dealing with complex matters than conscious thought. Designing, which is based on creating, is the highest form of (cognitive) complexity according to the Revised Bloom's Taxonomy (Anderson, & Krathwohl, 2001). Intuition begins with the sense that what is not yet could be. Intuition is necessary to make leaps. It is "*an imaginative experience ... that guides us towards what we sense is an unknown reality latent with possibility*" (Sennet, 2008, p. 213). Therefore, a design process should enable or even stimulate intuition when designing systems and products that aim at a radical shift of meaning (Trotto et al., 2011).

Concluding, a design process for disruptive innovation needs on the one hand, to enable the designer to use her intuition and design action to envision new opportunities for social and societal transformation. It should stimulate the development of experienceable prototypes throughout the entire process, also at the early start. Coming from a first person perspective, the designer can also bring in her own value system and invite certain behaviour. This envisioning and making part should be intertwined with, on the other hand, a rooting in the real life context of use, through close cooperation with all stakeholders. This way designers can explore, discover, study, anticipate and react to meaning that emerges when people interact with these experienceable prototypes and (preliminary) products in a real life context, throughout the entire design process and beyond. This way the envisioned and emerging meaning of the design-to-be can be addressed in all phases of the design process.

2.2 Intelligent systems

The second development that asks for a new view on design processes is the shift towards designing intelligent systems. When looking at the field of Industrial Design, we see that during the last decades design has shifted its focus from one person – one product (technology) interaction, to several persons via a product interaction, and it is now shifting towards a network of interactions between people and intelligent products within the context of use. Moreover, it is shifting from designing static worlds in which users adapt to objects, to co-constructed adaptive worlds in which objects and persons adapt to each other and co-evolve (Evenson et al., 2010)



Fig. 2. Moving towards networks of interaction.

Instead of designing “closed” products and human-product interaction, a growing number of designers are moving towards developing open intelligent systems that are not finished when they leave the factory, but evolve in interaction through, for example, services and adaptation. Given the inextricably intertwinement of the designed world and people, (see previous section) not only do intelligent systems have the ability to adapt to users, but also users will adapt themselves to these systems. For example, a smart phone will adapt to its user through the different applications, personal ring-tones, background images, content and physical appearance. Newer versions move towards adaption during use, by analysing user behaviour and consequently adjusting functionality and actions accordingly. However, adaptation also works the other way around; people adapt to these systems. With the introduction of the smart phone, people have the possibility to be online and accessible 24x7 and have Internet access independent of their physical location. This has huge consequences for our behaviour, our perception of time, and our perception of leisure and work.

As a consequence of this mutual adaptation, mass customisation can grow to the level of individual user/product (system) combinations while in the mean time often unpredicted, usage patterns may emerge. Therefore designers of disruptive, intelligent systems, need a fast and good insight to what is happening with their experienceable prototypes and products in an, often increasingly diverse, social context and market (Gent van et al., 2011).

Finally, when designing intelligent systems, the complexity increases significantly. Moving towards such complexity implies that the challenges cannot be formulated exhaustively and that both challenges and solutions are not simply false or true; challenges are unique and there are multiple opportunities for solution spaces (Rittel, 1972). Consequently, designing complex systems cannot be tackled through problem solving in a linear controlled process. Kelly (1994) states that the only way to develop or manage complex systems is by letting go of control and enable the system to evolve without central authority or imposed control mechanism. Although this last take might be too bold for many designers and even goes against the grain of that what design has been until now, it stresses the need for an open

process that supports evolving systems. According to Nelson (1994) it requires new strategies of design, intervention and management. He states that being undisciplined using system thinking and being out-of-control during a creative, hands-on design process are essential for creating a complex unnatural (designed) world.

Concluding, a design process for intelligent or complex systems cannot be based on linear problem solving, but needs to support openness and letting go of control. It needs to support design action and quick iterations within the real life context that give a fast and good insight to what is happening within interaction with experienceable prototypes. It needs to support the emergence of new meaning and usage patterns, preferably over a longer period of time, and support co-evolvment. Moreover, it should be possible to apply the process to an infinite number of individual user/product (system) combinations which all may bring their own unpredicted usage pattern.

2.3 Open design

The third development that has in our opinion consequences for the design processes refers to the stakeholders and participants involved in the process, especially collaborative forms like open design, co-creation and participatory design. We see open design as a specific approach to design, in which a group of intrinsically motivated people from various backgrounds develop design opportunities and solutions together in an open community, based on respect for each other's skills and expertise. Open design requires a flexible and open platform that assumes open access, sharing, active participation, responsibility, commitment to do good work for its own sake, respect, change, learning and ever evolving knowledge and skills (Hummels, 2011).

Not only designers are participating in open design; in principle everyone can participate. Key aspect is that everyone brings in their own expertise, and respects and builds on the expertise of others. Consequently, open design implies that the boundary between designers and users / customers is blurring at least with respect to motivation, initiative and needs. We agree with Bruce Sterling (2005) this does not imply that everyone is now a designer, as IKEA and many others are implying. The design profession is still something that requires many years of education and practice, like any other profession. However, (potential) users/customers now bring in their own experience as well as their specific competencies. This can be the case during the design process, for example, during co-creation sessions (Sanders, 2009) or through co-reflection (Tomico Plasencia, 2009). Especially when moving towards interactive and intelligent systems, products and services, the role of the user increases when personalising and adapting products, as was discussed in the previous section 'Intelligent systems'. For example, F# and Visual Studio on a Windows 7 mobile phone enable users to customise the functionality on their phone completely.

Given this changing role of non-designers in the design process, it is important that designers are able to co-operate with experts and users/customers, respect their competencies and simultaneously reflect on their own. More importantly, we believe that in an open design process designers should not merely function as facilitators that run co-design sessions. We believe that open design has enhanced the opportunity for and discussion about designers as subjective participants of a design process in which they are part of the solution space. Obviously, they are part of the solution space when they see themselves as potential user and customers. But based on phenomenology, designers are always an inherent part of their designs and they could even exploit that. Due to the nature of their profession they regularly take a first person perspective, as was discussed in section 2.1.

Concluding, a design process for open design should stimulate the generation of experienceable solutions to explore, generate and validate ideas and steer further developments. It should facilitate the communication between the different people/experts involved. Moreover, 'design making' opens up new solution spaces that go beyond imagination, which becomes especially important in group-settings and for designing disruptive innovative products. Especially for an open design setting we would recommend the adage: reaching quality through making quantity, which asks for a highly iterative process of generating dozens of solutions and testing them in-situ. Moreover, the process should enhance a first person perspective. Finally, open design requires a flexible and open design process that stimulates sharing between and learning from a variety of people.

2.4 Self-directed and competency-centred learning

The fourth and last important development we see that asks for a new design process is a new learning paradigm based on self-directed and competency-centred learning. Not only the focus and the way of designing is changing, as we have discussed in the previous sections, also the education of design is changing, which requires a new view on design processes, as we show in this section.

The new learning paradigm, self-directed and competency-centred learning, stems from a new view on science. Prigogine and Stengers (1984) show that the history of western thinking can be divided into three paradigms: 1) the classical-Christian view developed by e.g. Aristotle, Ptolemy and Thomas Aquinas, 2) the classical-scientific view developed by e.g. Newton and 3) quantum physics, relativity, dissipative & self-organising structure view developed by e.g. Einstein, Bohr and Prigogine (Doll, 1986).

Einstein's theory of relativity dismantled the notion of objectivity and predictability as initiated by the classical-scientific view of Newton. Where Newton's world is essentially simple and closed: it can be modelled through time-reversible laws and all complexes can be reduced to simples, Prigogine's reality is multiple, temporal and complex. It is open and admissible to change. The non-linear nature of the interconnections within complex systems, implies that such systems cannot be reduced because the information is not comprised of separate elements but distributed in a pattern of connections (Fleener, 2005). These systems do not only refer to a sub-atomic level, but to all systems from micro- to macroscopic.

As a consequence, the open, interconnected and complex character of the third paradigm disrupts the quest for certainty, truth, simplicity and objective knowledge, as is often aimed for in 'classical' research (Fleener, 2005), and in 'classical' education. In the classical teacher-centred educational approach, teachers take a third person perspective, which Doll calls the God's-eye view. They determine what the student should know and they make use of a measured and uniform curriculum, with tests that are considered objective and predictive. The new paradigm however asks for a learner-centred approach based on a transformative curriculum that emphasises and supports a variety of procedures and interpretations, depending on the learner (Doll, 1986). It asks for new perspectives and learning theories that focus on learner-world relations (Birenbaum, 2003; Segers et al., 2003). In this new paradigm, novice designers learn to learn (what, how and why) and teachers facilitate their learning. Moreover, teachers have become learners too. This will switch their role towards teaching from a first person perspective instead of a third person perspective.

Learning theories based on this new paradigm such as constructivism is gaining interest. The individual or cognitive variants of constructivism assume the locus of knowledge

construction to be in the individual learner; the social or situative variants assume this locus to be in socially organised networks (Birenbaum, 2003). Common to both perspectives, however, is the notion of activity: it is the learner who creates meaning, affected by and reflecting her socio-cultural environment. It is about learning and performing through practical application, while simultaneously acquiring theoretical skills and building knowledge. It uses the making skills of the designer as well as her analytical skills to gain knowledge (Hummels & Vinke, 2009). It is a unity of theory and practice, where experience plays a crucial role (Dewey 1938).

We call the conceptual learning model that fits the above, self-directed and competency-centred learning, which is based on the learning model from Voorhees (2001).

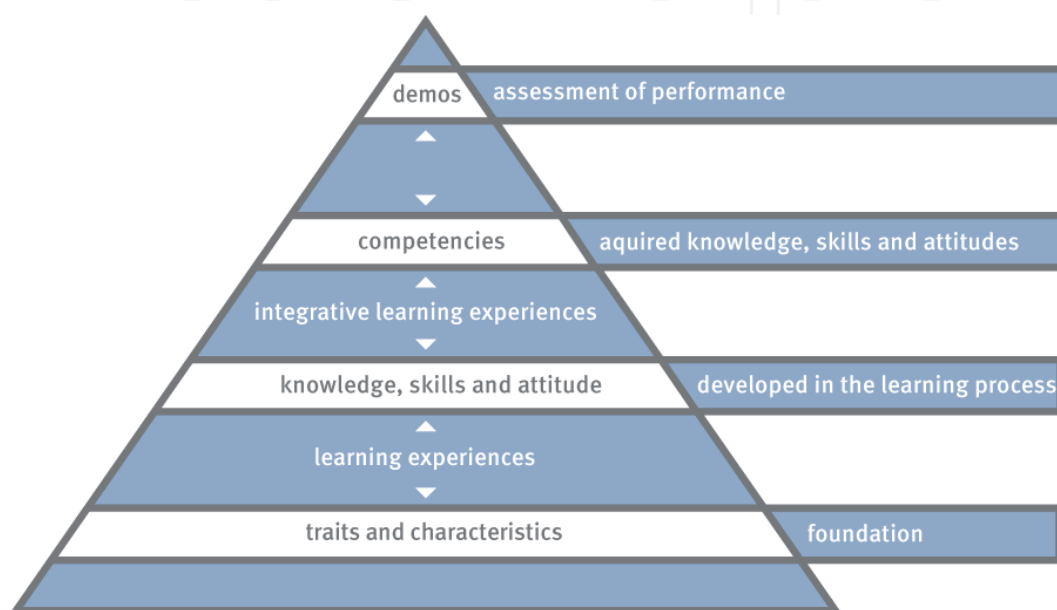


Fig. 3. Self-directed competency-centred learning model (Hummels & Vinke, 2009)

It starts from the traits and characteristics of the individual learner, who learns through doing and from experiences and thus develops knowledge, skills and attitudes in a specific context. When integrating these learning experiences the learner develops competencies which he can demonstrate when applying them. Competency-centred learning is experiential (learn by doing), exemplary (learn from specific situations), context-related (learn within a variety of contexts), reflective (in, on and for action) and it is self-directed, because it is the learner who creates meaning, which can lead to competency development.

Competency development within this paradigm and learning model follows an equilibrium - disequilibrium - re-equilibrium pattern (Piaget, 1971), where one goes from one stable state to another, in which the disequilibrium is often chaos through which one reaches order. Disequilibrium is the driving force of changing behaviour and development. Reflection and action are essential elements to regain order because they can change personal structures and ways of looking at the world and dealing with it (Doll, 1986). This fits Schön's reflective practice that is based on the ability of professionals to know, reflect and learn in and on action; to learn by doing, and through reflection gain an understanding that arises from experience (Schön, 1983). Consequently, designers need to trust their intuition, use their common sense, and dare to make mistakes, or as Schön states it, by entering into an experience, without judgment, responding to surprises through reflection,

we can learn from our actions. Or as Merleau-Ponty (2002) states, perception, through action, precedes cognition: reflection is a consequence of action.

It is important for novice designers to develop the ability to reflect in and on action as well as reflection for action, not only for designing itself, but also to stimulate learning and direct development. Especially in a learner-centred paradigm designers need to be able to direct their learning thus becoming autonomous and lifelong learners (Vinke & Hummels, 2010).

The need to become self-directed lifelong learners is becoming even more important nowadays, because the advances in science and technology follow each other so quickly that large amounts of knowledge and information get outdated rapidly. When looking at the design education of the first author (between 1985 and 1993), there has been an enormous change in focus, tools and techniques. The focus back then was mainly on 'one person - one product' interactions within a fairly static world. Most of the engineering part of the curriculum was based on mechanical engineering and hardly on digital electronics or informatics. Computers were mainly large boxes on desktops and not the mini-processors that are in all interactive devices nowadays. Consequently, functioning effectively in a rapidly changing society requires the ability to learn continuously.

So, what are the implications of a self-directed and competency-centred learning paradigm for design processes? Competency-based learning is a highly person- and context-dependent process. Since designers have different traits, characteristics and competencies, the new design process should accommodate these differences, breath flexibility and make designers aware that there are different ways to run a design project. The design process should enable chaos and a disequilibrium, next to a (re-)equilibrium, instead of breathing an atmosphere of control and rigidity. It should express that designers can make mistakes, and more importantly, that they can trust their intuition. Moreover, the design process should value design making (synthesising and concretising) next to design thinking (analysing and abstracting), and put a high emphasis on design action and experience. Moreover, the design process should emphasise and support reflection in, on and for action, not only to develop (tacit) knowledge and make decisions during the design process, but also to support novice designers becoming aware of what they have learned, and stimulate their overall development as a designer.

2.5 Implications of the changing field of design and education for the design process

In the previous sections we elucidated four developments in the field of industrial design and design education, and have sketched the implications for the design process. We do realise that a design process is merely a model of reality that emphasises certain values and downplays or even ignores other values. Professional designers have often internalised the design process, using and adjusting it based on the situation at hand. Therefore we believe that design processes are especially beneficial for students who are learning to become a designer. Novice designers have not internalised a process yet, and subsequently have not experienced and decided upon their preferred values. Based on the aforementioned developments, we are looking for a design process that makes novice designers aware of values like openness, diversity, flexibility and craftsmanship.

Next to stressing certain values, design processes are also a means to make ones activities explicit and thus have an opportunity to reflect on those actions. In addition, by making it explicit it can also smoothen the conversation to other stakeholders involved in the process, being it fellow students, participating experts and colleagues, clients or a coach. In addition, it can guide novice designers towards new possible activities within the design process.

We summarize briefly our findings from this chapter for the design process based on the aforementioned developments: disruptive innovation for societal transformation, intelligent systems, open design and self-directed competency-centred learning.

A design process for *disruptive innovation* needs to enable the designer to use her *intuition, design action and experience to envision new opportunities* for social and societal transformation. It should stimulate *design making* (synthesising and concretising) to open up new solution spaces that go beyond *imagination*, next to *design thinking* (analysing and abstracting). It should be a process that values knowledge, skills and attitudes. Moreover, it needs to stimulate *quick iterations*, reaching quality through *quantity*, by *exploring, validating and launching* designs in the *real life context*. By developing *experienceable prototypes* throughout the entire process, the designer gets a fast and good insight to what is happening *within interaction* in a *diverse social context and market*. In addition, the process needs to express and enable ingredients like *sharing, openness, uncertainty, subjectivity and complexity*. The design process should enable *chaos* and a *disequilibrium*, next to a *(re)equilibrium*. It should be able to deal with an infinite number of *individual user/product (system) combinations*. The process should be *flexible* and highly *person- and context-dependent*; support the *diversity* of designers to find *their preferred way* of creating design solutions within a certain *context*. The design process should preferably stimulate the awareness that designing regularly takes a *first person perspective*. Moreover, the design process should emphasise and support *reflection in, on and for action*, not only to develop (*tacit*) *knowledge* and *make decisions* during the design process, but also to support *novice designers* becoming aware of what they have *learned*, and stimulate and direct their *overall development* as a designer.

3. Current paradigms of design methodology

In the previous chapter we have formulated the characteristics of a process for designing disruptive innovative systems, products and services. Before developing our own process, we first explored if such a process already existed.

When looking at Dubberly's overview of design models (Dubberly, 2005), which is not an exhaustive but certainly a large collection of design models (well over eighty models) we see that a vast majority of the dozens of presented models start with some form of 'thinking' activity before moving towards synthesis, such as analysing, establishing needs, gathering and ordering information, understanding the context of use, establishing goals, planning, setting requirements, formulating the boundaries and the overall problem. Moreover, a vast majority of the presented models have a clear order and timeline line, be it linear, circular, a waterfall or wave-shaped, either with or without iterative loops and the possibility to redo certain steps.

The values that these models express seem to be incongruous with values like openness, flexibility and being out-of-control. Moreover, they seem to put cognition first, in contrast to Merleau-Ponty's stance that perception, through action, and pre-reflective experience precedes cognition: reflection is a consequence of action.

When looking at Dorst (1997) we see a similar pattern. He compares two influential paradigms of design methodology, one in which design is seen as a rational problem solving process (Simon, 1969; Roozenburg & Eekels, 1991), and one that regards design as an activity involving reflective practice (Schön, 1983).

3.1 Rational problem solving

This approach, which was introduced by Simon (1969), can be described as '... the search for a solution through the vast maze of possibilities (within the problem space) ... Successful

problem solving involves searching the maze selectively and reducing it to manageable solutions.’ (Simon, 1969). In order to find these solutions, the designer goes through the following basic design cycle:

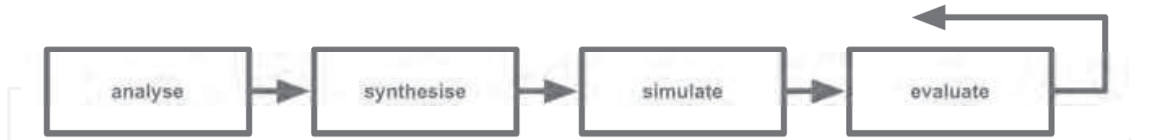


Fig. 4. Rational problem solving process.

There are many related processes that are based on this process such as the model of human-centred design activities as specified in ISO standard 13407 (Markopoulos et al., 2008). This model has comparable phases, although they are clustered differently and they put a large emphasis on participation of users (see Figure 5). Although most of these models have iterative loops and the possibility to redo certain steps, the overall process has a clear order and timeline incorporated. When contrasting it with our conclusion in chapter two, we see several discrepancies. Firstly, this design process starts with analysis before moving towards synthesis, thus blocking approaches that start with design making and experience. In this sense, it does not give equal weight to knowledge, skills and attitudes. Secondly, although the process is iterative (the designer makes several loops of these four steps), the process is sequential and fixed. It doesn’t allow for flexibility, personal freedom and context-dependency. Thirdly, although Simon stressed the ill defined and unstructured character of the design task, which we also consider important, he starts with a confined problem space, which does not comply with disruptive innovation and our search for transformation. According to the rational problem solving process, a designer can know beforehand, the width and breadth of his design challenge and its solution domain.

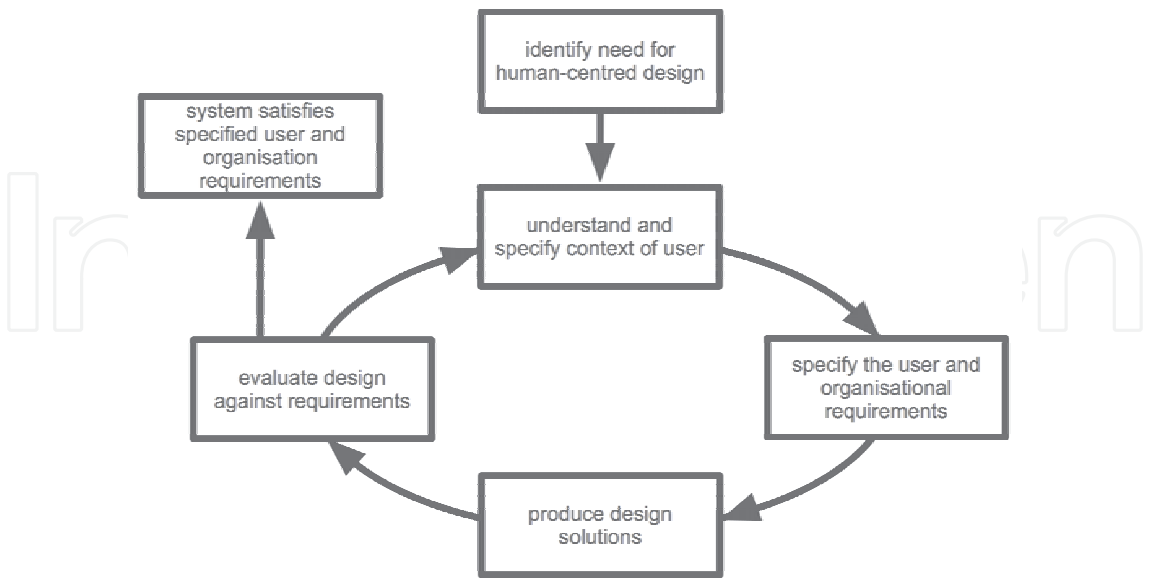


Fig. 5. Human-centred design process as specified in ISO standard 13407

We have shown that when designing complex systems, the challenges cannot be formulated exhaustively, challenges are unique and there are multiple opportunities for solution spaces.

Consequently, designing complex systems cannot be tackled through problem solving in a linear or cyclical controlled process, like the ones described above.

On the positive side, one can say that the process incorporates natural moments of reflection. For example, in the beginning of the synthesis phase, the designer is stimulated to diverge and develop many solutions, reflect on these ideas, converge and finally work towards one solution. As can be expected, these moments of reflection are guided by the requirements set within the analysis phase, which is again too limiting for our approach.

3.2 Reflective practice

Schön introduced in 1983 the reflective practitioner to stress the importance of the training of practitioners in the profession and to link the design process and task in a concrete design situation. The implicit 'knowing-in-action' is important, but this, hard to formalise, knowledge is difficult to teach. Therefore, Schön introduced reflection-in/on-action, in order to train the 'knowing-in-action' habits. In this process the designer goes through four steps:

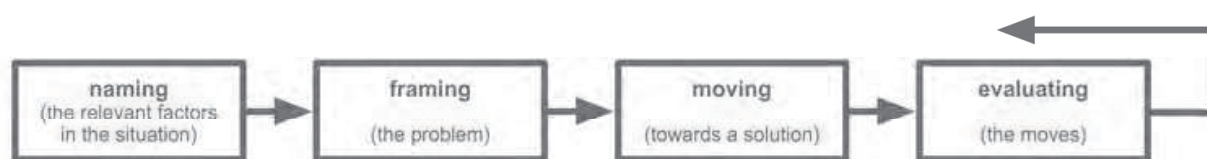


Fig. 6. Reflective practice design process.

Given the importance Schön attaches to implicit 'knowing-in-action' and reflection in and on action, the starting points of reflective practice match our conclusions in chapter two. It integrates knowledge, skills and attitude. It stimulates and acknowledges the ability of design professionals to know, reflect and learn in and on action; to learn by doing, and through reflection gain an understanding that arises from experience. Schön respects a designer's intuition, by letting her enter into an experience without judgment and respond to surprises through reflection, which is the way to learn from our actions.

So, why create a new design process and not adopt Schön's process? Firstly, the design process is rather global and it appears to offer insufficient support for our students to develop their vision and stimulate reflection. The moments of reflection are triggered by surprise during the process, which seems not enough for novice designers, because they have to develop their 'knowing-in-action' habits. Moreover, the design process is still sequential starting with naming and framing, which are both related to the analysis phases of the basic design cycle. So, in that sense, the analytical skills seem to prevail, even though Schön shows the importance of experience, making and intuition for reflective practice. Finally, although the design task is unique and context-dependent, the process as such is not flexible.

3.3 Concluding

Although there are many more design processes and approaches than we can describe here, we have concluded that most existing processes have positive and negative aspects for designing disruptive innovative intelligent systems, products and related services. Most processes use a sequential approach to gather information; a formal analysis phase precedes the creative conceptual phase. Moreover, the majority regards design action as something that implements knowledge instead as something that generates knowledge.

Since a design process is merely a model of reality which emphasises certain values and downplays or even ignores other values, we have created a new process to help novice

designers understand the principles of disruptive innovation, of designing intelligent systems, products and related services, of open design and of learning to become a designer within a competency-centred and self-directed learning setting. This process is called the Reflective Transformative Design process (RTD process) (Hummels and Frens, 2008). With our RTD process we do not aim at negating the existence and value of other used design and developmental processes. In many cases other processes can even be incorporated in the RTD process, due to its open character. Nevertheless, we want to offer a process expressing specific values for the changing field of design and design education.

4. Reflective Transformative Design process

The Reflective Transformative Design process (RTD process) is especially created to address the changing field of design and design education as discussed in chapter two. It supports designing disruptive innovative products and intelligent, open systems. Moreover, it does not only aim at supporting the creation such designs, but also aim at supporting novice designers to learn and develop while becoming a designer. In this chapter, we first explain the model, before elucidating how it supports the changing field of design and education.

4.1 The model

Developing design solutions, which are placed in the centre of this model, can be seen as a process of taking decisions based on too little information. The breadth and complexity of

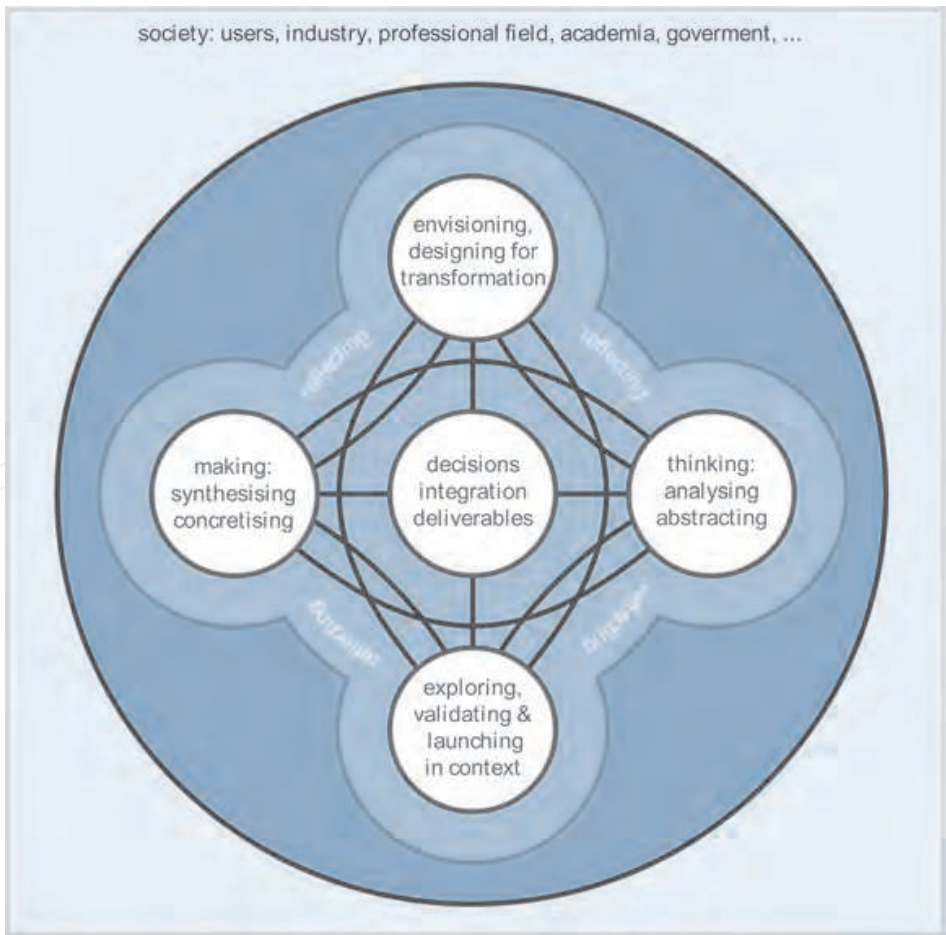


Fig. 7. The Reflective Transformative Design process.

the solution domain, and the interdependence of individual solutions, the design brief and vision make it impossible to determine beforehand if a decision is the right one. Therefore, we consider design decisions conditional. That is, a designer makes decisions to the best of her experience and knowledge. These decisions are not necessarily correct decisions, it is possible that further insight into the design challenge invalidates a decision, forcing the designer to rethink certain solutions and come up with more appropriate solutions. So decisions can change over time depending on the developments and emerging meaning. In a sense this links to characteristics like openness, uncertainty and being (partly) out-of-control. So instead of using a linear controlled process, the RTD process uses an open, explorative approach.

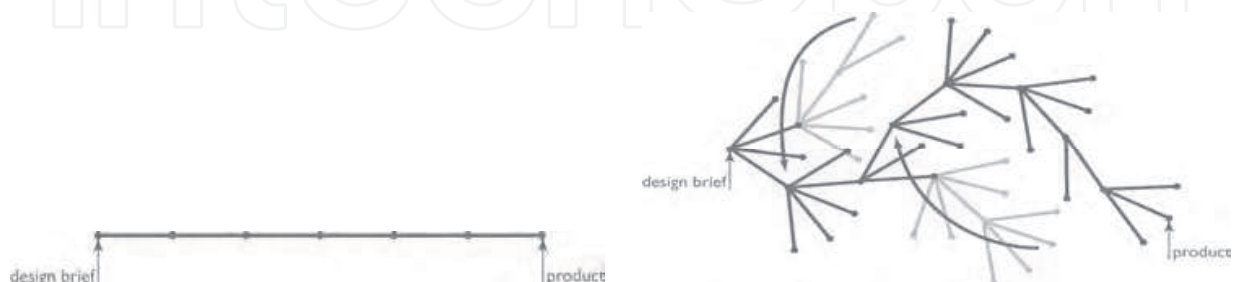


Fig. 8. A linear controlled process (left) versus an open, explorative process (right).

The RTD process knows two axes: vertically we distinguish drives and horizontally we distinguish strategies for information gathering to direct design decisions.

4.2 Drives (vertical axis)

We view the design process as a process where insight into design opportunities and the solution domain is achieved by continuous information gathering. Next to the design solution itself, we see two drives for information gathering.

The first drive is information gathering to direct the design decisions through the designer's vision (top circle). It focuses obviously on development of disruptive, innovative solutions to transform the behaviour and experience of users and society as a whole. Therefore, the RTD process encourages (novice) designers to create a vision on transformation from our current reality to a 'radical' new reality through an intelligent, open and/or complex system, product or service. This transformation can refer to personal, social and societal transformation. In the beginning of the project this vision might still be small and captured implicitly in the design brief if there is one. During the process, the vision can be developed and sharpened.

The second drive is information gathering to explore and validate design decisions in a real life context with users even beyond launching the system, product and services in the market (bottom circle). Because meaningfulness, value, and transformation are person- and context-related concepts that emerge in interaction, the possibilities and solutions have to be explored and tested extensively through experienceable prototypes and designs in the real life context. The emergence of meaning can preferably take place throughout the entire process, and later on also over a longer period of time, thus supporting co-evolution and adaptive behaviour.

4.3 Strategies (horizontal axis)

The drives are incorporated within two strategies that generate information and that reciprocally provide focus for each other. These strategies are indicated as the basic activities

that are central to academic thinking and action, consisting of analysing, synthesising, abstracting and concretising (Meijers, et al., 2005).

The first strategy revolves around design action, both synthesising and concretising, such as building experienceable prototype (left circle). Synthesising is the merging of elements into a coherent composition for a specific purpose. It goes from small to large. When concretising, one applies a general viewpoint to a specific situation or case. This action goes from large to small. This making strategy produces experiential information for the other activities in the design process. Design making enables the designer to use her intuition and through making the designer can open up new solution spaces that go beyond imagination. Reaching quality through making quantity supports decision-making.

The second strategy revolves around academic thinking: analysis and abstraction (right circle). While analysing, one unravels events, problems or systems into smaller subsets with a certain intention. So the activity goes from large to small. Abstracting does the opposite, going from small to large. It aims at making a viewpoint such as a theory, model or statement, relevant for more cases by bringing it to a higher aggregation level (Meijers et al., 2005). Academic thinking produces a more formal kind of information that (again) feeds into the connecting activities. Both strategies are valuable and should frequently alternate throughout the entire process.

4.4 Overall approach

Dependent on the person, context, or phase within the design process, designers determine where they start, and the order of the activities. This way the process supports flexibility, diversity and individuality, and it can even enhance chaos and going from a disequilibrium to a (re)equilibrium. The designers also determine how often they swap from one activity to another, although a high pace is recommended, especially during the early phases of the design process, but also during the later phases since this enables the designer to get a fast and good insight to what is happening within interaction in a diverse social context and market. As said, the RTD process is also an instrument to learn novice designers to become aware of values like openness, diversity, flexibility and craftsmanship. Moreover, the model actively supports reflection in, on and for action. The RTD process supports them to make their activities explicit and thus have an opportunity to reflect on those actions. When performing an activity within a circle, a student is stimulated to reflect in and on action, and an opportunity for reflection occurs every time the student switches activities. Therefore, we stimulate frequent changes from one activity to another, because this could help novices to

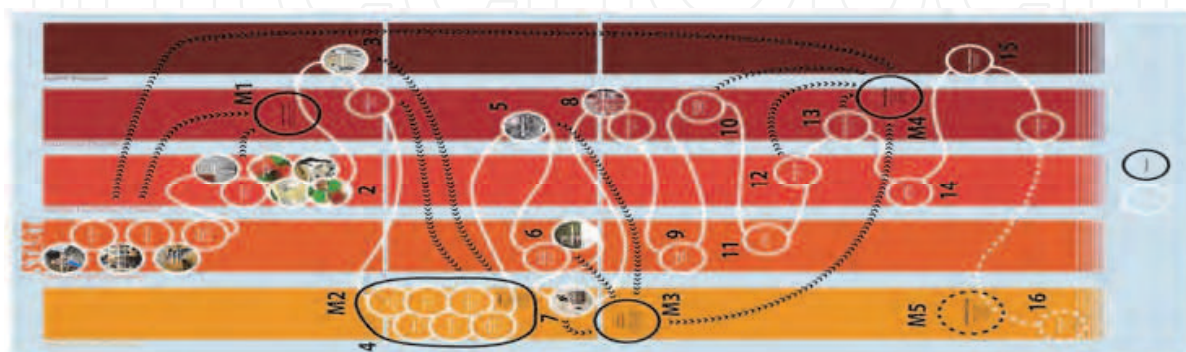


Fig. 9. A visualisation of the RTD design. The five circles were translated to rows and every activity was placed within, showing the relationship between activities.

train their reflective practice. The activity of reflection is indicated in the model (figure 7) by the lines between the mutual activities, and between the activities and the deliverables. Reflection on and for action can also be related to the entire project, learning activity or overall development. This is represented in the model by the reflection line of the outer circle.

In addition, by making the activities explicit by visualising all the steps, it can also smoothen the conversation to other stakeholders involved in the process. We encourage our design students to document their process in a schematic way (see figure 9). There is not one way for doing this; it is related to the skills of the students and their preference for a certain way of learning.

5. RTD process applied

The previous chapter described the model of the Reflective Transformative Design Process. In this chapter we describe and show the processes of two designs Other Brother and Ennea, in order to elucidate and discuss the possibilities of the RTD process to design disruptive innovative intelligent systems for transformation.

5.1 Other Brother

“The Other Brother” is a semi- autonomous device that captures images and video of spontaneous moments in the course of everyday life to enable people to re-experience these moments in a playful way. It is designed by John Helmes during his final Master's graduate project in cooperation with Microsoft Research Cambridge (UK) Lab (Helmes et al., 2009). The overall goal of this project was to design a situated, tangible object for a domestic setting, capturing natural and spontaneous social situations. It focused on more serendipitous, lightweight ways in which moments can be captured instead of conventional photo and video cameras, which require a person to take the initiative and to control the framing of the shot, leading to somewhat predictable results.

The Other Brother is the result of an iterative process using the RTD process, from initial (interactive) sketches, concepts and physical explorations towards several prototypes and a final design that were tested several times throughout the process in a home environment.



Fig. 10. The Other Brother captures images and video of spontaneous moments at home.

The project aimed at designing a disruptive innovative system. The client, Microsoft Research Cambridge (UK) Lab, did not set a specific brief up front. They gave full freedom to John as long as the project would fit the overall focus of the Socio-Digital Systems (SDS) department of MSR. After seeing a variety of projects of the SDS department, John decided to focus on connectedness in the broadest sense of the word. He started formulating the

overall goal to design a family of physical objects that are intertwined and enable people to be connected again in situations they are not connected right now. In order to explore the concept of connectedness, he used an extreme user paradigm to get inspired. Therefore, he started with generating 2D and 4D sketches for re-connecting people with a social phobia, and re-connecting inexperienced Internet users to experience privacy and security.



Fig. 11. Sketches to explore social phobia (left) and to explore Internet safety (right).

After finishing several 2D and physical sketches, John reflected upon his sketches and decided to focus on the creation of an object that could capture moments spent with others in the home. Four concepts were explored using computer sketches, evaluated with MSR and one concept was selected due to its serendipitous nature.

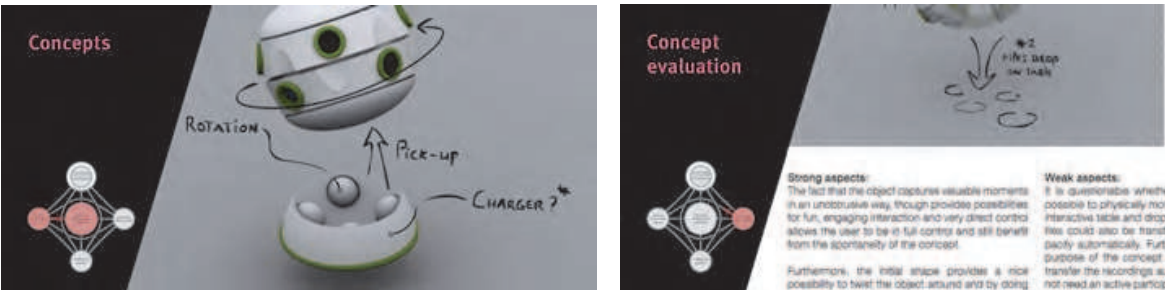


Fig. 12. Ideation and conceptualisation (left) and the evaluation of concepts (right).

Animation sketches were developed for watching the recorded files on an interactive table. Moreover, John started exploring cameras present in the market and research labs that have the option to respond in a dynamical way. This step, analysing existing products and literature, is generally done in an earlier stage when using other design processes. John explicitly decided to first develop his own vision and concepts, before being influenced by others.

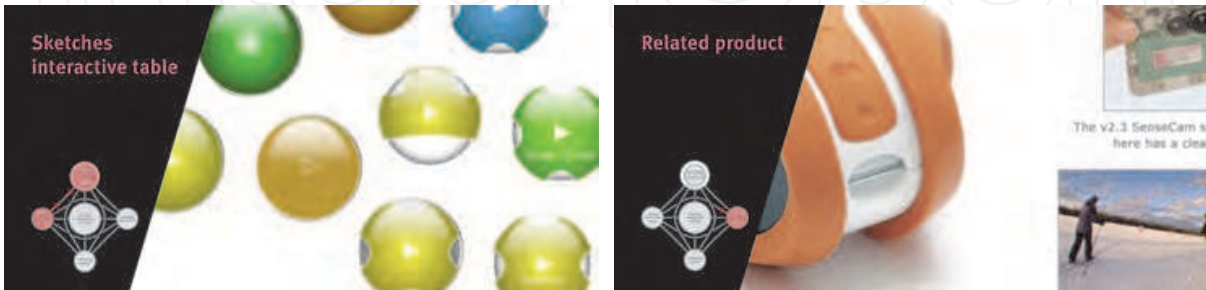


Fig. 13. Animated sketches (left) and a market evaluation of related products (right).

He sharpened his vision further by integrating a level of serendipity within the captured photos, videos and sounds. He predicted that the captured results would be much more

surprising when it is not possible for the user to exactly know what is being captured. The concept was further explored by means of a first working prototype. The main component of this prototype consisted of a digital photo camera controlled by external sensors and actuators.

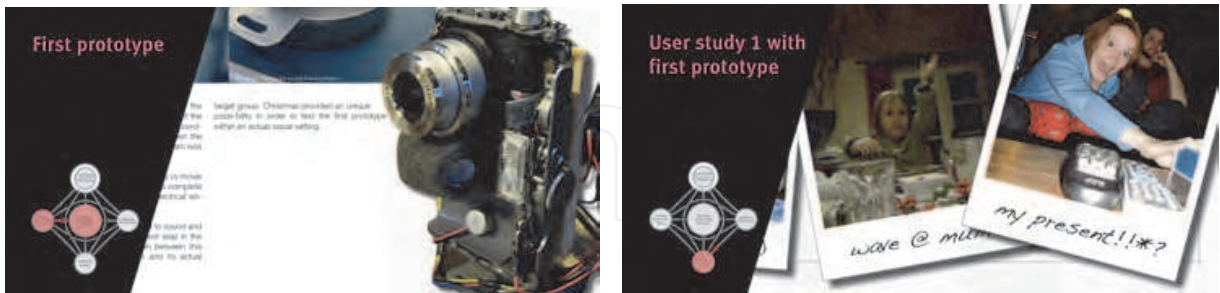


Fig. 14. First working prototype (left), explorative user study in the home situation (right).

Since meaning is generated in action, he initiated a first explorative user study with three families during Christmas to observe how people responded to the object and interact with it. Many questions arose during and after the study, which guided the direction of fine-tuning the vision. The fact that the first simple prototype was becoming an additional character within the group, a character taking part in the social activity, was further developed within the second prototype. The second prototype of The Other Brother was equipped with a front and back cover, a LED display and RGB-LEDs to change its colour. Moreover a website was made to view the photos made by The Other Brother, and a possible table-top interface was explored by means of a flash animation.



Fig. 15. Second working prototype (left) and a website to see the photos and videos (right).

After the initial deployment and re-design, a diary study in combination with an interview was executed within two different families as well as during a social meeting with a larger group of people. The main goal of this study was to deploy The Other Brother within a domestic environment for a longer period of time, and a social setting with a large group and observe people’s behaviour around it. The families were instructed to use The Other Brother for one week and were asked to keep track of their activities within a provided diary. They could view the photos and videos on the web and in a photo frame. The social meeting had an open character without instructions. The outcomes of these user studies were used to adjust the vision and re-design The Other Brother.

After creating a new design using computer sketches, the iterative process continued by means of translating the design into several Solid Works structures allowing to use 3D printing technologies in order to create a museum quality model. At the end of this process John reflected on his actions, as he had done regularly during the entire process.

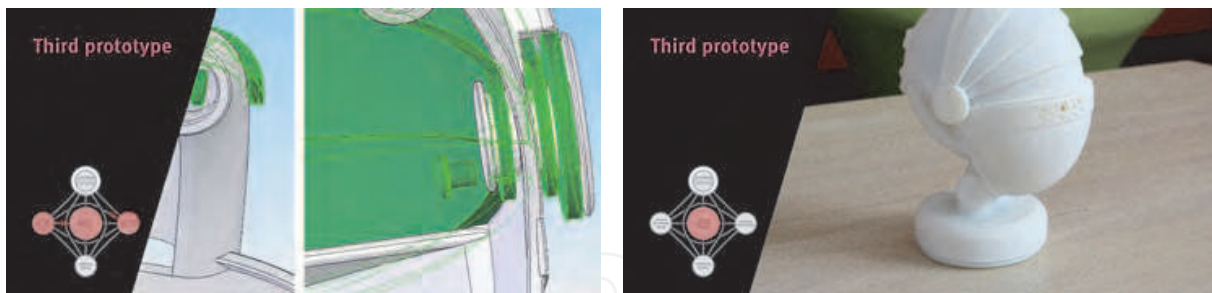


Fig. 16. Solid Works model (left) and the final working prototype (right).

It can be concluded that the Other Brother enables people to re-experience spontaneous moments from the past. Throughout the several studies it appeared that people found an emerging way of interacting with an innovative device that was radically new for them. The device and the captured fragments positively surprised them. This could have never been done without the working prototypes that John developed during the project. The studies enabled him to sharpen his vision, to study emerging behaviour and find possibilities for further development. Moreover, the RTD process enabled him to exploit his strength: ideation, conceptualisation and envisioning through interactive sketches and prototypes. John is someone who likes to use his making skills to initiate his decisions; truly reflection in, on and for action. He used this strategy at the start of the project too. The RTD process, which was new when he started using it for his project, legitimised him to start from making and envisioning, instead of analysing a problem. There were several people that questioned the validity and usefulness of starting with making and envisioning instead of analysing. But John proved them wrong. After having used the process during this project, he stuck with it and is still using it in his job.

The client, Socio-Digital Systems (SDS) department of MSR, deliberately gave him an open brief to become immersed in the concerns and questions that interested the group, and for them to be inspired by his designs. *"We were both surprised and pleased with the way this single device was being developed as part of a larger ecosystem of devices within the home. We hadn't expected such a breadth of vision."* (feedback client). Especially that last remark fits one of the main values of the RTD process: envisioning transformation. *"By far the biggest surprise for us as a group, however, was the realisation that the device itself appeared to have a life-like quality to it."* (feedback client). Again a remark that shows that disruptive innovation, and emerging behaviour and interaction is not something that one can imagine or reason upfront. It is something that grows in interaction, while making, envisioning, testing, analysing, creating, etcetera in a real life context during the entire design process.

5.2 Ennea

As said earlier, the RTD process is flexible, open and person-dependent, meaning that it can be used in many ways. Therefore we show the process of another project called Ennea.

Ennea is designed by Master's students Jasper Dekker, Laurens Doesborgh, Sjors Eerens, Jabe-Piter Faber and Jan Gillesen. It is a system that consists of several networked products that are coupled through an online platform. It is aimed at high school freshmen and is meant to guide them through their first year by analyzing their social behaviour and giving teachers the opportunity to aid in undesired situations (e.g. social isolation).



Fig. 17. Ennea is designed to support social behaviour of high school freshmen.

The Ennea ‘nodes’ are handed out to high school freshman when they enter high school and are carried by the pupils at all times. The nodes measure the proximity of other nodes and thus map the social structures in the group of high school freshmen. To be more specific, the measurements are condensed into two variables: (1) duration of contacts and (2) diversity of contacts. Based on these two variables each pupil gets assigned a ‘social’ role by the system that is representing her type of social behaviour. By rubbing two nodes together the pupils can see these roles temporarily appear on the small round screen of the node and can reflect on how they are doing in their new situation. Throughout the year these roles and social patterns are also discussed by teachers so as to make sure that nobody is ‘left behind’ and isolated.

The Ennea system was the result of a six-week master class that was sponsored by Microsoft research (USA). The students were asked to design a product or system within the context of learning and education using the RTD process (then at its infancy). The process that led to Ennea started rather analytical. By quickly cycling through analytical activities (reading literature, studying online information) and envisioning activities the students created an understanding of what their opportunity for design was to be. When they were satisfied with their vision they went on to explore through interactive and tangible sketches how their vision could take form.

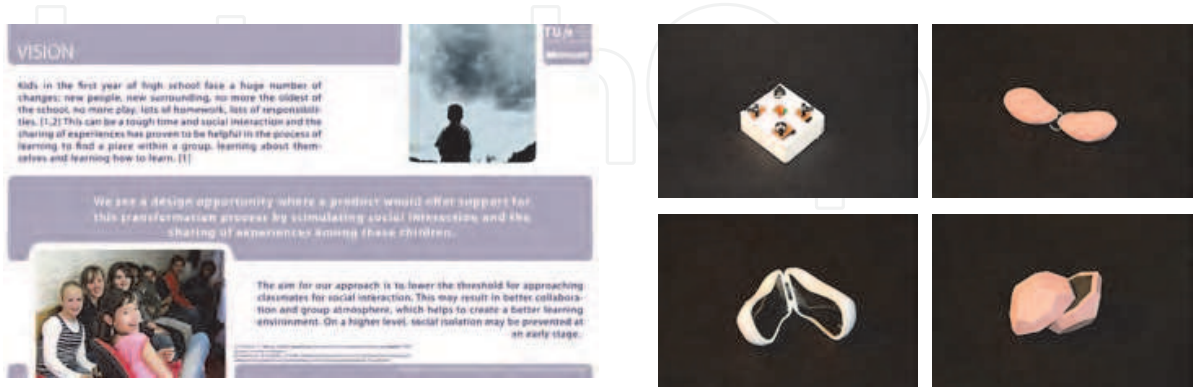


Fig. 18. Vision that led to Ennea (left) and exploration through tangible sketches (right).

They presented a vision, a scenario and a prototype that was scrutinized by coaches and fellow students. This led to a process of reflection on the starting points for their project and a rewritten vision.



Fig. 19. Adjusted vision (left) roles temporarily appear and scenario with a first concept (right)

From there they went to the high school freshmen themselves and commenced in a co-design session in context. The results of this activity were analyzed and slowly but certainly their understanding of the design opportunity became more fine-grained. They solidified their proposal with a thorough exploration of form and interaction.



Fig. 20. Co-design session with freshmen (left), exploration of form and interaction (right).

They finalized the design by creating a set of working prototypes that were tested in context.



Fig. 21. Fully working prototypes (left) and testing designs in context with freshmen (right).

The process was very iterative in the sense that all activities were done multiple times throughout the process. Because the students reflected on what they did and on what they learned they were aware of the process they were going through (sometimes helped by

coaches) and consciously steered their process through the activities of the RTD process. Therefore, the order in which the activities were done was not the same for each iteration. When looking at their process in retrospect it is striking to see that the goal of the project (that what the students wanted to accomplish) was under development almost till the moment that they started making the final prototypes. This highlights a typical characteristic of the RTD process: the process offers students the ability to keep momentum in their projects even when important decisions are still based on assumptions. The process does not fix the decision points in the process (as a sequential process does) but encourages exploration and the gathering of insight by means of different activities and reflection. The students were able to fine-tune and even change parts of their point of departure because they were filling in their assumptions while exploring and contextualizing their insights through their activities. Next to this the students commented on how the process allowed them to 'make mistakes' during the process. They were encouraged to keep up the tempo of their activities, as there was only limited time for the project. This led to quick successions of activities and many moments of 'reflection on action'. Because they started so intensively and because they made multiple, quick design cycles they found the opportunities and the dead-ends of the project early on in the process leaving them much more time to ground and fine-tune the project.

6. Conclusions and future developments

In this text we have shown that the changing field of industrial design and design education towards disruptive innovation for transformation, intelligent systems, open design and self-directed competency-centred learning, asks for a new view on design processes. The Reflective Transformative Design process is created to address these developments and emphasis values like openness, flexibility, diversity, context- and person dependency, envisioning a new society, intuition, craftsmanship, design making and design thinking, knowledge, skills and attitudes, and development through reflection. Given the importance of these values, one can regard the RTD process as an attitude rather than a method. Moreover, we have seen that the process forms the solution. For example, The Other Brother was a result of John Helmes' attention for envisioning, making and testing in a real life context and his desire to follow his intuition and get surprised in his search for disruptive innovation. We have seen similar results during the class *Multi-disciplinary perspectives on the design process?* that was run together with Panos Markopoulos. In this class we compared and discussed the different perspectives, strengths and weaknesses of three design processes in comparison with the RTD process with help from Philips Research (Value Proposition House), Bright Innovation Pittsburgh (Sales, Learn, React, Build), Astcon Rozwiazania Informatyczne (Agile: SCRUM) and Microsoft Research Cambridge (RTD process). The results from this class showed that every process stresses specific values and has specific outcomes. The RTD process appeared to be especially suitable for creating a flexible product vision for unknown needs, see figure 22.

We believe that design processes including the RTD process are especially beneficial for novice designers who are learning to become a designer. It is a means to stress certain values, to make ones actions explicit and thus have an opportunity to reflect on those actions, to smoothen the conversation to other stakeholders involved in the process, and to guide novice designers towards new possible activities within the design process. Over the

years designers find their own strength and weaknesses, and preferred approach. They have incorporated the process and reflection in and on action has been internalised.

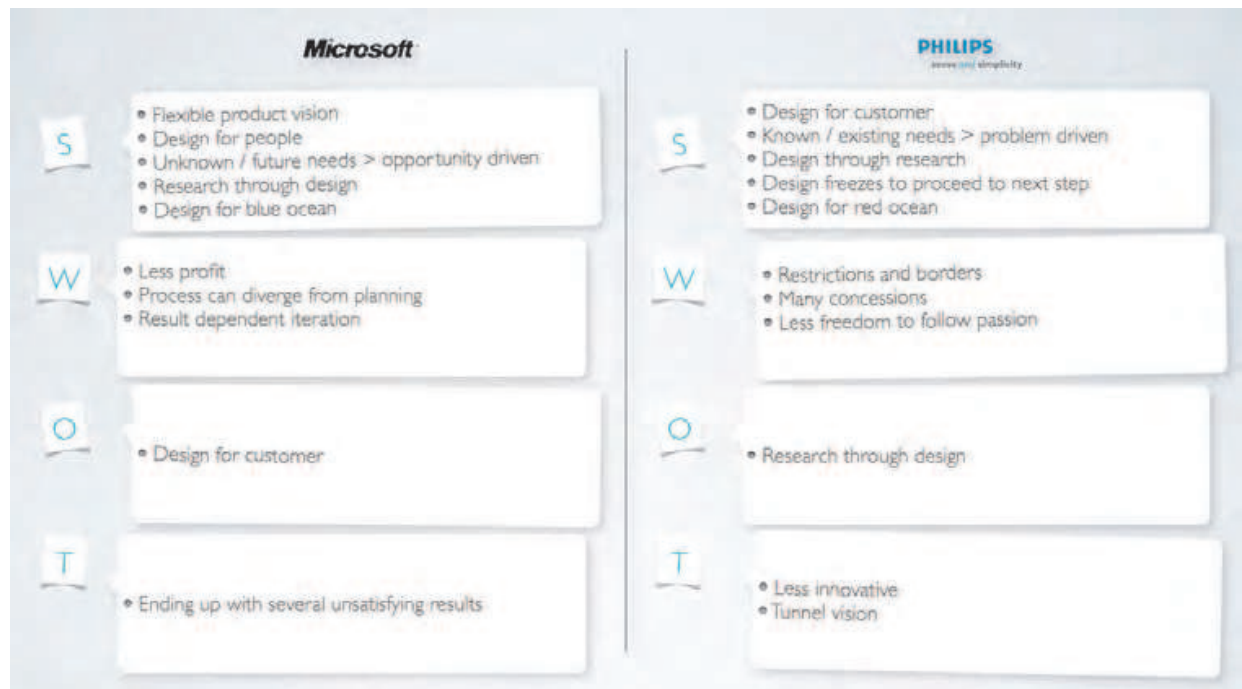


Fig. 22. SWOT analysis comparing the RTD process used at MSR Cambridge (left) and the Value Proposition House process used at Philips Research (right).

Consequently, the different activities within the RTD process will intertwine and be less discernable. The preference for certain activities within the RTD process will differ per person, resulting in a kind of personal process profile for every designer, see figure 23..

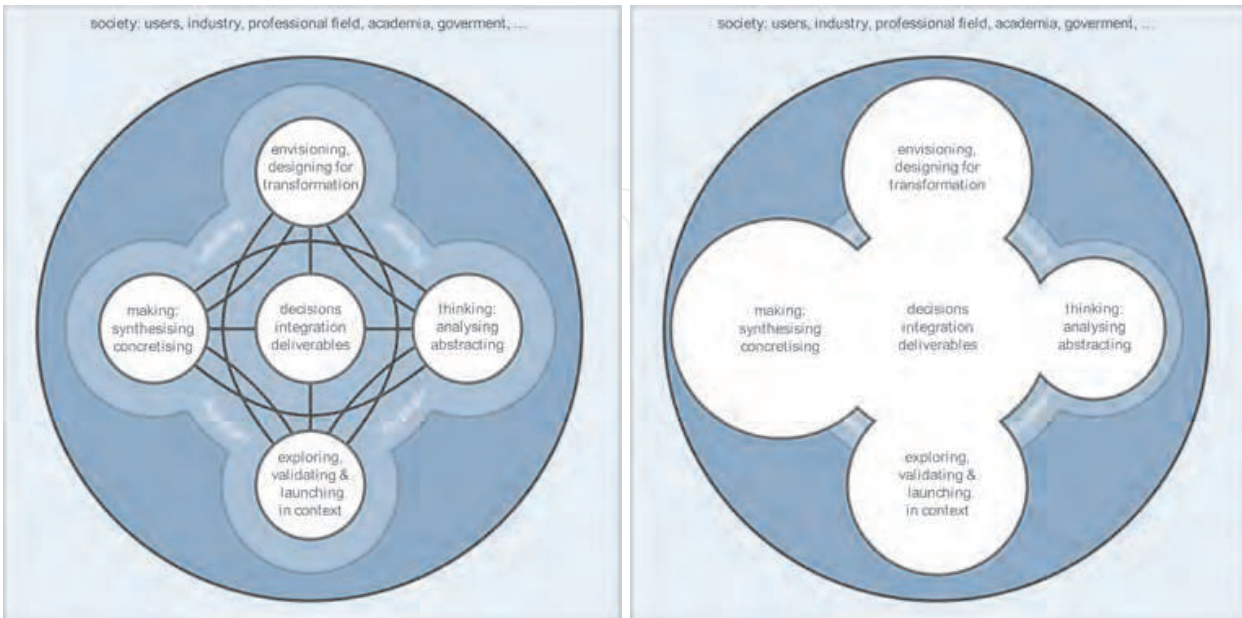


Fig. 23. Over the years the different activities within the RTD process will intertwine and result in a kind of personal process profile (right).

We have used the RTD process the last few years and it is still developing. Students experiment with a variety of visualisations to encourage reflection. Moreover, we are exploring together with industrial partners how we can extend the value for industry. Furthermore, we are exploring the need for new design methods that accompany the process. For example, PhD student Carl Megens is developing a flexible and dynamic Personas method that complements the RTD process. Finally, we are exploring the possibilities of real life settings during the entire design process. We are developing Experiential Design Landscapes to trigger and study emerging patterns in interaction with disruptive innovative systems. The data obtained from Landscapes is monitored, and via data-mining techniques emerging patterns are detected and responded upon. In this manner design synthesis, emerging behaviour and market analysis become integrated (Gent van et al., 2011).

7. Acknowledgment

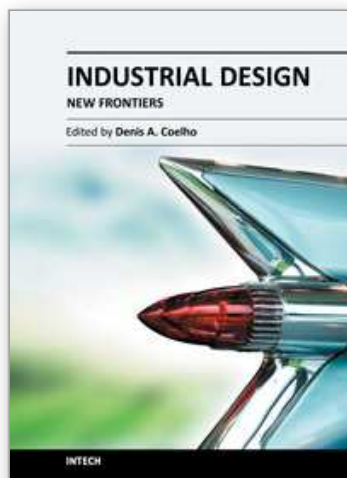
We like to thank all staff members and students who helped developing the RTD process, including Oscar Tomico, John Helmes, Jasper Dekker, Laurens Doesborgh, Sjors Eerens, Jabe-Piter Faber, Jan Gillesen, Panos Markopoulos, Carl Megens, Aarnout Brombacher, Sabine van Gent and Lu Yuan.

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A new breed of modern designers is on the way. These non-traditional industrial designers work across disciplines, understand human beings, as well as business and technology thus bridging the gap between customer needs and technological advancement of tomorrow. This book uncovers prospective designer techniques and methods of a new age of industrial design, whose practitioners strive to construct simple and yet complex products of the future. The novel frontiers of a new era of industrial design are exposed, in what concerns the design process, in illustrating the use of new technologies in design and in terms of the advancement of culturally inspired design. The diverse perspectives taken by the authors of this book ensure stimulating reading and will assist readers in leaping forward in their own practice of industrial design, and in preparing new research that is relevant and aligned with the current challenges of this fascinating field.

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