QUANTITATIVE AND QUALITATIVE DESIGN INFORMATION IN DESIGN EDUCATION

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ABSTRACT
Embodiment Design is well known in product development. However "Embodiment Design, designing with materials, manufacturing and geometry to fulfill a new function or upgrading the function" is less known in product development. In the introduction an evolutionary path of embodiment design is given. In early stages there is already a need of structuring of quantitative and qualitative design information on the three product levels.
For the course Design Studio 4, design groups consist of five or six third year students, which receive assignments to design an electrically driven product. Design studio 4 is scheduled as a 280 study hour course (28 ects) and is divided over two quarters. The student groups mainly work individually in the first quarter, but they can collaborate with each other. They used design tools most appropriate to them and their task. All the generated quantitative and qualitative design information has to be discussed in weekly meeting with the tutor. The tutor pushes the groups to develop concept designs with innovated solutions. In the second quarter design teams are formed and they have to optimize the chosen concept design. The results are written down in the design report as quantitative and qualitative design information on the three product levels. A user test is also performed with a functioning prototype. In conclusion the quantitative and qualitative design information enriched design education if it is being structured well on the three product levels. In addition the design teams and tutor experience synergy during the weekly meetings.

Keywords: design education, new knowledge design, teaching tool

1 INTRODUCTION

Embodiment design is well known in product development. Kesselring [1] was the first to refer to about Embodiment Design and introduced a set of principles: minimum manufacturing costs, minimum requirements, minimum of weight, minimum losses and optimum handling. These principles are mostly calculated at the end of the design process and are used as verification almost at the end of the design process.

Pahl and Beitz [2] have used the principles of Kesselring in another way. They formulated a method that follows from concept to detail design. The industrial designer has to follow the steps of Embodiment Design to determine the overall layout, the preliminary form design (geometry and material of component or part) and manufacturing processes. Hereby technical and economic considerations are of enormous importance to come to a desired solution. The design process is complex in particular for the Embodiment Design process:

1. many activities need to be performed simultaneously
2. repeating some steps at a higher level of product structure (assembly. subassembly, component, part)
3. change in the lay-out (numbers of parts, geometry, material or process) has repercussions for the solution in other parts of the final product

Wilson W.R.D. [3] discusses Embodiment Design in his winter 2005 course ME 395; Introduction to Mechanical Design. According to Wilson, Embodiment Design embraces Product Architecture, Configuration Design and Parametric Design. He refers to Preliminary Design instead of Embodiment Design and Product Design instead of Embodiment Design and Detailed Design. The Design process has very complicated activities more than all of these models:

1. reiteration
2. parallel process (concurrent engineering)
3. design for manufacturing at the end of the process

Otto and Wood [4] have followed two roads for mapping concept embodiment. One approach takes the general way of refining geometry and layout. This is referred to as the basic method. The second approach could be systems modeling, embodiment principles and FMEA. This is referred to as advanced method. They have tried to find an answer to the question; 'Is the transition between concept development and concept embodiment defined'. Their answer is "NO" For the basic method they followed the general process of embodiment (after Pahl and Beitz 1996) and used the their checklist

The advanced method contains systems modelling under varying input conditions. The product architectures and concept solutions are generated during the concept development. The concept embodiment principles are executed after modelling and the calculations are based on the physical models of the concepts. The last task is to formulate the physical model in a mathematical description and find a balance in relation to the working principle. Finally the embodiment steps lead to the final product design.

Ashby and Johnson [5] have formulated the dominant inputs to the design process such as: market need, business strategy, industrial design, science, environment and technology. Although the basic assumption is more principle than with the others the embodiment is still a part of the design process. The focus lays on material selection instead of embodiment design. In spite of the design process they discriminate between the process of technical design and industrial design. They start with materials to come to a product solution. As this is only a part of embodiment, it could be a great restraint of their method

Kandachar and Langeveld [6] have formulated an approach for Embodiment Design that is based on the FMGP model of a product. The Embodiment Design starts directly after the program of demands and ends with the product design. The program of demands can be divided in four groups of demands that correspond to the design aspects: function (F), material (M), geometry (G) and manufacturing .process (P) The activity of selection that is referred during the design process is also mentioned. Of course much iteration takes place in this model. Figure 1 shows the place of the FMGP model and, Embodiment Design in the design process. It indicates that the three known design phases (concept design, embodiment design, and detailed design) are included in the approach by Kandachar and Langeveld [7].

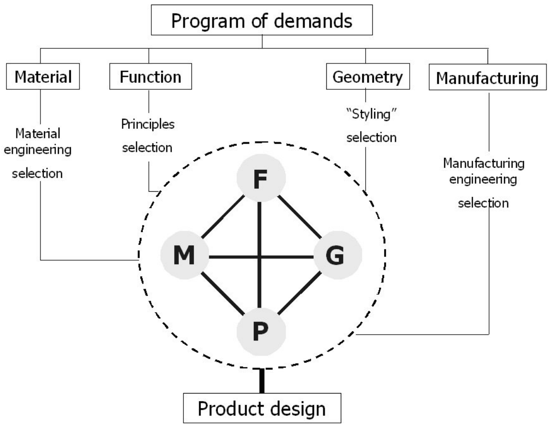

Figure 1 The design process from program of demands to product design with the FMGP-model

The use of design activities in the early stage of the design is called design with X [8]. This requires quantitative and qualitative design information. Quantitative design information can be data about the design aspects such as function, material, process, geometry, cost and innovation and visual such as 3D-model, images, exploded view, movies and sketches. Qualitative design information can be data about remarks, special attention, norms and standards and environment.

Table 1 Example of quantitative and qualitative data on three product levels

Product level	*Component – Sub-assembly level*	*Part level*
Quantitative data	**Quantitative data**	**Quantitative data**
Function: Mini Stepper	**Function**: Gas spring	**Function**: Stepper
Material: Wood, multi plywood	**Material**: Metal	**Material**: Multi plywood
Process: Assembly on single point	**Process**: Assembly on automated line	**Process**: Blade sawing, steam pressure bending
Geometry: Curved surface	**Geometry**: Cylindrical	**Geometry**: Curved surface and curved contour
Costs: ±€ 125	**Costs**: ±€ 10	**Costs**: ±€ 12
Innovation: wood in home fitness appliance	**Innovation**: non	**Innovation**: Wood bending
Image: not available	**Image**: not available	**Image**: not available
Sketches: see figure 5	**Sketches**: see figure 5	**Sketches**: see figure 5
Computer model: not available	**Computer model**: not available	**Computer model**: not available
Qualitative data	**Qualitative data**	**Qualitative data**
Remarks: also glass and natural fiber are examined	**Remarks**: number of strokes	**Remarks**: Decision make or buy
Special attention: Simple mechanism	**Special attention**: Stroke and force	**Special attention**: surface finish
Norms and Standards: no special	**Norms and Standards**: product standard	**Norms and Standards**: NPR for surface finish
Manufacture: Company name	**Manufacture**: Company name	**Manufacture**: Company name
User group: indoor trainer	**User group**: indoor trainer	**User group**: indoor trainer
Environment: indoor and outdoor	**Environment**: indoor	**Environment**: wood

2 DESIGN STUDIO 4

Design Studio 4 has two periods divided into two quarters. The first quarter is scheduled for 118 study hours. An analysis of the design problem is started in the first week and finished in the same week with a group report and an initial program of requirements and wishes. Following this the group works on a more individual basis with idea generation, concept design and preliminary design. The first period is completed with a work report and evaluation on the preliminary design and the design process. Finally, the group has to choose one of the designs, or combine a set of principles and solutions, from all of the individual designs.

In the second quarter there is for scheduled 162 study hours. This quarter consists mostly of 3D-Modelling, prototyping and user testing. The students form a design team with a project leader, a designer, a reporter / communicator, a prototype planner and an engineer/technical drafter. Most assignments are to design an electrically driven product such as a foam cutter, cross-cut saw, powered sealant-gun, powered scissors, electric kitchen scale and powered potato cutter Three product design results are shown in figure 2. The powered scissors will be used as an example for explaining the information flow through the design process.

Figure 2 Three prototypes shown cross-cut saw, powered scissor and foam cutter

A good assignment requires quantitative design information. But during a design process enormous amounts of design information are generated. This gathered information needs to be structured in quantitative information and qualitative information, but also on three different levels: product, component sub-assembly and part level (see table 1).

3 THE FIRST QUARTER

The idea generation can be focussed on design with X, which is explained by the tutor during the first meeting of the idea phase. The students are working individually in this phase of the design, but can collaborate with the other group members. They use the idea generation method that suits them best. They only work with the main drivers from the program of requirements and wishes (see table 2). The tutor meets the student groups weekly and checks / discusses the progress and results. These meetings have many different aspects, such as scaffolding, commenting (from the tutor), stimulating and motivating both students and tutor, comparing, using and deepening ideas, teaching each other, sharpening quantitative and qualitative information, etc. All group members come up with several concept designs and they will work out one chosen concept to a product design. The choice is based on the quantitative and qualitative information of the concepts on the three product levels.

Finally, the first quarter of design studio 4 is finished with a design report. The group now chooses a single, 'best' design from the individual designs, principles and solutions. For this they use the Harris profile method, which is shown in figure 3.

Table 2 Ten main drivers out the program of requirement and wishes.

1. the product must be held by hand	2. the batteries must be rechargeable
3. the manual operation must be clear and unambiguous	4. the main function must be blocked if the device is not being used.
5. the working principle must be clear	6. the cutting blades must be removable
7. the device is for right- and left handed use	8. the applied materials must be recyclable
9. the device should not harm the user	10. the ease of use must be suitable for people with less muscle function

Design six (far right in figure 3) is chosen as the best combination of use, innovativeness, safety, flexibility, technology and price.

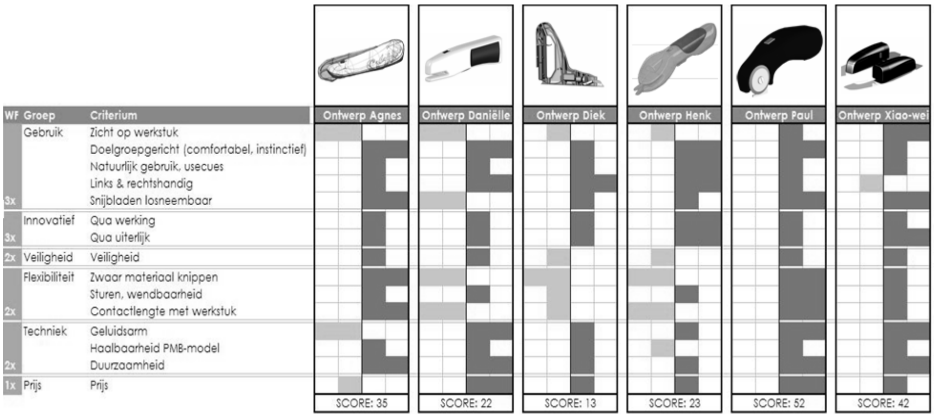

Figure 3 Concept choice is made with a Harris profile of the six powered scissors.

4 THE SECOND QUARTER

The design team has to optimize the chosen product concept to a real product design. An enormous amount of quantitative and qualitative design information is generated during this optimization, in the embodiment phase of the design process. This information consists of sketches, lay-out, exploded views, electric scheme, calculation power drive considerations, material selection, manufacturing process choices, design for assembly etc. The tutor gives weekly feedback about the progress and the generated design information so the students stay attentive to it. Actually making the parts and assembling of the parts to a working prototype (see figure 4) is the most rewarding experience of the whole project. The students are confronted with their own mistakes and lack of details. Tolerances and accuracy are serious problems to overcome during the manufacturing of the parts in the mechanical workshop. All these aspects are important teaching experiences, about what is feasible and possible concerning the quantitative and qualitative design information.

Figure 4 Inside of a powered scissor (prototype)

Also the user test with the working prototype is really instructive to carry out. Here, the students learn how users handle the prototype by making observations on the quantitative and qualitative design information. Typically, the users use the prototype rather different than the designers have intended.

5 CONCLUSIONS

Quantitative and qualitative design information significantly enriches design education, because it stimulates and motivates both students and tutor during the weekly meetings. The quantitative and qualitative design information should be structured well on all three product levels, in order to keep an overview on the enormous amounts of information. The product can reach a higher level of quality, as the design choices are based on quantitative design information, as well as the product requirements, qualitative design information and product wishes. During the weekly group meetings, a debate on the quantitative and qualitative design information takes place, in which a rich group process exists. Both students and tutor experience this as pure synergy.

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