Competency Monitoring in Design Education;
On the development of a framework and a web-based tool for the monitoring
of design competencies

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Abstract: The Delft Faculty of Industrial Design Engineering developed a new bachelor
curriculum, which was introduced in September 2007. The school aimed for a radical revision of
its bachelor curriculum in order to overcome some long-lasting weaknesses of former programs, in
particular the lack of utilization of engineering science and behavioral science in design projects.
The new curriculum aims at the development of competencies. It comprises of large thematic
multi-disciplinary courses in which knowledge and skills are acquired in the context of realistic
problems typical of the practice of product development.
Competency-based learning requires students to monitor the development of their competencies.
To that end we have developed a framework that defines some 39 competencies within 12
competency domains. This framework helps staff members to define the learning objectives for
their design courses in a common language and provides students with a preview of the
competencies they are expected to develop in course of the study programme. Based on this
framework a web-based tool has been developed that facilitates the students to monitor the growth
of their design competencies and to define personal learning objectives for courses still to be taken.
The use of the tool has been tested in a pilot project. Full-scale implementation after a second test
is planned for in September 2009.

Keywords: Design Education, Bachelor Curriculum, Competency Monitoring, Interface Design

1. Introduction

1.1 From disciplinary based education towards competency-based education

A persistent problem of the Delft Industrial Design Engineering (IDE) program has been the gap between theory
and practice. IDE students take courses in engineering sciences, human sciences, mathematics, statistics and the
like; however in tackling practical design projects, they fail to apply this knowledge to the extent that their
design would benefit and tend to rely upon their intuition and experience. In our view this derives from the
compartmentalized disciplinary structure of the former IDE curriculum. Like in most traditional university
curriculums, mechanics, mathematics, material science, as well as ergonomics and consumer behavior, etc., were
taught in isolation and often with an emphasis on abstract theory without much reference to concrete practical
problems. As a consequence many IDE students were not motivated to study these topics, and tend to postpone the courses concerned. Moreover, students who had passed these courses were often unable to apply their new theoretical knowledge when working on concrete design problems.

To address this problem the new curriculum has been focused on the development of the student's competencies. Competency is the ability to perform a specific task, action or function successfully. Competency-based education moves away from what academics believe graduates need to know about their discipline to what students need to know and be able to do in complex task situations that are typical for their future professional practice. When speaking of “competencies”, we adopt a broad understanding of the term: we mean cognitive competencies (knowledge), functional competencies (skills) as well as social competencies (behavior). Design competency requires the ability to integrate knowledge, skills and attitudes from different domains. Therefore knowledge, skills and attitudes are not conveyed any longer in mono-disciplinary courses in isolation from practice. Instead, the new curriculum comprises of large thematic multi-disciplinary courses in which new knowledge and skills are acquired in the context of realistic design problems typical of the practice of product development.

1.2 The new bachelor’s curriculum

An overview of the new curriculum is shown in figure 1. A series of design projects (the gray cells) forms the core of the new curriculum. In these projects integration of knowledge and skills is central.

<table>
<thead>
<tr>
<th>Quarter 1</th>
<th>Quarter 2</th>
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<tbody>
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<td><strong>Year 1</strong></td>
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Figure 1. New bachelor curriculum of Faculty of Industrial Design Engineering, TU Delft

In the very first course of the curriculum (PD1, Product Design 1) students are introduced to the different aspects and activities of product design. This practical beginning strengthens the student's motivation for more theoretical courses and contributes to a better understanding of the need and purpose for different kinds of knowledge and skills in design. The course PD2 focuses on the phase of conceptual design, both from the point of view of users and the context of use, and technical functionality and producibility. In PD3 students do not
receive a design brief, but they are asked to generate new business ideas for a particular company. So it starts in
the strategic "fuzzy front end" of product development. But the students must demonstrate the feasibility and
quality of their ideas by working them out into concept designs. PD4 starts with conceptual design and runs into
the phases of embodiment and detailed design. In this course students must completely work out their design
concept and prove its viability by different forms of modeling. The series of design projects is concluded by the
bachelor-final project in which students largely individually must demonstrate their overall competency to be an
industrial designer at bachelor level.

The design courses are supplemented by thematic courses that provide for the knowledge and skills to be
integrated in the product development projects. Also these courses are directed towards the development of the
student's design competencies. This means that subject matter and study tasks and assignments are always
presented in relation to realistic problems that product designers might encounter in practice. Contrary to the
product development courses, which are project-based, the thematic courses make use of a spectrum of active
educational forms, but contrary to traditional ways of teaching, all thematic courses cover several disciplines at
the same time. For instance, the 1st year course ‘Products in Action’ introduces students to the engineering
knowledge and skills necessary in their professional career. The course integrates statics and mechanics of
materials, mathematics and engineering design into weekly assignments in which students focus on one or two
real products. The course puts emphasis on understanding the role of mathematical modeling used to calculate
design parameters before building physical models. Another example of a thematic course is the 2nd year course
‘Strategic Product Innovation’ (SPI). The main issue of this course is how companies decide which new products
they want to introduce to the market. The course mixes marketing, sustainability, graphic design and design
methodology with business aspects. For more details on this curriculum and examples of these courses see [1].

2. The competency framework

2.1 Function and requirements

Competency-based learning requires the students to monitor the development of their competencies in relation to
their personal objectives and the learning goals of the courses they follow. Communicating about competencies
asks for an explicit and clear description of the competencies at hand. In our case this is especially true as in the
bachelor programme three to four hundred students take courses together. Therefore, building on the work of
Meijers et al. [2], a framework of competencies was developed with the following requirements in mind: The
framework should …

- give an overview and insight in the relationships between the competencies;
- be complete and detailed enough to be usable by lecturers to (re)define their courses;
- be compact enough for the students (a maximum of 4 competencies per competency domain);
- be broadly supported by staff and students.

To meet the last requirement, much attention was paid to involve students and staff in the development of the
framework. Several meetings were organized where staff members worked together on definitions of the
competencies. Representatives of the students were involved too and tests were planned for final checks with
students.
2.2 The Competency ‘Eye’

The competency framework has to contain a lot of information on different levels: not only on the competencies themselves, but also on the rather complex relationship between them. Therefore a visual representation was chosen to communicate its content effectively. In figure 2 the framework with 12 competency domains is shown. They are divided into three levels of abstraction and grouped in concentric circles to show their relationship.

From the centre to the outer ring:

1. Domain based competencies; i.e. the concrete knowledge, skills and behavior that are characteristic for the discipline of Industrial Design Engineering;
2. General academic competencies which apply to every academic study programme;
3. Competencies relating to the social, historical and economic context of IDE as a discipline.

There were several reasons to choose for a concentric circular representation over a list of words or three separate squares or circles. First of all, a list often suggests a hierarchy in importance that is not relevant here. The concentric circles show that higher levels of abstraction include the lower ones. Finally, a symbolic advantage of this representation is that the student’s portrait can be put in the middle to illustrate that he or she is the core of the study.

Figure 2. The Competency Eye of IDE; domains of design competency
2.3 Courses and competencies

For (re-)defining the content of courses, a more detailed definition of competencies is needed. In the process of writing and re-writing with staff members, the competency domains have been divided into 39 competencies that each describes a well-defined piece of knowledge and skills. In figure 3 they are listed in keywords. In a more detailed version (not shown in this paper) a full description of each competency is given to avoid confusion that keywords might cause as far as possible.

**Competencies Bachelor Curriculum**  
**Industrial Design Engineering, TU Delft**

1. **Product Strategy**  
1.1 Basics of business study  
1.2 Strategic methods  
1.3 Market introduction

2. **User**  
2.1 Man-product relationship  
2.2 Physical and cognitive interaction between man and product  
2.3 Setup and execution of user tests

3. **Product Function and Construction**  
3.1 Working principles, functions and system theory  
3.2 Modeling with statics, strength of materials, dynamics, mathematics  
3.3 Constructing products and product reliability

4. **Production**  
4.1 Materials and material properties  
4.2 Manufacturing processes

5. **Formgiving**  
5.1 Form and function  
5.2 The meaning of form  
5.3 Formgiving processes

6. **Visualisation**  
6.1 Design drawing  
6.2 Technical documentation  
6.3 High- en low-fidelity prototyping

7. **Research**  
7.1 (Re)defining a research question  
7.2 Research methods and statistics  
7.3 Doing research in the context of product development

8. **Design**  
8.1 (Re)defining a design problem  
8.2 Knowing and integrating all aspects of product development  
8.3 Creative potential en synthetic skills  
8.4 Design methods and techniques

9. **Scientific Approach**  
9.1 Attitude of curiosity and lifelong learning  
9.2 Recognizing and filling gaps in knowledge  
9.3 Systematic approach, validating decisions

10. **Intellectual Skills**  
10.1 Self-reflection  
10.2 Logical reasoning  
10.3 Awareness of orders of magnitude  
10.4 Developing and defending a point of view

11. **Communication and Teamwork**  
11.1 Reporting, verbally and visually  
11.2 Oral presentation, verbally and visually  
11.3 Working Professionally / according to a plan / in a team  
11.4 International orientation

12. **Industrial Design and Society**  
12.1 History of Industrial Design, role and impact in society  
12.2 Ethical and normative aspects of industrial design  
12.3 Trends and developments in society  
12.4 Cultural variations

**Figure 3. The 39 competencies of the Bachelor IDE curriculum in keywords**

Based on this list, each course is to be assigned a set of competencies and learning goals with regard to the level of these competencies are to be specified. In this way the coherence within the curriculum is safeguarded. For the students the framework gives a clear overview of the curriculum and shows in which course they can develop which competencies. As an example figure 4 shows the distribution of the domain-based competencies (numbers 1 – 6 in figure 3) over the design projects (PD1 – PD4). A potential problem that occurs specifically for the design courses is that they integrate many aspects of the other courses; hence many competencies are being addressed, up to 20 per project!
The Competency Monitor: an online web based tool

3.1 Function and requirements

To enable the student to practically monitor the growth of their competencies, a digital monitoring tool was developed. The main requirements for this tool were:

- must visualize the growth of the student’s competencies;
- provide for room for the student to reflect on his/her competency development per course;
- provide for room for the coach to react on the student’s reflections;
- have an attractive, simple, user friendly interface; only 1 or 2 interaction levels to avoid ‘getting lost’;
- should be flexible enough to follow changes in the curriculum and in the competency framework;
- the Monitor should be coupled to the TU Delft Blackboard login-system for privacy reasons.
3.2 Design of the interface

The interface of the Competency Monitor (figure 5) is divided in two parts: an input area below and an output area, the actual growth monitor, above. In the input area, courses and competencies can be selected and a text box is presented where students can write reflections and remarks during and at the end of each course. Three questions are asked to help the students structure their reflections and to make sure they go enough in depth:

1. **What? (max. 50 words)**
   What did you do within this course to obtain the learning goals for this competency? Upload texts or images as learning evidence.

2. **So what? (max. 100 words)**
   Look back and describe what you have learned from this; with the slider you can score your learning from insufficient to good. Mention literature that you have used to enhance your learning process.

3. **Now what? (max. 100 words)**
   What insight does it give you regarding your learning behavior or regarding your design skills and how can you use this insight in the future?

In a 4th text box there is room for the coach to react to the student’s reflection. In order to stimulate the students to focus on the essence, a maximum amount of words is set for each of the three answers. It also helps to keep the time spent on reflecting limited. Setting the slider (in question 2) results in changes in the upper part of the interface, the output part or growth monitor.

Figure 5. User interface of the Competency Monitor (only available with Dutch text; © 2009 Antenna-men)
In this part of the interface the Competency Eye is visible in a similar structure but with different visual elements in order to make the growth of each competency domain visible: lines for IDE domain-based competencies, ellipses for the academic competencies and a circle for the domain of context competencies. These elements literally grow, depending on the score a student gives for his or her own development in this field. A timeline at the bottom of the page allows to go back and forward in time: by passing over it with the cursor, the user sees the lines and ellipses grow (or shrink when the cursor is moved back in time) and so can easily identify problems if competency domains don’t appear to be developing. At any time the student can refresh his or her portrait in the middle of the image, so when passing over the timeline also the portrait of the student will change with time. Behind this interface lies a database, which stores the student’s quantitative scores and archives the reflections. Every quarter the status of the student’s study is automatically saved and ‘frozen’. This technical side of the monitor does not fit in the theme of this paper; therefore it will not be discussed further.

3.3 User test

The user interface has been tested during the first stages of development with an early version of the application, which didn’t look like the final interface yet, but with the database working according to the choices made. The goals of the first test were to see if the competency framework and the monitoring system meet the requirements as mentioned in 3.1. Because in this stage the goal was to obtain qualitative information only a small number of students was interviewed. Eight students who had just finished PD1 were asked to evaluate the Competency Eye and the Competency Monitor, specifically with regard to the user interaction. This was done by giving the students a few short assignments like “reflect on three competencies of your own choice that were part of PD1”. The sessions were videotaped for later reference.

The students had little or no problem to execute the assignments using the monitor. The reactions were mostly positive, especially because the students liked to have an overview of their study, and the tool gave them an preview of the learning objectives of the bachelor curriculum as a whole. They understood that the Competency Monitor is a personal tool and not another summative assessment tool for the staff. Remarkably there was much difference between individual students regarding the time it took to write a reflection with a total of about 250 words: this varied from 5 to 15 minutes per competency. Some students stated that reflecting on 10 or more competencies (in some design projects 20 competencies are being addressed) would take them too much time (2 to 5 hours). On the other hand, in the present setup students are supposed to spend 4 hours writing reflections for PD2, so there would not be a greater time spending with the new tool. A test of the final full version of the interface of the Competency Monitor will take place soon, but unfortunately too late to be reported in this paper.

3.4 Results of the user test

The students are positive about the idea to have an individual Competency Monitor that can help them plan and communicate about their study progress with their coaches. They appreciate how their development is being visualized by the system; they can literally see ‘growth’. Critical remarks were made about the time it would take to reflect; 2 to 5 hours per course (two courses per 10 weeks). They expect in particular time problems within the design projects, but at the same time they are confident that after some practice the time needed to reflect will decrease to an acceptable level. The students also suggested that monitoring growth with this system only works if it is presented to them as an obligation; otherwise gaps are to be expected in the data in the monitoring system.
Students were very precise and honest in scoring their own development and gave valuable feedback about the course (in this case PD1) when a learning goal wasn’t addressed by the activities within the course. Some remarks about the interface, like highlighting text when selected, were to be expected since the application was in an early stage of development. Nevertheless it helped us to work out the application in the right direction.

4. Discussion and conclusions

Because the results of the second test with the final version of the interface are not yet available, our conclusions are preliminary only. Offering students an online tool to monitor their competency development can help students to better manage their learning process. It increases their awareness of the initiatives they should take and acts as an effective communication means to keep the attention of both students and coaches on the learning goals of the courses. In order to arrive at a system that is easy and even fun to use, a balance had to be found between theoretical correctness and pragmatism. The longer the list of competencies the less accessible it will be to the students. On the other hand, a too pragmatic list would lack academic precision and would not challenge students to rise to a higher level of understanding, thinking and working. A point of attention is that the monitoring system must be an integral part of the courses themselves. In our case it will be mandatory for the students to reflect at the end of each course. This is quite strict, but we expect that otherwise many students will not reflect at all or only briefly, without depth.

The method used for developing the framework and the online tool was in fact a design method: defining the function and goals first, setting criteria and conceiving and testing alternatives. The procedure of inviting many colleagues and students to work with us on this monitoring system took a lot of time but resulted in a robust model that is expected to live long. We expect our students will better understand the learning lines in our curriculum and we are confident the competency framework and monitor will help to close the gap between theory and practice.

5. References
