C. Hummels, D. Vinke, J. Frens, and J. Hu, "Competency-centered Education for Designing Interactive and Intelligent Products," Creation and Design, vol. 13, no. 2, pp. 4-17, 2011.

Competency-centered Education for Designing Interactive and Intelligent Products[1]

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Abstract

Societal, scientific and technological developments are changing the field of industrial design. The field expands towards designing for intelligent systems, products and related services. If one truly likes to design such disruptive systems, we believe that it implies a specific view on and attitude towards education. The Department of Industrial Design, Eindhoven University of Technology, has been facilitating students to become professional designers in designing interactive and intelligent products, systems and related services. In order to do so, the department offers a self-directed, competency-centered education model, including both our competency framework and the reflective transformative design process, in which learning and working come together. Students learn to learn (what, how and why) and we facilitate their learning in order for them to have the ability to deal creatively and flexibly with the large amounts of constantly evolving information in our 'knowledge era' and become the designers of the future.

[1] This article is based on the book "Eindhoven Designs (volume 2)" (Hummels & Vinke, 2009)

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编者按："交互设计"研究人工制品、环境和系统的行为，以及使这些行为的外观元素的设计和定义，探索产品、人与物质、文化、历史之间的对话，是二十一世纪设计的重要发展趋势。本刊编辑部特别"交互设计"专题，邀请几位国内设计界资名专家和学者，就适应性交互智能产品设计、智能家居环境、信息可视化、人机直觉化交互等，展开系列研究。

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适应交互智能产品设计需要的素质教育模式

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摘要： 荷兰埃因霍芬科技大学工业设计系自建系以来就注重培养学生成长为交互智能产品、系统及相关服务的专业设计师。我系创立并实施了一种新型的以能力素质为中心的教育模式。此模式包括素质架构及建立在这个架构上贯穿求实的设计流程两个方面。这个教育模式注重学生学习的方法（目标、方式和原因），从多方面培养学生在新的知识时代成为能够在应对大量不断变化的信息中保持创造性和灵活性的设计师。

Abstract: Societal, scientific and technological developments are changing the field of industrial design. The field expands towards designing for intelligent systems, products and related services. If one truly likes to design such disruptive systems, we believe that it implies a specific view on and attitude towards education. The Department of Industrial Design, Eindhoven University of Technology has been facilitating students to become professional designers in designing interactive and intelligent products, systems and related services. In order to do so, the department offers a self-directed, competency-centered education model, including both our competency framework and the reflective transformative design process, in which learning and working come together. Students learn to learn (what, how and why) and we facilitate their learning in order for them to have the ability to deal creatively and flexibly with the large amounts of constantly evolving information in our 'knowledge era' and become the designers of the future.

DOI 编码：10.3969/J.ISSN.1674-4187.2011.02.001

1. Introduction

In 2001, Eindhoven University of Technology (TU/e) started the Department of Industrial Design (ID) based on discussions with leading industry representatives, including Philips, Ericsson and Océ. The need from the industry has led to the focus of the department on the design of intelligent systems, products and related services, which addresses such issues as adaptive behavior, context-awareness and highly dynamic interaction. Instead of designing "closed" products and human-product interaction, our design students are educated to develop open systems that are not finished anymore when they leave the factory, but evolve in interaction through e.g. services and adaptation.

Since technology is changing so rapidly, it is potentially capable of transforming our lives and society in ways that we cannot know of beforehand. Therefore we want to educate future designers who are able to apply these 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.

We want them to explore and develop highly disruptive products, where the term "disruptive" implies the absence of a well- established frame of reference for users or the market. This implies that our students do not only need to develop the next generation of systems, products and services with which people can pursue their lives, but also investigate what kind of life and society we (designers, users, industry, society, ...) want these systems to support. This requires a central place for creating a vision on social/societal transformation next to user/market explorations and validation. Moreover, it requires support for exploring opportunities instead of solving problems (Hummels & Frens, 2008). All in all, it demands a holistic, creative, flexible and open attitude, in which designers explore new opportunities.

During the discussions with industry, it became clear that they were interested in hiring academically trained Industrial Design engineers, who are able to lead and work in multi-disciplinary teams, bringing the different perspectives together, and to bridge the worlds of new technological and business strengths on the one hand, and the societal and user desires, needs and opportunities on the other.

The approach of becoming such an integrator was also scrutinized when looking at the societal developments with respect to learning: present-day society asks for self-directed and life-long learning. Society in the twenty-first century is characterized by rapid changes in various domains, e.g. political, economic, social, aesthetical and ethical. At the same time, science and technology are developing at a very high pace, which is turning this era into a 'knowledge age'. The amount of knowledge is increasing very fast and is expected to go on growing at an even higher pace. Together with the advances in information and communication technology, this increases the volume of easily accessible information beyond imagination. Functioning effectively in this society requires the ability to deal creatively and flexibly with large amounts of constantly evolving information and the ability to learn continuously. Life-long learning, in turn, requires the ability to direct and regulate your learning. The notion of self-directed or self-regulated learning refers to the degree in which students are behaviorally, meta-cognitively and motivationally active in their learning.

These societal changes are reflected in the professional workplace. They also denote the challenge that higher education faces in having to prepare students to become professional experts in this new workplace. They need to become experts who create, apply and disseminate knowledge, and continuously construct and reconstruct their expertise in a process of life-long learning. They also need to become experts who are required to work in teams, to cooperate with experts in various fields, and to participate in complex networks of information, resources and instruction. Meeting the goals of education requires a high consistency between instruction, learning and assessment. Since the goals of education in the knowledge era have changed, a new perspective for this consistency is needed (Birenbaum, 2003; Segers, Dochy, & Cascallar, 2003).

Based on these observations, ID has chosen competency-centered learning as the educational model, in which learning and working come together. Students learn to learn (what, how and why) and we facilitate their learning in order for them to have the ability to deal creatively and flexibly with the large amounts of constantly evolving information in our 'knowledge era'. Competency-centered learning offers students the opportunity to give equal weight to knowledge, skills and attitudes, and stimulates them to learn by doing. Within our department, a competency is defined as an individual's ability to select, acquire, and use the knowledge, skills, and attitudes that are required for effective behavior in a specific professional, social or learning context. Therefore it offers a holistic view of design, where the student develops the overall competence to design by integrating, in our case, ten competency areas related to users, (interaction) design, technology, business, society, modeling, processes, ideation, teamwork and self-directed learning.

The nature of design beautifully intertwines the different types of knowledge with different human skills, in this case cognitive, emotional, perceptual-motor and social, sometimes implicit, sometimes explicit (Jun Hu, Chen, Bartneck, & Rauterberg, 2010). It is about learning and performing through practical application, while simultaneously acquiring theoretical skills. For example, design uses formal scientific notations (based on mathematics) as well as knowledge that is harder to formalise (e.g. aesthetics and creativity). Moreover, knowledge can be obtained through the analytical skills of the designer (e.g. analysing user behavior), as well as through the synthetic skills of the designer (e.g. building physical models).

In addition to skills and knowledge, competency development focuses on the designer's attitude, such as taking responsibility and professionalism. Therefore our students work as 'junior employees'

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in an authentic and professional context. Moreover, competency-centered learning is a highly person-and-context-dependent process. A different context asks for different competencies, and different students will prefer different competencies and develop them differently. Therefore, our students take responsibility for and create their own program. We have developed a variety of learning activities with an emphasis on experiential learning and self-reflection, while taking into account differences between individual students. Students can choose from these learning activities such as projects, assignments and modules that best match their learning goals and required competency development for a particular semester.

2. Competency-centered learning

Competency-centered educational approaches like ours are rooted in recent societal developments and in the constructivist learning paradigm. Pivotal in the constructivist perspective on learning is the notion of activity: learning is an active construction of meaning by the learner.

2.1 Background to our approach

Societal changes and developments have turned the 21st century into a 'knowledge era'. These changes have affected the professional workplace, and thus the demands placed on graduates: they need to be able to function as 'knowledge-managers' rather than 'knowledge-owners' (Dochy, Segers, & De Rijdt, 2002).These developments have also affected theories about learning, such as the constructivist perspective on learning. Our competency-centered learning approach is rooted in these societal changes and in the constructivist learning paradigm. Preparing graduates for their changing role in society requires a student-centered approach. In terms of educational goals this also implies a shift from teaching a specific body of knowledge to facilitating students' ability to learn and to develop continuously: to acquire knowledge, skills and attitudes needed to perform a task or role in a specific and often complex setting.

The constructivist paradigm includes learning theories that focus on mind-world relations. The individual or cognitive theories assume the locus of knowledge construction to be in the mind of the individual learner; the social or situative theories assume this locus to be in socially organized networks (Birenbaum, 2003). Common to both perspectives, however, is the key notion of activity: the understanding that learning and knowledge are an active construction of meaning by the learner. Furthermore, both focus on the learning process as a whole and on the interactions within this whole (Dochy, et al., 2002). Learners construct meaning by relating new information to what they already know. In doing so, they are influenced by their motivational and affective make-up as well as by their social-cultural environment (Tigelaar, 2005). We adhere to Birenbaum's reconciliatory view that these two perspectives are rather two sides of the same coin: it is the interaction between them that provides a starting point for unravelling the phenomenon of learning.

A constructivist perspective on learning has implications for the role of the student, for the design of the curriculum and assessment, and for the role of the 'teacher'. The curriculum should allow for active student participation and control, offer ample opportunity for interaction, and provide an authentic context for students' learning. Learning activities as well as assessments should allow for, or even necessitate, a holistic and integrative approach. Students need to develop the ability to reflect, to self-regulate their learning, to take responsibility, to learn from experience and to assess themselves. Staff members need to make a shift from teacher-focused to learning-focused, and their role needs to change from being an authoritative source of knowledge to facilitating students' learning. This requires a shift in their personal conceptions of knowledge, intelligence, teaching and learning (Birenbaum, 2003).

2.1.1 Exemplary learning

Students develop their competencies in a specific context. This context varies according to the learning activity and role at hand. In a five-year program we cannot offer students all possible contexts, design problems and design opportunities. Moreover, they will encounter new, unthought-of contexts and changing roles in their professional practice. This implies that students' learning is exemplary. They demonstrate that they can learn from particular experiences and that they can acquire knowledge, skills and attitudes in particular contexts. At the same time this shows their ability to analyze the context and to determine if and what new learning this requires on their part. In other words, this also demonstrates their potential: to analyze new and different contexts and to act accordingly. The exemplary nature of learning in a competency-centered curriculum stresses the relevance of authentic learning activities that reflect students' future work as a designer.

2.1.2 Context-related learning

What students learn is influenced or mediated by the tools and signs of their socio-cultural environment, as well as the established communities of practice which their academic discipline represents (Birenbaum, 2003; Schön, 1983). This implies that learning is context-related. It also implies that learning includes enculturation into and participation in these communities of practice, and adoption of the principles and standards shared by members of these communities. If we want to facilitate students' learning we should create opportunities for them to learn in an authentic context. That is why we have designed different types of learning activities, varying in the degree of authenticity. Projects, for example, reflect professional practice quite strongly. In their project, students have the opportunity to experience and perform various activities and roles, to deal with a real client and to be coached by professional design practitioners (about 35% of the teachers).

2.1.3 Reflective learning

Our view of reflective learning builds on the 'experiential learning cycle' (Kolb, 1984), the 'reflective practitioner'(Schön, 1983), and 'reflection in learning' (Moon, 1999). In our curriculum, students do various curricular learning activities. These activities become learning experiences by the meaning students give to them. By constructing this meaning, students build new knowledge, and relate this to existing knowledge. Reflection is a mental process that facilitates this creation of meaning and knowledge. If students articulate their reflections, for example by discussing their ideas or views with others or by writing them down, these reflections become a representation of their learning, which can be shared with others and may result in a new or transformed learning experience. As such, these reflections are an integral part of learning itself (Moon, 1999).

2.2 Competency and competency areas

The notion of competency is defined as "an individual's ability to acquire, select and use the knowledge, skills and attitude that are required for effective behavior in a specific professional, social or learning context". From this definition the role of knowledge acquisition appears: acquiring knowledge is no longer an end but a means to develop a particular competency needed to perform a specific task or role. Put differently, acquiring a specific, well-defined body of knowledge is no longer at the core of a competency-centered educational approach. Instead, students learn how to construct meaning by performing authentic learning activities. This construction of meaning includes the acquisition of context related knowledge, skills and attitudes, as well as knowledge about learning: knowing why, how, when and what to learn.

Based on the department's focus and learning approach, we have developed the ID Competence Framework. Being a student and developing through a competency-centered learning approach, puts an emphasis on activities and processes. So becoming a designer is not merely about being able to deliver qualitative excellent intelligent systems, products and related services, it is also about the process and competence of accomplishing this excellent design, and the process of becoming a competent designer. Therefore, the ID Competence Framework tries to capture the overall competence of designing, which consists of both the process of designing and becoming a designer, and the resulting design. The overall competence of designing is shaped by the integration of:

1. The student's development of the different competency areas, both with respect to 'weight' (breadth and depth per competency area) and 'profile' (the contour of all competency areas with respect to depth) as well as the student's insight in their competency development. So the development of competency areas refers to process (of designing and of becoming a designer) as well as to content (the elements of a design).
2. The extent to which the student is in control of the activities he/she performs within the (design) process of a specific learning activity, as well as the process 'profile' of a student: the path and steps the student prefers to take in the (design) process, so which steps and in which order.
3. The quality of the student's overall design or the whole of his/her deliverables, including the extent to which the student's deliverables show the student's own 'signature'.
4. The student's overall attitude including the professional and personal attitude.

The ID Competence Framework (Figure 1) includes ten specific competency areas that are involved during designing, related to the content of the system, product or service to be designed, and/or to the approach needed for the act of designing or becoming a designer. These ten competency areas are:

- Self-Directed and Continuous Learning: Take responsibility for and give direction to your own personal development, based on a continuous process of self-reflection and out of curiosity for future developments in technology and society.
- Descriptive and Mathematical Modeling: Being able to create and apply descriptive and mathematical models by using formal and mathematical tools, in order to justify design decisions and support the design of complex, highly dynamic and intelligent systems.
- Integrating Technology: Being competent in integrating technology means being able to explore, visualize, create and demonstrate

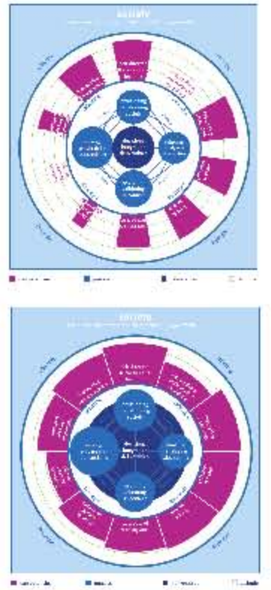

Fig1. Growth over the years in the competence framework

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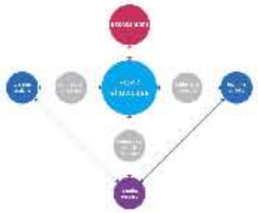

Fig 2. Overview of the learning environment

innovative concepts and experiences using technology, as well as analyzing the technical and economic feasibility of complex designs in which technology is integrated. Moreover, one needs to understand scientific writings and be able to communicate with engineers and researchers of another discipline.

• Ideas and Concepts: Develop visions, innovative ideas and concepts through creativity techniques, experimentations and the translation of research.

• Form and Senses: Experience and develop through doing and abstraction, aesthetical (physical) languages that connect thought and interactive form, in order to communicate specific properties of the design concept.

• User Focus and Perspective: Understand human characteristics, goals and needs, the context of use, and create empathy with users throughout the design process. Design user-system interaction for user experiences.

• Social Cultural Awareness: The focus of our education at ID is on designing intelligent systems, products and related services for social and societal transformation. Therefore, you need to learn to drive the design process from an awareness and understanding of developments in society, envision your designs in society, place the development of systems in a broader perspective, and take position in and evaluate the impact and mediating role of a system, product or service on society.

• Designing Business Processes: Bringing new products to users in a global market of a dynamic international industrial context requires knowledge of industrial business processes.

• Design and Research Processes: Master the design process and the research process, and adjust these processes to the demands of the task at hand.

• Teamwork and Communication: Work together towards a common goal using all strengths within a team and communicate opinions, ideas, information and results clearly and convincingly.

Although all competencies have strong relationships and together are necessary for the overall competence of designing, some of these competencies can be seen as meta-competencies. These competencies are necessary for all other competencies to develop. Especially Self-Directed and Continuous Learning is an important meta-competency, but also Teamwork and Communication as well as Design and Research Processes have a meta-character. Modeling in general can be considered a meta-competency but in this framework we focus on a specific kind of modeling.

Figure 1 shows an example of the growth of a student's competences over years, as well as an integrated view on the growth in applying reflective transformative design process. The reflective transformative design process will be described later in this article.

2.3 Facilitating competency-centered learning

This competency-centered learning environment for our students includes various mechanisms that facilitate, support and enhance students' learning and competency development at the level of a curricular learning activity as well as the semester as a whole: personal development plan, curricular learning activities, showcase, reflection, feedback and assessments. Figure 2 gives a schematic overview of the relationships between the components of the learning environment.

2.3.1 Personal Development Plan

It is the students' responsibility to determine what kind of industrial designer they want to become, taking into account the department's focus on designing intelligent systems, products and services. They capture this by setting long-term goals for their overall competence of designing in their Personal Development Plan (PDP). They manage their growth as a designer by determining what competency development this requires and what learning activities they need to select for a particular semester in order to achieve this. They include this in their PDP by setting short-term goals for that semester. Typical moments to reflect on their progress, and to review and adjust their PDP are halfway through and towards the end of the semester. At the assessment students' long and short-term goals serve as a point of reference to establish their development of the overall competence of designing and their growth as a designer.

2.3.2 Curricular learning activities

During the semester, students are engaged in various curricular learning activities, each with their own specific focus, scope and size, either representing individual or team work. Characteristic of all learning activities, however, is that students go through an iterative learning loop: a loop of competency development in a specific context. In other words, learning activities create opportunities for students to develop their competencies by acquiring context-specific knowledge, skills and attitudes.

Projects, for example, provide students with quite an authentic learning context. Students perform design activities and roles that are derived from or similar to tasks and roles in the professional practice of designing. Performing these tasks and roles is not an end in itself. It is intended to generate a meaningful learning experience: learning to determine what to perform, how to achieve this performance and why to achieve this. The 'how' refers to competencies to be developed and the 'why' to the ultimate goal of all the generated learning experiences: contributing to and shaping students' overall competence of designing, their vision on designing, their growth as a designer, and their ability to learn. Since students' achievements within learning activities are not an end in themselves, they are not assessed separately. Instead, students receive written feedback at the conclusion of a learning activity.

2.3.3 Showcase

Students also go through iterative learning loops at the level of a semester as a whole: their growth as a designer. The showcase plays a crucial part in this learning loop: it is the students' tool to monitor and communicate their development of the overall competence of designing and their vision on designing. The showcase as a communication tool for a student's overall development is a pivotal element of the assessment.

The showcase is a visual, interactive and integrative representation of students' overall development. In order to create their showcase students review what they have achieved in their learning activities of a particular semester, framed in the short-term goals they set in their PDP. They examine their deliverables, feedbacks and reflections and determine how these have contributed to and shaped their overall competence of designing and vision on designing. They evaluate this overall development, with the long-term goals in their PDP as a point of reference. This evaluation results in a coherent and overall picture of what they achieved in the semester as a whole. Students link this 'top-layer' of the showcase to the evidence layer by including integrative reflections. The evidence layer contains a careful selection of their deliverables, feedbacks and reflections, which corroborates their overall development and growth.

In order to demonstrate their growth as a designer across semesters, students include a time dimension in the top-layer of their showcase. The overall development students have achieved in a particular semester (present) is fitted in with their growth as a designer up to that point (past, which refers to previous semesters) and their view of the designer they want to become (future, which embodies the long-term goals in their PDP). The past is transformed, the present becomes the past, and the future becomes the present.

2.3.4 Reflection

In the course of curricular learning activities, students reflect at various moments. The common element in these reflective moments is that they help students understand and enhance their learning. By reflecting they give meaning to what they are doing or, put differently, they articulate what an activity or experience means for their own learning or development. When performing a design activity, they capture valuable learning moments by reflection in action. During the (design) process they reflect on action by reviewing what they have achieved so far, or by connecting newly acquired knowledge to prior knowledge. They reflect for action by identifying what knowledge or skills they still need to acquire to accomplish high-quality deliverables, or to perform a specific task or role effectively; or by determining what design activity they need to perform as a next step. Students are advised to write these reflections on a regular basis, for example in a 'learning journal' (Hummels & Frens, 2008; Moon, 1999); and to include corresponding visualizations of their deliverables and process. At the conclusion of a curricular learning activity they reflect on and for action as well. They look back to establish what they have achieved in the learning activity as a whole and how this has contributed to developing particular competencies. They look forward by determining how they can put this to use or expand their development in future learning activities, either within the same or in the next semester.

In the process of creating a showcase it is also students' reflections that help them understand and deepen their learning, this time at the level of their overall competence of designing, vision on designing and growth as a designer. Students mostly reflect on action by examining what they have achieved in the semester as a whole and how this had contributed to their overall development and growth. They reflect for action by determining what to achieve in the next semester, given the long-term ambitions for their growth as a designer. But creating a showcase may also offer moments of reflection in action. When reviewing the semester as a whole, students may have valuable or surprising learning moments, for example understanding what a particular competency area is about, or seeing a discrepancy between their competency profile and their envisioned competence of designing.

The explanation above shows that, depending on the content and scope of students' learning and activity, their (written) reflections vary in the level of abstraction, detailing and specificity. Their reflections on action within a learning activity, for example, are at the low end of abstraction and at the high end of detailing. The integrative reflections in the top-layer of their showcase, on the other hand, are at the high end of abstraction and at the low end of detailing.

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2.3.5 Feedback

Learning, which includes acquiring and applying knowledge, is an individual process on the student's part: it is an active construction of meaning by the learner. Feedback is a very powerful way of supporting and enhancing students' learning. It provides students with qualitative information on how they learn (process) and on what they learn (results). The scope of this feedback is a curricular learning activity, the exception being competency coach feedback: this addresses students' learning and competency development process of the semester as a whole. Feedback provides students with an 'external' perspective, which is complementary to the 'internal' perspective of their own reflection. During the process of a learning activity, staff members give verbal feedback on a regular basis and in a dialogue. This feedback helps students understand their process and competency development. Students can use this feedback to enhance their learning within the learning activity and achieve high-quality deliverables. The written feedback which students receive from staff members at the conclusion of a learning activity helps them to establish what they have achieved in the learning activity as a whole and how this contributes to their overall competence of designing. This written feedback also serves as evidence for the students' showcase and, as such, is input for the assessor.

2.3.6 Assessment

The focus of the assessment is students' development of the overall competence of designing, their vision on designing and their growth as a designer. The various elements of the assessment are the end-of-term exhibition at which students show their project; students' showcase; and a meeting between the assessor and student. The formal function of the assessment is to decide whether or not the student is promoted to the next block, and receives 30 credits or not. In our case this is determined by the developmental stage a student has achieved, related to the block he/she has been doing. Assessments also have a feedback function: the assessment gives qualitative information on the developmental stage the student has achieved, and how the student's growth has evolved since the previous assessment. As such, this gives the student feedback on his/her ability to self-assess. Last but not least, the assessment fulfills a feed-forward function: it gives students pointers to fine-tune or adjust their long-term goals for their growth as a designer and to set competency development goals in their PDP for the next semester.

3. Design process for competency-centered learning

Being a student and developing through a competency-centered learning approach, puts an emphasis on processes. So becoming a designer is inextricably bound up with delivering qualitative excellent intelligent systems, products and related services, the process and competence of accomplishing this excellent design, i.e. the process of designing, and the process of becoming a competent designer. These two aspects are especially addressed in the meta-competency areas 'Self-Directed and Continuous Learning' and 'Design and Research Processes'.

Because we consider these processes extremely important, we have developed a specific process that is based on the department's educational foundations and is suited for designing disruptive systems, products and services: the reflective, transformative process (RT process). This process can be used for both settings: the act of designing as well as the course of becoming a designer.

Moreover, due to this importance, we have decided to emphasize these processes deliberately in the ID competence framework in addition to the competency areas. This way we can stress the importance of specific aspects of the process. Moreover, the meta-competencies also address other aspects that are not included in the RT process. The learning activity perspective focuses predominantly on the process of designing.

Therefore we will provide an in-depth explanation of the reflective, transformative design process (Hummels & Frens, 2008). Before doing so, we will first reflect on the necessity to develop such a process.

3.1 Design processes

Both in literature and practice, one can find many design processes, all emphasizing different aspects of the design process. Dorst, for example, compares two influential paradigms of design methodology (Dorst, 1997), namely one in which design is seen as a rational problem-solving process (Roozenburg & Eekels, 1995; Simon, 1969); and one in which design is seen as an activity involving reflective practice (Schön, 1983).

The rational problem-solving process, 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.' (Koca et al., 2009). In order to find these solutions, the designer goes through basic design cycles which use four design activities: analyze, synthesize, simulate, evaluate.

In 1983 Schön introduced 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 (Schön, 1983). The implicit 'knowing-in-action' is important, but this hard-to-formalize knowledge is difficult to teach. Therefore, he introduces reflection-in/on-action, in order to train and guide the 'knowing-in-action' habits. In this process the designer goes through four steps: naming (the relevant factors in the situation) → framing (the problem) → moving (towards a solution)→ evaluating (the moves). The rational problem-solving process and its derivatives are used frequently not only in the industrial (product) design world, but also in the human-computer interaction field and the user-centered engineering and design field, such as the model of human-centered design activities as specified in ISO standard 13407 (Markopoulos, Read, & MacFarlane, 2008). This model has comparable phases, although they are clustered differently and they put a large emphasis on participation of users: understand and specify context of user → specify the user and organizational requirements → produce design solutions → evaluate design against requirements. Pallman distinguishes three approaches: a conservative, a romantic and a pragmatic approach (Pallman, 2003). The conservative approach has its philosophical base in rationalism and has similarities with Simon's process. Design is seen as a scientific or engineering endeavor. The design process is supposed to advance gradually through a series of structured steps from the abstract (requirements) to the concrete (resulting design) (Löwgren, 1995). The romantic approach gives prominence to the role of the designer who is seen as an imaginative mastermind, a 'creative genius', an artist equipped with almost magical abilities of creation. The process is seen as a 'black box', because the designer is not interested or able to explain how the final design came about. The process itself is guided by the designer's values and taste with respect to quality and aesthetics (Stolterman, 1994). The pragmatic approach gives importance to the position of the design project. Instead of being related to science or art, this approach sees design as a form of hermeneutic process of interpretation and creating meaning. It is closely related to Schön and sees designing as a reflective conversation with the materials of the design process.

There are many more design processes, coming from a business perspective, for example, or from informatics and mathematics. For example, the new product development (NPD) process that focuses on the complete process of bringing a new product or service to market. This process focuses predominantly on the different stages from idea generation and screening, to concept development and testing, to business analysis and testing (beta and market) down to technical implementation and commercialization. The design of intelligent systems, products and services has strong implications for this process. Because we are aiming at disruptive designs, there is no well- established frame of reference for users or the market. So, one important consequence of the development of strongly innovative products is a growing market uncertainty regarding 'if', 'how', and 'when' users can and will adopt such products. Often, it is not even clear to what extent these products are understood and interacted with in the intended manner. The perception of the user and the designer may be completely different. The technical mediation of a device or system and the transformation of a person's behavior and experience is a context-and person-dependent process, which requires a specific role for users in the design process (Koca, et al., 2009).

What all these processes reveal is that they are a representation of reality, and they amplify as well as reduce certain aspects of the process, either the focus on reflection, or the user, or the business aspects, and so on. The educational foundation of ID requires, in our opinion a process that can be used for the design process of disruptive systems as well as for the process of becoming a designer. With our reflective transformative 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 RT process, due to the open character. Nevertheless, we want to offer our students a process that supports developing their overall competence of designing in the field of intelligent systems, products and related services, their vision on designing and their growth as a designer, and emphasize the important aspects of our educational approach. Next we will elucidate the three implications for the RT process based on the department's educational foundation.

3.2 Reflective, transformative design process

When looking at the department's foundation with respect to focus and educational approach, we see three implications for the RT design process (Hummels & Frens, 2009):

1. As stated earlier, we educate students who are able to apply new technologies in innovative, daring and preferably beautiful ways, driven by a design vision of how our (social) world could be in the (near) future, and based on explorative studies and solid research with users in the

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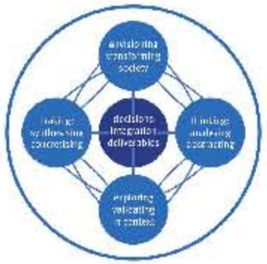

Fig 3. The reflective transformative design process

social-cultural context. This requires a central place for creating a vision on social and societal transformation in the design process that we teach our students, as well as a central place for exploring and validating with users in the context of use.

2. Competency-centered learning is a highly context-and-person-dependent process. A different context asks for different competencies and different students will prefer different competencies and develop them differently. Therefore, our students create their own program. The character of this education model and the notion that "the designer" and "the context" do not exist, ask for diversity of design processes or flexibility within.

3. Competency-centered learning gives equal weight to knowledge, skills and attitudes, and stimulates students to learn by doing. It is about learning and performing through practical application, while simultaneously acquiring theoretical skills. Both aspects are bridged by reflection on action. This approach fits the profession of industrial design perfectly. Consequently, the design process we offer the students should be holistic and give equal weight to knowledge, skills and attitudes throughout the process and stimulate reflection.

Therefore, we have created a flexible and open design process, the "reflective transformative design process" that addresses these three aspects (Hummels & Frens, 2008). Developing design solutions can be seen as a process of taking decisions based on too little information. The breadth of 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. The process knows two axes: vertically we distinguish drives and horizontally we distinguish strategies (Figure 3).

3.2.1 Drives (vertical axis)

We view the design process as a process where insight into the design opportunity and 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). We stimulate the development of innovative solutions to transform the behavior and experience of users and society as a whole. Therefore we encourage students to create a vision on transformation from our current reality to a new reality through an interactive/intelligent system. We encourage students to search for innovative solutions that are meaningful and valuable for users and our society. In the beginning of the project this vision might still be small and captured implicitly in the project brief. During the process, the vision can be developed and sharpened. Competency area Social Cultural Awareness has a natural inclination towards this activity, which doesn't mean that this activity isn't important for the other competency areas, nor that the other activities are not important for Social Cultural Awareness.

The second drive is information gathering to explore and validate design decisions in society with users (bottom circle). Because meaningfulness, value, technological mediation and social transformation are person and context-related issues, the possibilities and solutions have to extensively explored and tested in society. Competency area User Focus and Perspective has a natural affinity with this activity, which again doesn't mean that this activity isn't important for the other competency areas, nor that the other activities are not important for User Focus and Perspective.

3.2.2 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 analyzing, synthesizing, abstracting and concretizing (Meijers, Boeghuis, Mutsaers, Overveld, & Perrenet, 2005).

The first strategy revolves around design action, both synthesizing and concretizing, such as building experiential prototypes (left circle). Synthesizing is the merging of elements into a coherent composition for a specific purpose. It goes from small to large. Although designers often think of sketching and prototyping as synthesizing activities, the result of synthesizing can also be, for example, a theory or a descriptive model. When concretizing, one applies a general viewpoint to a specific situation or case. This action goes from large to small. This strategy produces experiential information for the other activities in the design process.

The second strategy revolves around academic thinking: analysis and abstraction (right circle). While analyzing, 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 equally valuable and should frequently alternate throughout the entire process. Dependent on the person, context, or phase within the design process, students determine where they start, how often they swap from one activity to another, and the order of the activities. This way the process supports flexibility and individuality. Moreover, the model actively supports reflection in, on and for action. The mental activity of giving meaning to a learning activity and, by doing so, building new knowledge that relates to existing knowledge is called reflection (Moon, 1999). When performing an activity within a circle, a student reflects on action. An opportunity for reflection on and for action occurs every time the student switches activities. Therefore, we stimulate frequent changes from one activity to another. This could help novices in design to train their reflective practice. The activity of reflection is indicated in the model 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 learning activity on a higher level. This is represented in the model by the reflection line of the outer circle (Figure 3).

4. Learning Activities

Within our competency-centered learning approach we offer a variety of curricular learning activities to reflect professional practice. This includes the experience with and performance of different tasks and roles. In order to enable students to become unique designers, we give them the opportunity to address their individual learning needs. This implies a shift in staff roles. We offer at least seven different learning activities: projects, assignments, modules, workshops and IDentity weeks.

Students have different ways of learning and different needs for developing their competencies. That is why we do not have one fixed program for all students (supply-oriented). Instead, we develop various types of curricular learning activities, each with their specific characteristics (e.g. authentic versus constructed context, focus on competence of designing versus specific competency areas, individual versus teamwork). Our students are responsible for determining what to learn and which learning activities suit best (demand-oriented). This implies that all our learning activities are 'electives'. Students' selection of learning activities is framed within the department's view on designing, the ten competency areas, and the overall focus on intelligent systems, products and related services. As junior employees, students are required to perform learning activities that represent authentic tasks and roles. In addition, they need to do a particular amount and type of work per semester, for example four assignments and a project for the second block of the first Bachelor's course year. By making a Personal Development Plan at the start of each semester, students determine per type of learning activity the ones that provide the best opportunity to develop their competencies and overall competence of designing. So learning activities are not an end to themselves but a means to generate learning processes and facilitate competency development in a specific context. To put it differently, learning activities are not a target but a gate that opens up the knowledge, skills and attitudes needed by students in order to develop their competencies. In terms of students' learning, this implies that process and output are equally important. Students' focus should not be on completing the learning activity successfully (task-orientation), but on exploring opportunities for competency development that enable them to accomplish high-quality deliverables. The deliverables which students produce in the context of the various learning activities serve a double purpose. Wanting to achieve high-quality deliverables triggers competency development in breadth as well as depth. Breadth refers to developing all aspects covered by a competency area as much as possible; depth refers to developing a particular aspect of a competency area several times, in various contexts. At the same time, the deliverables which students accomplish are tangible proof of having developed one or more competencies. As explained before, students' achievements within learning activities are not an end in themselves so they are not assessed separately. Instead, students receive written feedback at the conclusion of a learning activity. In terms of the ID Competence Framework, the various types of learning activities address different goals. Assignments and modules, for example, mostly facilitate development of one or two competency areas and some of the activities of the design process. A project or internship, on the other hand, offers students the opportunity to develop and integrate the full range of competency areas and design activities. Ultimately, however, students' competency development is meant to feed and enhance their overall competence of designing and their vision on designing. Students' showcase and the assessment process reflect this interaction between the learning activity perspective and the overall competence of designing perspective: the focus is on students' competence of designing and their vision on

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Fig4. Tactile Texting

Fig 5. Moving Media

Fig 6. Opus4

Fig 7. CIDS

designing, backed up by the quality of students' deliverables and competency development achieved in learning activities, rather than on the successful completion of separate learning activities.

Staff members in various roles facilitate, support and enhance students' learning and development. Staff roles include competency coach, project coach, expert, assignor, module lecturer and assessor.

4.1 Projects

Projects are the backbone of the ID curriculum. Within the projects, students develop their competencies in an authentic context, often including a real client. Projects allow for integration of the competencies into a design process, integration of research processes into the design, and interaction between the learning activity perspective and overall competence of designing.

Projects may vary in focus, they all enable students to develop and integrate their competencies as well as their overall competence of designing, to develop and express their vision on designing, and to experience their growth as a designer. There should be room for students to explore: experiencing success as well as living down a poor performance. As these projects are the backbone of the ID curriculum, they get a much larger part of 'dedicated time' than assignments or modules, for example. A typical Bachelor's project takes up 60% of dedicated time per semester whereas the final Master's project is a full semester. We want students to be able to experience different views and expertise. One way to achieve this is by cross-coaching. For example, during the semester, first year Bachelor's students work with their main coach but with at least one other coach from the Theme that is coaching the same project.

Let's give a few examples of project outcomes. Tactile Texting (Figure 4), made by Master graduate Guust Hilte, is a product that enables people to input text in touch-screen based mobile phones with- out having to look at the screen. The text input is done using one hand only. By moving your thumb through 'gullies', you can 'write' a character. By pushing down a button on the back of the prototype, the character is sent to a mobile phone via bluetooth. In this way you can input text while using your other hand and your sight for other activities, like cycling or walking.

Moving Media (Figure 5), designed by master graduate Tom Prinsen, is an intelligent remote control for controlling and transferring personal media. His project aimed at finding new and better control and interaction possibilities for home entertainment systems. Through a wide range of research and explorations a personal remote control has been developed for controlling and transferring media throughout the complete house. Wireless technology enables the remote control to know what devices are nearby and through this it can adapt its control and interaction possibilities. Because it is a personal remote control, every family member now has a personal access point to his or her media.

Opus4 (Figure 6), by Bachelor graduate Mendel Broekhuijsen is a mood-based exploring system for listening & browsing music in libraries. It is designed to overcome the existing boundaries between musical genres by providing music recommendation purely based on signal analysis. Used as private listening and browsing device, it inspires the visitors to find music that is on the edges of their musical taste.

CIDS (Figure 7), which is designed by 1st year Bachelor students Dounia Bourjila, C. Tessa van Doesburg and Geert van den Boogaart, is a decentralized system to bring primary school children together. To stimulate children in primary school to play together, this decentralized system was developed. CIDS is a system of multiple "agents" which are all equal, and thus have no leader. One "agent" in itself is pretty simple. But a combination of multiple "agents" causes more complex behaviour. Every "agent" in this system has a colourful LED which expresses its behaviour through patterns. These patterns should challenge the children to build larger groups of "agents", and because of this explore the possibilities together.

4.2 Assignments and modules

Assignments are learning activities for Bachelor's students. They represent 48 hours of individual work (as a counter balance to the team work in projects). The scope of an assignment is mostly one or two competency areas. Modules are learning activities for Master's students. They represent 40 to 240 hours of either small group or individual work. The scope of a module is mostly the area of one or two or more capacity groups, depending on the module size. Compared to the authentic context of projects, assignments and modules are more constructed by nature.

Assignments provide Bachelor's students with the opportunity for either awareness building of a particular competency area, for in-depth competency development or, in some cases, for the acquisition of specific knowledge and skills. Likewise, modules provide Master's students with the opportunity for extensive expertise building in particular competency areas or, in some cases, for the acquisition of specialized knowledge and skills. This competency development enables or enhances development of the overall competence of designing and vision on designing. It may also enhance students' competency development in their FMP. Assignors and module lecturers facilitate and support students' learning and competency development from an expert point of view. They also help students to put the competency areas involved into the wider perspective of the design process and the competence framework. Next we give a few examples of assignments and modules.

In the module 'designing for interaction' the students were challenged to create a design within the theme of learning and education. They were explicitly instructed to use the reflective transformative design process, then in its formative phase. One of the projects was 'Runes' (Figure 8), a system of products to support tutor classes in high school, the other example was 'Sense six' (Figure 9), a system that supports learning in action of extreme sports. Particularly interesting in these projects was how the students had different approaches in using the reflective transformative design process to quickly create insight in the design problem at hand. The first group iterated between analysis and the creation of a vision to direct their design process. From there they started their ideation process by means of the creation of quick prototypes after which they validated their findings by means of co-design sessions with high-school students. The second group of students took a different approach: they started by making experienceable prototypes and iterated between doing and the creation of a vision. They went on to validate their approach by visiting skate parks and finally grounded their work in theory. While we realize that this test provides only limited detail, this example corroborated our assumption that a design process is needed that is as versatile as the designers that use them.

The assignments and modules are specially tailored and designed for the profiles of our design students. We give two examples. Designing intelligent products, systems and related services require the designers to be able to integrate technology in their designs. Among other skills, programming is the key for the designers to prototype and experiment with the intelligent behaviors. However most of the design students do not have inherent affinity towards programming and electronics. In the assignment "Creative Programming for Designers", the AdMoVeo robotic platform (Figure 10) is designed purely for the purpose of teaching the industrial design students basic skills of programming (Alera & Hu, 2009; J. Hu & Alera, 2009, 2010). Moreover we aim at a platform that motivates and encourages the design students to explore their creativity with their passions in graphical and behavioral design, which in turn gives them spontaneous and intrinsic drive in learning programming.

The other example in tailoring the content for design students is the Master module "UML in action". When designing product behavior, the designer often needs to communicate to experts in computer software and protocols. In present-day software engineering, formal specification methods such as the Universal Modeling Language have been widely accepted. Teaching design students these formal methods is non-trivial because most of design students often have difficulties in programming the behaviors of complex produces and systems. Instead of programming, we use a technique, namely "acting-out" (Figure 11), for design students to master the formal methods. The experience shows that acting-out not only worked out very well as a teaching technique, but also showed the potential for bridging the processes of industrial design and software engineering (J. Hu, Rose, Feije, & Qian, 2007).

4.3 Workshops

Workshops are short activities intended to introduce particular topics that help students develop their competencies within the context of their project.

Workshops are comparatively short learning activities. Their size may vary from a few hours to a full day. Workshops provide students with an introduction to various topics, for example information brokering, design processes, reflection, group dynamics, creating a showcase, mathematical modeling, electronics or a theme-related topic. These introductions are meant to initiate and support students' competency development within the projects. Workshops can also provide students with specific expertise, either linked to a particular competency area.

4.4 IDentity weeks

IDentity weeks are 'vertical' activities for all ID students. In these weeks students' activities focus on their personal development, on their learning and development process, and on their overall competence of designing. ID weeks occur three times per semester: at the start, halfway and towards the end of the semester. The first ID week is intended for students to reflect on what they have achieved the previous semester in terms of overall competence of designing and their vision as a designer. In order to do so, they review their previous showcase and assessment. They include the outcomes of this review in their Personal Development Plan (PDP) to determine

Fig 8. Runes

Fig 9. Sense six

Fig 10. AdMoVeo robot for teaching creative programming

Fig 11. Acting-out in learning UML

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or adjust their long-term goals for their growth as a designer. In the ID week halfway through the semester, students start with their showcase for that semester. They reflect on what they have achieved in their learning activities so far, as related to the goals they set in their PDP. They relate this to the competency areas and select the deliverables that illustrate their competency development best. In the ID week towards the end of the semester, students essentially repeat the process they have gone through in the second ID week. They reflect on what they have achieved in all their learning activities. They select the learning evidence that proves their development best. They process reflections and visuals in the past, present and future dimension of their showcase.

5. Concluding Remarks

Ten years after the department started, we have now more than 550 students, both Bachelor and Master, and around 80 staff members involved in education. The department has been facilitating students to become professional designers. Our graduates distinguish themselves from other designers in various ways. They design interactive and intelligent systems are life-long and self-managing learners, develop their expertise and identity continuously, and contribute to building communities at the intersection of design, engineering and science. Our competency-centered model, including both the competence framework and the reflective transformative design process, plays an important role in facilitating the education, which is not only unique, but also makes the offered education very competitive.

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Eindhoven 埃因霍温
Eindhoven University of Technology 埃因霍温科技大学
Competency 能力素质或根据背景翻译简洁表达。
Competency Framework 素质架构
Competence 综合能力
Overall competence 总体综合能力
Reflective 反思的
Transformative 革命性的，变革的
Reflective Transformative Process 能思变交的流程
Exemplary learning 范例中学
Context-related learning 背景中学
Reflective learning 学而思，思而学
Self-Directed and Continuous Learning 持续自导学习
Descriptive and Mathematical Modeling 描述建模和数学建模
Ideas and Concepts 思路和概念
Form and Sense 外形和感官
User Focus and Perspective 从用户为中心和从用户角度出发 / 用户驱动设计
Social Cultural Awareness 社会文化意识
Design Business Processes 商业流程设计
Design and Research Processes 设计和研究综合流程 / 设计和研究综合
Teamwork and Communication 团队合作和交流

Reference:

[1] Alaes, S., & Hu, J. (2009). AdMoVeo: A Robotic Platform for Teaching Creative Programming to Designers. In M. Chang, R. Kuo, Kinshuk, G.-D. Chen & M. Hirose (Eds.), Learning by Playing. Game-based Education System Design and Development (Vol. 5670/2009, pp. 410-421). Banff, Canada: Springer Berlin / Heidelberg.

[2] Birenbaum, M. (2003). New insights into learning and teaching and their implications for assessment. Optimising new modes of assessment: In search of qualities and standards, 13-36.

[3] Dochy, F., Segers, M., & De Rijdt, C. (2002). Nieuwe ontwikkelingen: de assessmentcultuur. Assessment in onderwijs: nieuwe toetsvormen en assessment in studentgericht onderwijs en competentiegericht onderwijs/F. Dochy, L. Heylen en H. Van de Mosselaer (Eds.).-Utrecht: Lemma, 11-31.

[4] Dorst, K. (1997). Describing design: a comparison of paradigms. Delft University of Technology.

[5] Fallman, D. (2003). Design-oriented human-computer interaction.

[6] Hu, J., & Alaes, S. (2009). AdMoVeo: An Educational Robotic Platform For Learning Behavior Programming. Paper presented at the DeSForM 2009: Design and Semantics of Form and Movement.

[7] Hu, J., & Alaes, S. (2010). AdMoVeo: Created For Teaching Creative Programming. Paper presented at the Workshop Proceedings of the 18th International Conference on Computers in Education (ICCE 2010).

[8] Hu, J., Chen, W., Bartnack, C., & Rauterberg, M. (2010). Transferring Design Knowledge: Challenges and Opportunities. In X. Zhang, S. Zhong, Z. Pan, K. Wong & R. Yun (Eds.), Entertainment for Education. Digital Techniques and Systems (Vol. 6249, pp. 165-172): Springer Berlin / Heidelberg.

[9] Hu, J., Raus, R., Feijs, L., & Qian, Y. (2007). UMI in Action: Integrating Formal Methods in Industrial Design Education Technologies for E-Learning and Digital Entertainment (Vol. 4469/2007, pp. 489-494): Springer.

[10] Hummels, C., & Frens, J. (2008). Designing for the unknown: A design process for the future generation of highly interactive systems and products.

[11] Hummels, C., & Frens, J. (2009). The reflective transformative design process.

[12] Hummels, C., & Vinke, D. (2009). Eindhoven Designs (volume 2): Eindhoven University of Technology.

[13] Koca, A., Funk, M., Karapanos, E., Rauterberg, M., Reinink, A., van der Aalst, W., Carpenter, N., et al. (2009). Soft reliability: an interdisciplinary approach with a user-system focus. Quality and Reliability Engineering International, 25(1), 3-20.

[14] Lövgren, J. (1995). Applying design methodology to software development.

[15] Markopoulos, P., Read, J. C., & MacFarlane, S. (2008). Evaluating children's interactive products: principles and practices for interaction designers: Morgan Kaufmann Pub.

[16] Meijers, A., Bouhuis, V., Meteors, E., Overveld, C., & Perucart, J. (2005). Criteria voor academische bachelor en master curricula: Criteria for academic bachelor's and master's curricula.

[17] Moon, J. A. (1999). Reflection in learning and professional development: Theory and practice: Routledge.

[18] Roozenburg, N. F. M., & Eekels, J. (1995). Product design: fundamentals and methods: John Wiley & Sons.

[19] Schön, D. A. (1983). The reflective practitioner: Basic books New York.

[20] Segers, M., Dochy, F., & Cascallar, E. (2003). The era of assessment engineering: Changing perspectives on teaching and learning and the role of new modes of assessment. Optimising new modes of assessment: In search of qualities and standards, 1-12.

[21] Simon, H. A. (1969). The science of the artificial: MIT press.

[22] Stolterman, E. (1994). Guidelines or aesthetics: design learning strategies. Design Studies, 15(4), 448-458.

[23] Tigelaar, E. H. (2005). Design and evaluation of a teaching portfolio. Maastricht University.

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1. Introduction

In 2001, Eindhoven University of Technology (TU/e) started the Department of Industrial Design (ID) based on discussions with leading industry representatives, including Philips, Ericsson and Océ. The need from the industry has led to the focus of the department on the design of intelligent systems, products and related services, which addresses such issues as adaptive behavior, context-awareness and highly dynamic interaction. Instead of designing "closed" products and human-product interaction, our design students are educated to develop open systems that are not finished anymore when they leave the factory, but evolve in interaction through e.g. services and adaptation.

Since technology is changing so rapidly, it is potentially capable of transforming our lives and society in ways that we cannot know of beforehand. Therefore we want to educate future designers who are able to apply these 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. We want them to explore and develop highly disruptive products, where the term "disruptive" implies the absence of a well- established frame of reference for users or the market. This implies that our students do not only need to develop the next generation of systems, products and services with which people can pursue their lives, but also investigate what kind of life and society we (designers, users, industry, society, …) want these systems to support. This requires a central place for creating a vision on social/societal transformation next to user/market explorations and validation. Moreover, it requires support for exploring opportunities instead of solving problems (Hummels & Frens, 2008). All in all, it demands a holistic, creative, flexible and open attitude, in which designers explore new opportunities.

During the discussions with industry, it became clear that they were interested in hiring academically trained Industrial Design engineers, who are able to lead and work in multi-disciplinary teams, bringing the different perspectives together, and to bridge the worlds of new technological and business strengths on the one hand, and the societal and user desires, needs and opportunities on the other.

The approach of becoming such an integrator was also scrutinized when looking at the societal developments with respect to learning: present-day society asks for self-directed and life-long learning. Society in the twenty-first century is characterized by rapid changes in various domains, e.g. political, economic, social, aesthetical and ethical. At the same time, science and technology are developing at a very high pace, which is turning this era into a 'knowledge age'. The amount of knowledge is increasing very fast and is expected to go on growing at an even higher pace. Together with the advances in information and communication technology, this increases the volume of easily accessible information beyond imagination. Functioning effectively in this society requires the ability to deal creatively and flexibly with large amounts of constantly evolving information and the ability to learn continuously. Life-long learning, in turn, requires the ability to direct and regulate your learning. The notion of self-directed or self-regulated

learning refers to the degree in which students are behaviorally, meta-cognitively and motivationally active in their learning.

These societal changes are reflected in the professional workplace. They also denote the challenge that higher education faces in having to prepare students to become professional experts in this new workplace. They need to become experts who create, apply and disseminate knowledge, and continuously construct and reconstruct their expertise in a process of life-long learning. They also need to become experts who are required to work in teams, to cooperate with experts in various fields, and to participate in complex networks of information, resources and instruction. Meeting the goals of education requires a high consistency between instruction, learning and assessment. Since the goals of education in the knowledge era have changed, a new perspective for this consistency is needed (Birenbaum, 2003; Segers, Dochy, & Cascallar, 2003).

Based on these observations, ID has chosen competency-centered learning as the educational model, in which learning and working come together. Students learn to learn (what, how and why) and we facilitate their learning in order for them to have the ability to deal creatively and flexibly with the large amounts of constantly evolving information in our 'knowledge era'.

Competency-centered learning offers students the opportunity to give equal weight to knowledge, skills and attitudes, and stimulates them to learn by doing. Within our department, a competency is defined as an individual's ability to select, acquire, and use the knowledge, skills, and attitudes that are required for effective behavior in a specific professional, social or learning context. Therefore it offers a holistic view of design, where the student develops the overall competence to design by integrating, in our case, ten competency areas related to users, (interaction) design, technology, business, society, modeling, processes, ideation, teamwork and self-directed learning.

The nature of design beautifully intertwines the different types of knowledge with different human skills, in this case cognitive, emotional, perceptual-motor and social, sometimes implicit, sometimes explicit (Jun Hu, Chen, Bartneck, & Rauterberg, 2010). It is about learning and performing through practical application, while simultaneously acquiring theoretical skills. For example, design uses formal scientific notations (based on mathematics) as well as knowledge that is harder to formalize (e.g. aesthetics and creativity). Moreover, knowledge can be obtained through the analytical skills of the designer (e.g. analyzing user behavior), as well as through the synthetic skills of the designer (e.g. building physical models).

In addition to skills and knowledge, competency development focuses on the designer's attitude, such as taking responsibility and professionalism. Therefore our students work as 'junior employees' in an authentic and professional context. Moreover, competency-centered learning is a highly person-and-context-dependent process. A different context asks for different competencies, and different students will prefer different competencies and develop them differently. Therefore, our students take responsibility for and create their own program. We

have developed a variety of learning activities with an emphasis on experiential learning and self-reflection, while taking into account differences between individual students. Students can choose from these learning activities such as projects, assignments and modules that best match their learning goals and required competency development for a particular semester.

2. Competency-centered learning

Competency-centered educational approaches like ours are rooted in recent societal developments and in the constructivist learning paradigm. Pivotal in the constructivist perspective on learning is the notion of activity: learning is an active construction of meaning by the learner.

2.1 Background to our approach

Societal changes and developments have turned the 21st century into a 'knowledge era'. These changes have affected the professional workplace, and thus the demands placed on graduates: they need to be able to function as 'knowledge-managers' rather than 'knowledge-owners' (Dochy, Segers, & De Rijdt, 2002).These developments have also affected theories about learning, such as the constructivist perspective on learning. Our competency-centered learning approach is rooted in these societal changes and in the constructivist learning paradigm. Preparing graduates for their changing role in society requires a student-centered approach. In terms of educational goals this also implies a shift from teaching a specific body of knowledge to facilitating students' ability to learn and to develop continuously: to acquire knowledge, skills and attitudes needed to perform a task or role in a specific and often complex setting.

The constructivist paradigm includes learning theories that focus on mind-world relations. The individual or cognitive theories assume the locus of knowledge construction to be in the mind of the individual learner; the social or situative theories assume this locus to be in socially organized networks (Birenbaum, 2003). Common to both perspectives, however, is the key notion of activity: the understanding that learning and knowledge are an active construction of meaning by the learner. Furthermore, both focus on the learning process as a whole and on the interactions within this whole (Dochy, et al., 2002). Learners construct meaning by relating new information to what they already know. In doing so, they are influenced by their motivational and affective make-up as well as by their social-cultural environment (Tigelaar, 2005). We adhere to Birenbaum's reconciliatory view that these two perspectives are rather two sides of the same coin: it is the interaction between them that provides a starting point for unravelling the phenomenon of learning.

A constructivist perspective on learning has implications for the role of the student, for the design of the curriculum and assessment, and for the role of the 'teacher'. The curriculum should allow for active student participation and control, offer ample opportunity for interaction, and provide an authentic context for students' learning. Learning activities as well as assessments should allow for, or even necessitate, a holistic and integrative approach. Students need to develop the ability to reflect, to self-regulate their learning, to take responsibility, to

learn from experience and to assess themselves. Staff members need to make a shift from teacher-focused to learning-focused, and their role needs to change from being an authoritative source of knowledge to facilitating students' learning. This requires a shift in their personal conceptions of knowledge, intelligence, teaching and learning (Birenbaum, 2003).

2.1.1 Exemplary learning

Students develop their competencies in a specific context. This context varies according to the learning activity and role at hand. In a five-year program we cannot offer students all possible contexts, design problems and design opportunities. Moreover, they will encounter new, unthought-of contexts and changing roles in their professional practice. This implies that students' learning is exemplary. They demonstrate that they can learn from particular experiences and that they can acquire knowledge, skills and attitudes in particular contexts. At the same time this shows their ability to analyze the context and to determine if and what new learning this requires on their part. In other words, this also demonstrates their potential: to analyze new and different contexts and to act accordingly. The exemplary nature of learning in a competency-centered curriculum stresses the relevance of authentic learning activities that reflect students' future work as a designer.

2.1.2 Context-related learning

What students learn is influenced or mediated by the tools and signs of their socio-cultural environment, as well as the established communities of practice which their academic discipline represents (Birenbaum, 2003; Schön, 1983). This implies that learning is context-related. It also implies that learning includes enculturation into and participation in these communities of practice, and adoption of the principles and standards shared by members of these communities. If we want to facilitate students' learning we should create opportunities for them to learn in an authentic context. That is why we have designed different types of learning activities, varying in the degree of authenticity. Projects, for example, reflect professional practice quite strongly. In their project, students have the opportunity to experience and perform various activities and roles, to deal with a real client and to be coached by professional design practitioners (about 35% of the teachers).

2.1.3 Reflective learning

Our view of reflective learning builds on the 'experiential learning cycle' (Kolb, 1984), the 'reflective practitioner'(Schön, 1983), and 'reflection in learning' (Moon, 1999). In our curriculum, students do various curricular learning activities. These activities become learning experiences by the meaning students give to them. By constructing this meaning, students build new knowledge, and relate this to existing knowledge. Reflection is a mental process that facilitates this creation of meaning and knowledge. If students articulate their reflections, for example by discussing their ideas or views with others or by writing them down, these reflections become a representation of their learning, which can be shared with others and may result in a new or transformed learning experience. As such, these reflections are an integral part of learning itself (Moon, 1999).

2.2 Competency and competency areas

The notion of competency is defined as "an individual's ability to acquire, select and use the knowledge, skills and attitude that are required for effective behavior in a specific professional, social or learning context". From this definition the role of knowledge acquisition appears: acquiring knowledge is no longer an end but a means to develop a particular competency needed to perform a specific task or role. Put differently, acquiring a specific, well-defined body of knowledge is no longer at the core of a competency-centered educational approach. Instead, students learn how to construct meaning by performing authentic learning activities. This construction of meaning includes the acquisition of context related knowledge, skills and attitudes, as well as knowledge about learning: knowing why, how, when and what to learn.

Based on the department's focus and learning approach, we have developed the ID Competence Framework. Being a student and developing through a competency-centered learning approach, puts an emphasis on activities and processes. So becoming a designer is not merely about being able to deliver qualitative excellent intelligent systems, products and related services, it is also about the process and competence of accomplishing this excellent design, and the process of becoming a competent designer.

Therefore, the ID Competence Framework tries to capture the overall competence of designing, which consists of both the process of designing and becoming a designer, and the resulting design. The overall competence of designing is shaped by the integration of:

1. The student's development of the different competency areas, both with respect to 'weight' (breadth and depth per competency area) and 'profile' (the contour of all competency areas with respect to depth) as well as the student's insight in their competency development. So the development of competency areas refers to process (of designing and of becoming a designer) as well as to content (the elements of a design).

2. The extent to which the student is in control of the activities he/she performs within the (design) process of a specific learning activity, as well as the process 'profile' of a student: the path and steps the student prefers to take in the (design) process, so which steps and in which order.

3. The quality of the student's overall design or the whole of his/her deliverables, including the extent to which the student's deliverables show the student's own 'signature'.

4. The student's overall attitude including the professional and personal attitude.

The ID Competence Framework (Figure 1) includes ten specific competency areas that are involved during designing, related to the content of the system, product or service to be designed, and/or to the approach needed for the act of designing or becoming a designer. These ten competency areas are:

- *Self-Directed and Continuous Learning*: Take responsibility for and give direction to your own personal development, based on a continuous process of self-reflection and out of curiosity for future developments in technology and society.
- *Descriptive and Mathematical Modeling*: Being able to create and apply descriptive and mathematical models by using formal and mathematical tools, in order to justify design decisions and support the design of complex, highly dynamic and intelligent systems.
- *Integrating Technology*: Being competent in integrating technology means being able to explore, visualize, create and demonstrate innovative concepts and experiences using technology, as well as analyzing the technical and economic feasibility of complex designs in which technology is integrated. Moreover, one needs to understand scientific writings and be able to communicate with engineers and researchers of another discipline.
- *Ideas and Concepts*: Develop visions, innovative ideas and concepts through creativity techniques, experimentations and the translation of research.
- *Form and Senses*: Experience and develop through doing and abstraction, aesthetical (physical) languages that connect thought and interactive form, in order to communicate specific properties of the design concept.
- *User Focus and Perspective*: Understand human characteristics, goals and needs, the context of use, and create empathy with users throughout the design process. Design user-system interaction for user experiences.
- *Social Cultural Awareness*: The focus of our education at ID is on designing intelligent systems, products and related services for social and societal transformation. Therefore, you need to learn to drive the design process from an awareness and understanding of developments in society, envision your designs in society, place the development of systems in a broader perspective, and take position in and evaluate the impact and mediating role of a system, product or service on society.
- *Designing Business Processes*: Bringing new products to users in a global market of a dynamic international industrial context requires knowledge of industrial business processes.
- *Design and Research Processes*: Master the design process and the research process, and adjust these processes to the demands of the task at hand.
- *Teamwork and Communication*: Work together towards a common goal using all strengths within a team and communicate opinions, ideas, information and results clearly and convincingly.

Although all competencies have strong relationships and together are necessary for the overall competence of designing, some of these competencies can be seen as meta-competencies. These competencies are necessary for all other competencies to develop. Especially Self-Directed and Continuous Learning is an important meta-competency, but also Teamwork and Communication as well as Design and Research Processes have a meta-character. Modeling in general can be considered a meta-competency but in this framework we focus on a specific kind of modeling.

Figure 1 shows an example of the growth of a student's competences over years, as well as an integrated view on the growth in applying reflective transformative design process. The reflective transformative design process will be described later in this article.

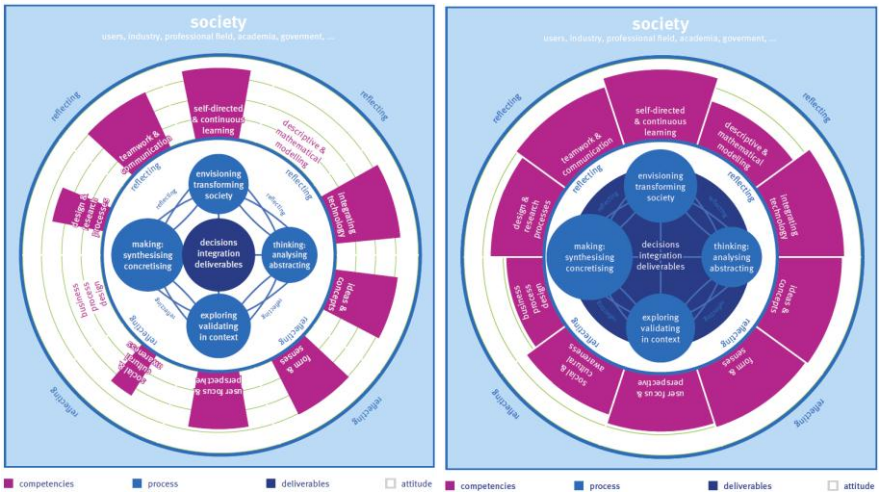

Figure 1. Growth over the years in the competence framework

2.3 Facilitating competency-centered learning

This competency-centered learning environment for our students includes various mechanisms that facilitate, support and enhance students' learning and competency development at the level of a curricular learning activity as well as the semester as a whole: personal development plan, curricular learning activities, showcase, reflection, feedback and assessments. Figure 2 gives a schematic overview of the relationships between the components of the learning environment.

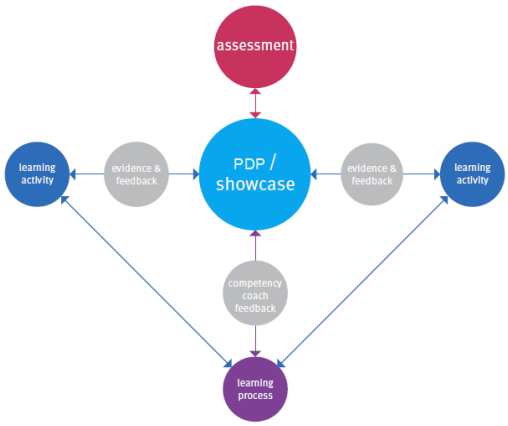

Figure 2.Overview of the learning environment

2.3.1 Personal Development Plan

It is the students' responsibility to determine what kind of industrial designer they want to become, taking into account the department's focus on designing intelligent systems, products and services. They capture this by setting long-term goals for their overall competence of

designing in their Personal Development Plan (PDP). They manage their growth as a designer by determining what competency development this requires and what learning activities they need to select for a particular semester in order to achieve this. They include this in their PDP by setting short-term goals for that semester. Typical moments to reflect on their progress, and to review and adjust their PDP are halfway through and towards the end of the semester. At the assessment students' long and short-term goals serve as a point of reference to establish their development of the overall competence of designing and their growth as a designer.

2.3.2 Curricular learning activities

During the semester, students are engaged in various curricular learning activities, each with their own specific focus, scope and size, either representing individual or team work. Characteristic of all learning activities, however, is that students go through an iterative learning loop: a loop of competency development in a specific context. In other words, learning activities create opportunities for students to develop their competencies by acquiring context-specific knowledge, skills and attitudes.

Projects, for example, provide students with quite an authentic learning context. Students perform design activities and roles that are derived from or similar to tasks and roles in the professional practice of designing. Performing these tasks and roles is not an end in itself. It is intended to generate a meaningful learning experience: learning to determine what to perform, how to achieve this performance and why to achieve this. The 'how' refers to competencies to be developed and the 'why' to the ultimate goal of all the generated learning experiences: contributing to and shaping students' overall competence of designing, their vision on designing, their growth as a designer, and their ability to learn. Since students' achievements within learning activities are not an end in themselves, they are not assessed separately. Instead, students receive written feedback at the conclusion of a learning activity.

2.3.3 Showcase

Students also go through iterative learning loops at the level of a semester as a whole: their growth as a designer. The showcase plays a crucial part in this learning loop: it is the students' tool to monitor and communicate their development of the overall competence of designing and their vision on designing. The showcase as a communication tool for a student's overall development is a pivotal element of the assessment.

The showcase is a visual, interactive and integrative representation of students' overall development. In order to create their showcase students review what they have achieved in their learning activities of a particular semester, framed in the short-term goals they set in their PDP. They examine their deliverables, feedbacks and reflections and determine how these have contributed to and shaped their overall competence of designing and vision on designing. They evaluate this overall development, with the long-term goals in their PDP as a point of reference. This evaluation results in a coherent and overall picture of what they achieved in the semester as a whole. Students link this 'top-layer' of the showcase to the evidence layer by including

integrative reflections. The evidence layer contains a careful selection of their deliverables, feedbacks and reflections, which corroborates their overall development and growth.

In order to demonstrate their growth as a designer across semesters, students include a time dimension in the top-layer of their showcase. The overall development students have achieved in a particular semester (present) is fitted in with their growth as a designer up to that point (past, which refers to previous semesters) and their view of the designer they want to become (future, which embodies the long-term goals in their PDP). The past is transformed, the present becomes the past, and the future becomes the present.

2.3.4 Reflection

In the course of curricular learning activities, students reflect at various moments. The common element in these reflective moments is that they help students understand and enhance their learning. By reflecting they give meaning to what they are doing or, put differently, they articulate what an activity or experience means for their own learning or development. When performing a design activity, they capture valuable learning moments by reflection in action. During the (design) process they reflect on action by reviewing what they have achieved so far, or by connecting newly acquired knowledge to prior knowledge. They reflect for action by identifying what knowledge or skills they still need to acquire to accomplish high-quality deliverables, or to perform a specific task or role effectively; or by determining what design activity they need to perform as a next step. Students are advised to write these reflections on a regular basis, for example in a 'learning journal' (Hummels & Frens, 2008; Moon, 1999); and to include corresponding visualizations of their deliverables and process. At the conclusion of a curricular learning activity they reflect on and for action as well. They look back to establish what they have achieved in the learning activity as a whole and how this has contributed to developing particular competencies. They look forward by determining how they can put this to use or expand their development in future learning activities, either within the same or in the next semester.

In the process of creating a showcase it is also students' reflections that help them understand and deepen their learning, this time at the level of their overall competence of designing, vision on designing and growth as a designer. Students mostly reflect on action by examining what they have achieved in the semester as a whole and how this had contributed to their overall development and growth. They reflect for action by determining what to achieve in the next semester, given the long-term ambitions for their growth as a designer. But creating a showcase may also offer moments of reflection in action. When reviewing the semester as a whole, students may have valuable or surprising learning moments, for example understanding what a particular competency area is about, or seeing a discrepancy between their competency profile and their envisioned competence of designing.

The explanation above shows that, depending on the context and scope of students' learning and activity, their (written) reflections vary in the level of abstraction, detailing and specificity. Their reflections on action within a learning activity, for example, are at the low end of

abstraction and at the high end of detailing. The integrative reflections in the top-layer of their showcase, on the other hand, are at the high end of abstraction and at the low end of detailing.

2.3.5 Feedback

Learning, which includes acquiring and applying knowledge, is an individual process on the student's part: it is an active construction of meaning by the learner. Feedback is a very powerful way of supporting and enhancing students' learning. It provides students with qualitative information on how they learn (process) and on what they learn (results). The scope of this feedback is a curricular learning activity, the exception being competency coach feedback: this addresses students' learning and competency development process of the semester as a whole. Feedback provides students with an 'external' perspective, which is complementary to the 'internal' perspective of their own reflection.

During the process of a learning activity, staff members give verbal feedback on a regular basis and in a dialogue. This feedback helps students understand their process and competency development. Students can use this feedback to enhance their learning within the learning activity and achieve high-quality deliverables. The written feedback which students receive from staff members at the conclusion of a learning activity helps them to establish what they have achieved in the learning activity as a whole and how this contributes to their overall competence of designing. This written feedback also serves as evidence for the students' showcase and, as such, is input for the assessor.

2.3.6 Assessment

The focus of the assessment is students' development of the overall competence of designing, their vision on designing and their growth as a designer. The various elements of the assessment are the end-of-term exhibition at which students show their project; students' showcase; and a meeting between the assessor and student. The formal function of the assessment is to decide whether or not the student is promoted to the next block, and receives 30 credits or not. In our case this is determined by the developmental stage a student has achieved, related to the block he/she has been doing. Assessments also have a feedback function: the assessment gives qualitative information on the developmental stage the student has achieved, and how the student's growth has evolved since the previous assessment. As such, this gives the student feedback on his/her ability to self-assess. Last but not least, the assessment fulfills a feed-forward function: it gives students pointers to fine-tune or adjust their long-term goals for their growth as a designer and to set competency development goals in their PDP for the next semester.

3. Design process for competency-centered learning

Being a student and developing through a competency-centered learning approach, puts an emphasis on processes. So becoming a designer is inextricably bound up with delivering qualitative excellent intelligent systems, products and related services, the process and competence of accomplishing this excellent design, i.e. the process of designing, and the process

of becoming a competent designer. These two aspects are especially addressed in the meta-competency areas 'Self-Directed and Continuous Learning' and 'Design and Research Processes'.

Because we consider these processes extremely important, we have developed a specific process that is based on the department's educational foundations and is suited for designing disruptive systems, products and services: the reflective, transformative process (RT process). This process can be used for both settings: the act of designing as well as the course of becoming a designer. Moreover, due to this importance, we have decided to emphasize these processes deliberately in the ID competence framework in addition to the competency areas. This way we can stress the importance of specific aspects of the process. Moreover, the meta-competencies also address other aspects that are not included in the RT process. The learning activity perspective focuses predominantly on the process of designing. Therefore we will provide an in-depth explanation of the reflective, transformative design process (Hummels & Frens, 2008). Before doing so, we will first reflect on the necessity to develop such a process.

3.1 Design processes

Both in literature and practice, one can find many design processes, all emphasizing different aspects of the design process. Dorst, for example, compares two influential paradigms of design methodology (Dorst, 1997), namely one in which design is seen as a rational problem-solving process (Roozenburg & Eekels, 1995; Simon, 1969); and one in which design is seen as an activity involving reflective practice (Schön, 1983).

The rational problem-solving process, 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.' (Koca et al., 2009). In order to find these solutions, the designer goes through basic design cycles which use four design activities: analyze, synthesize, simulate, evaluate.

In 1983 Schön introduced 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 (Schön, 1983). The implicit 'knowing-in-action' is important, but this hard-to-formalise knowledge is difficult to teach. Therefore, he introduces reflection-in/on-action, in order to train and guide the 'knowing-in-action' habits. In this process the designer goes through four steps: naming (the relevant factors in the situation) → framing (the problem) → moving (towards a solution) → evaluating (the moves).

The rational problem-solving process and its derivatives are used frequently not only in the industrial (product) design world, but also in the human-computer interaction field and the user-centered engineering and design field, such as the model of human-centered design activities as specified in ISO standard 13407 (Markopoulos, Read, & MacFarlane, 2008). This model has comparable phases, although they are clustered differently and they put a large

emphasis on participation of users: understand and specify context of user → specify the user and organizational requirements → produce design solutions → evaluate design against requirements.

Fallman distinguishes three approaches: a conservative, a romantic and a pragmatic approach (Fallman, 2003). The conservative approach has its philosophical base in rationalism and has similarities with Simon's process. Design is seen as a scientific or engineering endeavor. The design process is supposed to advance gradually through a series of structured steps from the abstract (requirements) to the concrete (resulting design) (Löwgren, 1995). The romantic approach gives prominence to the role of the designer who is seen as an imaginative mastermind, a 'creative genius', an artist equipped with almost magical abilities of creation. The process is seen as a 'black box', because the designer is not interested or able to explain how the final design came about. The process itself is guided by the designer's values and taste with respect to quality and aesthetics (Stolterman, 1994). The pragmatic approach gives importance to the position of the design project. Instead of being related to science or art, this approach sees design as a form of hermeneutic process of interpretation and creating meaning. It is closely related to Schön and sees designing as a reflective conversation with the materials of the design process.

There are many more design processes, coming from a business perspective, for example, or from informatics and mathematics. For example, the new product development (NPD) process that focuses on the complete process of bringing a new product or service to market. This process focuses predominantly on the different stages from idea generation and screening, to concept development and testing, to business analysis and testing (beta and market) down to technical implementation and commercialization. The design of intelligent systems, products and services has strong implications for this process. Because we are aiming at disruptive designs, there is no well- established frame of reference for users or the market. So, one important consequence of the development of strongly innovative products is a growing market uncertainty regarding 'if ', 'how', and 'when' users can and will adopt such products. Often, it is not even clear to what extent these products are understood and interacted with in the intended manner. The perception of the user and the designer may be completely different. The technical mediation of a device or system and the transformation of a person's behavior and experience is a context-and person-dependent process, which requires a specific role for users in the design process (Koca, et al., 2009).

What all these processes reveal is that they are a representation of reality, and they amplify as well as reduce certain aspects of the process, either the focus on reflection, or the user, or the business aspects, and so on. The educational foundation of ID requires, in our opinion a process that can be used for the design process of disruptive systems as well as for the process of becoming a designer. With our reflective transformative 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 RT process, due to the open character. Nevertheless, we want to offer our students a process that supports developing their overall competence of

designing in the field of intelligent systems, products and related services, their vision on designing and their growth as a designer, and emphasize the important aspects of our educational approach. Next we will elucidate the three implications for the RT process based on the department's educational foundation.

3.2 Reflective, transformative design process

When looking at the department's foundation with respect to focus and educational approach, we see three implications for the RT design process (Hummels & Frens, 2009):

1. As stated earlier, we educate students who are able to apply new technologies in innovative, daring and preferably beautiful ways, driven by a design vision of how our (social) world could be in the (near) future, and based on explorative studies and solid research with users in the social-cultural context. This requires a central place for creating a vision on social and societal transformation in the design process that we teach our students, as well as a central place for exploring and validating with users in the context of use.
2. Competency-centered learning is a highly context-and-person-dependent process. A different context asks for different competencies and different students will prefer different competencies and develop them differently. Therefore, our students create their own program. The character of this education model and the notion that "the designer" and "the context" do not exist, ask for diversity of design processes or flexibility within.
3. Competency-centered learning gives equal weight to knowledge, skills and attitudes, and stimulates students to learn by doing. It is about learning and performing through practical application, while simultaneously acquiring theoretical skills. Both aspects are bridged by reflection on action. This approach fits the profession of industrial design perfectly. Consequently, the design process we offer the students should be holistic and give equal weight to knowledge, skills and attitudes throughout the process and stimulate reflection.

Therefore, we have created a flexible and open design process, the "reflective transformative design process" that addresses these three aspects (Hummels & Frens, 2008). Developing design solutions can be seen as a process of taking decisions based on too little information. The breadth of 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. The process knows two axes: vertically we distinguish drives and horizontally we distinguish strategies (Figure 3).

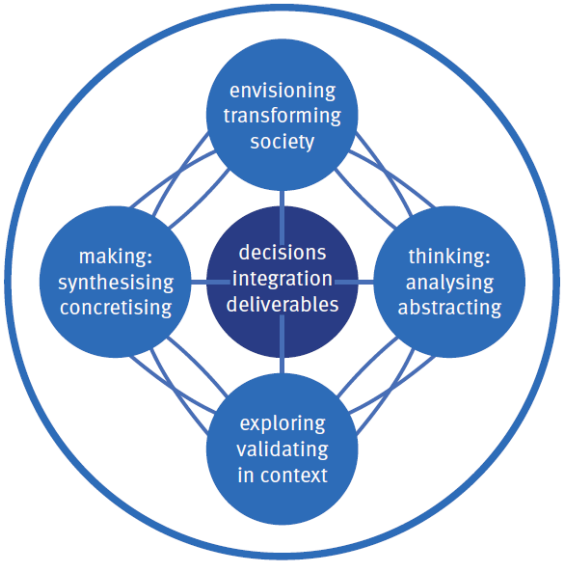

Figure 3. The reflective transformative design process

3.2.1 Drives (vertical axis)

We view the design process as a process where insight into the design opportunity and 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). We stimulate the development of innovative solutions to transform the behavior and experience of users and society as a whole. Therefore we encourage students to create a vision on transformation from our current reality to a new reality through an interactive/intelligent system. We encourage students to search for innovative solutions that are meaningful and valuable for users and our society. In the beginning of the project this vision might still be small and captured implicitly in the project brief. During the process, the vision can be developed and sharpened. Competency area Social Cultural Awareness has a natural inclination towards this activity, which doesn't mean that this activity isn't important for the other competency areas, or that the other activities are not important for Social Cultural Awareness.

The second drive is information gathering to explore and validate design decisions in society with users (bottom circle). Because meaningfulness, value, technological mediation and social transformation are person and context-related issues, the possibilities and solutions have to extensively explored and tested in society. Competency area User Focus and Perspective has a natural affinity with this activity, which again doesn't mean that this activity isn't important for the other competency areas, nor that the other activities are not important for User Focus and Perspective.

3.2.2 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 analyzing, synthesizing, abstracting and concretizing (Meijers, Borghuis, Mutsaers, Overveld, & Perrenet, 2005).

The first strategy revolves around design action, both synthesizing and concretizing, such as building experiential prototypes (left circle). Synthesizing is the merging of elements into a coherent composition for a specific purpose. It goes from small to large. Although designers often think of sketching and prototyping as synthesizing activities, the result of synthesizing can also be, for example, a theory or a descriptive model. When concretizing, one applies a general viewpoint to a specific situation or case. This action goes from large to small. This strategy produces experiential information for the other activities in the design process.

The second strategy revolves around academic thinking: analysis and abstraction (right circle). While analyzing, 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 equally valuable and should frequently alternate throughout the entire process.

Dependent on the person, context, or phase within the design process, students determine where they start, how often they swap from one activity to another, and the order of the activities. This way the process supports flexibility and individuality. Moreover, the model actively supports reflection in, on and for action. The mental activity of giving meaning to a learning activity and, by doing so, building new knowledge that relates to existing knowledge is called reflection (Moon, 1999).

When performing an activity within a circle, a student reflects on action. An opportunity for reflection on and for action occurs every time the student switches activities. Therefore, we stimulate frequent changes from one activity to another. This could help novices in design to train their reflective practice. The activity of reflection is indicated in the model 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 learning activity on a higher level. This is represented in the model by the reflection line of the outer circle (Figure 3).

4. Learning Activities

Within our competency-centered learning approach we offer a variety of curricular learning activities to reflect professional practice. This includes the experience with and performance of different tasks and roles. In order to enable students to become unique designers, we give them

the opportunity to address their individual learning needs. This implies a shift in staff roles. We offer at least seven different learning activities: projects, assignments, modules, workshops and IDentity weeks.

Students have different ways of learning and different needs for developing their competencies. That is why we do not have one fixed program for all students (supply-oriented). Instead, we develop various types of curricular learning activities, each with their specific characteristics (e.g. authentic versus constructed context, focus on competence of designing versus specific competency areas, individual versus teamwork). Our students are responsible for determining what to learn and which learning activities suit best (demand-oriented). This implies that all our learning activities are 'electives'. Students' selection of learning activities is framed within the department's view on designing, the ten competency areas, and the overall focus on intelligent systems, products and related services.

As junior employees, students are required to perform learning activities that represent authentic tasks and roles. In addition, they need to do a particular amount and type of work per semester, for example four assignments and a project for the second block of the first Bachelor's course year. By making a Personal Development Plan at the start of each semester, students determine per type of learning activity the ones that provide the best opportunity to develop their competencies and overall competence of designing. So learning activities are not an end in themselves but a means to generate learning processes and facilitate competency development in a specific context. To put it differently, learning activities are not a target but a gate that opens up the knowledge, skills and attitudes needed by students in order to develop their competencies.

In terms of students' learning, this implies that process and output are equally important. Students' focus should not be on completing the learning activity successfully (task-orientation), but on exploring opportunities for competency development that enable them to accomplish high-quality deliverables. The deliverables which students produce in the context of the various learning activities serve a double purpose. Wanting to achieve high-quality deliverables triggers competency development in breadth as well as depth. Breadth refers to developing all aspects covered by a competency area as much as possible; depth refers to developing a particular aspect of a competency area several times, in various contexts. At the same time, the deliverables which students accomplish are tangible proof of having developed one or more competencies. As explained before, students' achievements within learning activities are not an end in themselves so they are not assessed separately. Instead, students receive written feedback at the conclusion of a learning activity.

In terms of the ID Competence Framework, the various types of learning activities address different goals. Assignments and modules, for example, mostly facilitate development of one or two competency areas and some of the activities of the design process. A project or internship, on the other hand, offers students the opportunity to develop and integrate the full range of competency areas and design activities. Ultimately, however, students' competency

development is meant to feed and enhance their overall competence of designing and their vision on designing. Students' showcase and the assessment process reflect this interaction between the learning activity perspective and the overall competence of designing perspective: the focus is on students' competence of designing and their vision on designing, backed up by the quality of students' deliverables and competency development achieved in learning activities, rather than on the successful completion of separate learning activities.

Staff members in various roles facilitate, support and enhance students' learning and development. Staff roles include competency coach, project coach, expert, assignor, module lecturer and assessor.

4.1 Projects

Projects are the backbone of the ID curriculum. Within the projects, students develop their competencies in an authentic context, often including a real client. Projects allow for integration of the competencies into a design process, integration of research processes into the design, and interaction between the learning activity perspective and overall competence of designing.

Projects may vary in focus, they all enable students to develop and integrate their competencies as well as their overall competence of designing, to develop and express their vision on designing, and to experience their growth as a designer. There should be room for students to explore: experiencing success as well as living down a poor performance. As these projects are the backbone of the ID curriculum, they get a much larger part of 'dedicated time' than assignments or modules, for example. A typical Bachelor's project takes op 60% of dedicated time per semester whereas the final Master's project is a full semester. We want students to be able to experience different views and expertise. One way to achieve this is by cross-coaching. For example, during the semester, first year Bachelor's students work with their main coach but with at least one other coach from the Theme that is coaching the same project.

Let's give a few examples of project outcomes. Tactile Texting (Figure 4), made by Master graduate Guust Hilte, is a product that enables people to input text in touch-screen based mobile phones with- out having to look at the screen. The text input is done using one hand only. By moving your thumb through 'gullies', you can 'write' a character. By pushing down a button on the back of the prototype, the character is sent to a mobile phone via bluetooth. In this way you can input text while using your other hand and your sight for other activities, like cycling or walking.

Figure 4. Tactile Texting

Moving Media (Figure 5), designed by master graduate Tom Frissen, is an intelligent remote control for controlling and transferring personal media. His project aimed at finding new and better control and interaction possibilities for home entertainment systems. Through a wide range of research and explorations a personal remote control has been developed for controlling and transferring media throughout the complete house. Wireless technology enables the remote control to know what devices are nearby and through this it can adapt its control and interaction possibilities. Because it is a personal remote control, every family member now has a personal access point to his or her media.

Figure 5. Moving Media

Opus4 (Figure 6), by Bachelor graduate Mendel Broekhuijsen is a mood-based exploring system for listening & browsing music in libraries. It is designed to overcome the existing boundaries between musical genres by providing music recommendation purely based on signal analysis. Used as private listening and browsing device, it inspires the visitors to find music that is on the edges of their musical taste.

Figure 6. Opus4

CIDS (Figure 7), which is designed by 1st year Bachelor students Dounia Bourjila, C. Tessa van Doesburg and Geert van den Boogaart, is a decentralized system to bring primary school children together. To stimulate children in primary school to play together, this decentralized system was developed. CIDS is a system of multiple "agents" which are all equal, and thus have no leader. One "agent" in itself is pretty simple. But a combination of multiple "agents" causes more complex behaviour. Every "agent" in this system has a colourful LED which expresses its behaviour through patterns. These patterns should challenge the children to build larger groups of "agents", and because of this explore the possibilities together.

Figure 7. CIDS

4.2 Assignments and modules

Assignments are learning activities for Bachelor's students. They represent 48 hours of individual work (as a counter balance to the team work in projects). The scope of an assignment is mostly one or two competency areas. Modules are learning activities for Master's students. They represent 40 to 240 hours of either small group or individual work. The scope of a module is mostly the area of one or two or more capacity groups, depending on the module size. Compared to the authentic context of projects, assignments and modules are more constructed by nature.

Assignments provide Bachelor's students with the opportunity for either awareness building of a particular competency area, for in-depth competency development or, in some cases, for the acquisition of specific knowledge and skills. Likewise, modules provide Master's students with the opportunity for extensive expertise building in particular competency areas or, in some cases, for the acquisition of specialized knowledge and skills. This competency development enables or enhances development of the overall competence of designing and vision on designing. It may also enhance students' competency development in their FMP. Assignors and module lecturers facilitate and support students' learning and competency development from an expert point of view. They also help students to put the competency areas involved into the wider perspective of the design process and the competence framework. Next we give a few examples of assignments and modules.

In the module 'designing for interaction' the students were challenged to create a design within the theme of learning and education. They were explicitly instructed to use the reflective

transformative design process, then in its formative phase. One of the projects was 'Ennea' (Figure 8), a system of products to support tutor classes in high school, the other example was 'Sense six' (Figure 9), a system that supports learning in action of extreme sports. Particularly interesting in these projects was how the students had different approaches in using the reflective transformative design process to quickly create insight in the design problem at hand. The first group iterated between analysis and the creation of a vision to direct their design process. From there they started their ideation process by means of the creation of quick prototypes after which they validated their findings by means of co-design sessions with high-school students. The second group of students took a different approach: they started by making experienceable prototypes and iterated between doing and the creation of a vision. They went on to validate their approach by visiting skate parks and finally grounded their work in theory. While we realize that this text provides only limited detail, this example corroborated our assumption that a design process is needed that is as versatile as the designers that use them.

Figure 8. Ennea

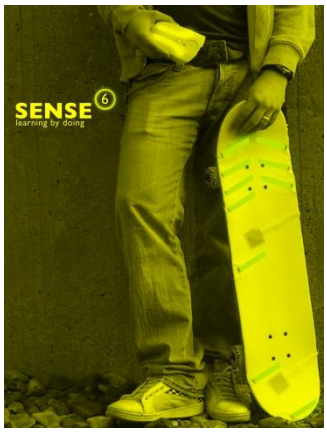

Figure 9. Sense six

The assignments and modules are specially tailored and designed for the profiles of our design students. We give two examples. Designing intelligent products, systems and related services require the designers to be able to integrate technology in their designs. Among other skills, programming is the key for the designers to prototype and experiment with the intelligent behaviors. However most of the design students do not have inherent affinity towards

programming and electronics. In the assignment "Creative Programming for Designers", the AdMoVeo robotic platform (Figure 10) is designed purely for the purpose of teaching the industrial design students basic skills of programming (Alers & Hu, 2009; J. Hu & Alers, 2009, 2010). Moreover we aim at a platform that motivates and encourages the design students to explore their creativity with their passions in graphical and behavioral design, which in turn gives them spontaneous and intrinsic drive in learning programming.

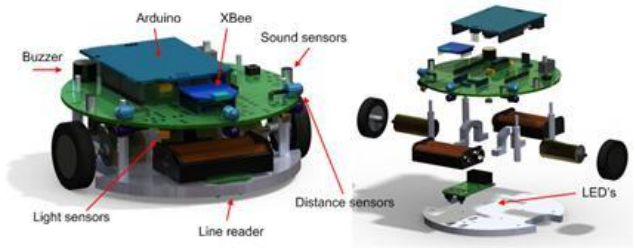

Figure 10. AdMoVeo robot for teaching creative programming

The other example in tailoring the content for design students is the Master module "UML in action". When designing product behavior, the designer often needs to communicate to experts in computer software and protocols. In present-day software engineering, formal specification methods such as the Universal Modeling Language have been widely accepted. Teaching design students these formal methods is non-trivial because most of design students often have difficulties in programming the behaviors of complex produces and systems. Instead of programming, we use a technique, namely "acting-out" (Figure 11), for design students to master the formal methods. The experience shows that acting-out not only worked out very well as a teaching technique, but also showed the potential for bridging the processes of industrial design and software engineering (J. Hu, Ross, Feijs, & Qian, 2007).

Figure 11. Acting-out in learning UML

4.3 Workshops

Workshops are short activities intended to introduce particular topics that help students develop their competencies within the context of their project.

Workshops are comparatively short learning activities. Their size may vary from a few hours to a full day. Workshops provide students with an introduction to various topics, for example information brokering, design processes, reflection, group dynamics, creating a showcase, mathematical modeling, electronics or a theme-related topic. These introductions are meant to initiate and support students' competency development within the projects. Workshops can also provide students with specific expertise, either linked to a particular competency area.

4.4 IDentity weeks

IDentity weeks are 'vertical' activities for all ID students. In these weeks students' activities focus on their personal development, on their learning and development process, and on their overall competence of designing. ID weeks occur three times per semester: at the start, halfway and towards the end of the semester. The first ID week is intended for students to reflect on what they have achieved the previous semester in terms of overall competence of designing and their vision as a designer. In order to do so, they review their previous showcase and assessment. They include the outcomes of this review in their Personal Development Plan (PDP) to determine or adjust their long-term goals for their growth as a designer. In the ID week halfway through the semester, students start with their showcase for that semester. They reflect on what they have achieved in their learning activities so far, as related to the goals they set in their PDP. They relate this to the competency areas and select the deliverables that illustrate their competency development best. In the ID week towards the end of the semester, students essentially repeat the process they have gone through in the second ID week. They reflect on what they have achieved in all their learning activities. They select the learning evidence that proves their development best. They process reflections and visuals in the past, present and future dimension of their showcase.

5. Concluding Remarks

Ten years after the department started, we have now more than 550 students, both Bachelor and Master, and around 80 staff members involved in education. The department has been facilitating students to become professional designers. Our graduates distinguish themselves from other designers in various ways. They design interactive and intelligent systems are life-long and self-managing learners, develop their expertise and identity continuously, and contribute to building communities at the intersection of design, engineering and science. Our competency-centered model, including both the competence framework and the reflective transformative design process, plays an important role in facilitating the education, which is not only unique, but also makes the offered education very competitive.

References

Alers, S., & Hu, J. (2009). AdMoVeo: A Robotic Platform for Teaching Creative Programming to Designers. In M. Chang, R. Kuo, Kinshuk, G.-D. Chen & M. Hirose (Eds.), *Learning by Playing. Game-based Education System Design and Development* (Vol. 5670/2009, pp. 410-421). Banff, Canada: Springer Berlin / Heidelberg.

Birenbaum, M. (2003). New insights into learning and teaching and their implications for assessment. *Optimising new modes of assessment: In search of qualities and standards*, 13-36.

Dochy, F., Segers, M., & De Rijdt, C. (2002). Nieuwe ontwikkelingen: de assessmentcultuur. *Assessment in onderwijs: nieuwe toetsvormen en examinering in studentgericht onderwijs en competentiegericht onderwijs/F. Dochy, L. Heylen en H. Van de Mosselaer (Eds.).-Utrecht: Lemma*, 11-31.

Dorst, K. (1997). *Describing design: a comparison of paradigms.* Delft University of Technology.

Fallman, D. (2003). *Design-oriented human-computer interaction*.

Hu, J., & Alers, S. (2009). *AdMoVeo: An Educational Robotic Platform For Learning Behavior Programming*. Paper presented at the DeSForM 2009: Design and Semantics of Form and Movement.

Hu, J., & Alers, S. (2010). *AdMoVeo: Created For Teaching Creative Programming*. Paper presented at the Workshop Proceedings of the 18th International Conference on Computers in Education (ICCE 2010).

Hu, J., Chen, W., Bartneck, C., & Rauterberg, M. (2010). Transferring Design Knowledge: Challenges and Opportunities. In X. Zhang, S. Zhong, Z. Pan, K. Wong & R. Yun (Eds.), *Entertainment for Education. Digital Techniques and Systems* (Vol. 6249, pp. 165-172): Springer Berlin / Heidelberg.

Hu, J., Ross, P., Feijs, L., & Qian, Y. (2007). UML in Action: Integrating Formal Methods in Industrial Design Education *Technologies for E-Learning and Digital Entertainment* (Vol. 4469/2007, pp. 489-498): Springer.

Hummels, C., & Frens, J. (2008). *Designing for the unknown: A design process for the future generation of highly interactive systems and products*.

Hummels, C., & Frens, J. (2009). *The reflective transformative design process*.

Hummels, C., & Vinke, D. (2009). *Eindhoven Designs (volume 2)*: Eindhoven University of Technology.

Koca, A., Funk, M., Karapanos, E., Rozinat, A., van der Aalst, W., Corporaal, H., et al. (2009). Soft reliability: an interdisciplinary approach with a user–system focus. *Quality and Reliability Engineering International, 25*(1), 3-20.

Löwgren, J. (1995). *Applying design methodology to software development*.

Markopoulos, P., Read, J. C., & MacFarlane, S. (2008). *Evaluating children's interactive products: principles and practices for interaction designers*: Morgan Kaufmann Pub.

Meijers, A., Borghuis, V., Mutsaers, E., Overveld, C., & Perrenet, J. (2005). Criteria voor academische bachelor en master curricula: Criteria for academic bachelor's and master's curricula.

Moon, J. A. (1999). *Reflection in learning and professional development: Theory and practice*: Routledge.

Roozenburg, N. F. M., & Eekels, J. (1995). *Product design: fundamentals and methods*: John Wiley & Sons.

Schön, D. A. (1983). *The reflective practitioner*: Basic books New York;.

Segers, M., Dochy, F., & Cascallar, E. (2003). The era of assessment engineering: Changing perspectives on teaching and learning and the role of new modes of assessment. *Optimising new modes of assessment: In search of qualities and standards*, 1-12.

Simon, H. A. (1969). *The science of the artificial*: MIT press.

Stolterman, E. (1994). Guidelines or aesthetics: design learning strategies. *Design Studies, 15*(4), 448-458.

Tigelaar, E. H. (2005). *Design and evaluation of a teaching portfolio.* Maastricht University.