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DESIGN WITH X IS NEW IN PRODUCT DESIGN EDUCATION

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1. Introduction

Product design involves several phases, the generally accepted division of product design before manufacturing being:

- Clarification of the task
- Conceptual Design
- Embodiment Design
- Detail Design

The new definition of Embodiment Design (Langeveld and Kandachar 2005) has given the possibility of Design with X and can already be used in the conceptual phase. Design with X must be focused on innovations so the product design solutions have always an innovative character.

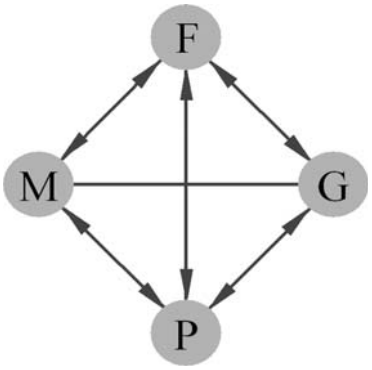

Figure 1. FMPG-model based on Ashby, relating the design aspects of a product: function (F), material (M), geometry (G) and process (P)

In the FMGP-model based on Ashby (2000), the design aspects (F, M, G and P) are defined with their relations, see figure 1. The relations are defined as activity. The relationship between the aspects depends on the aspect you start from. Design with X is the direction of an activity from the aspects to function. This has led to the definition of Embodiment Design focusing on innovations of the design aspects. Design with X is an efficient model for developing education courses which are based on Embodiment Design. When using Design with manufacturing you give special attention to a manufacturing process for example: assembly or parts making. There could also be paid attention to the cost, history, organization and much more implicit areas of manufacturing.

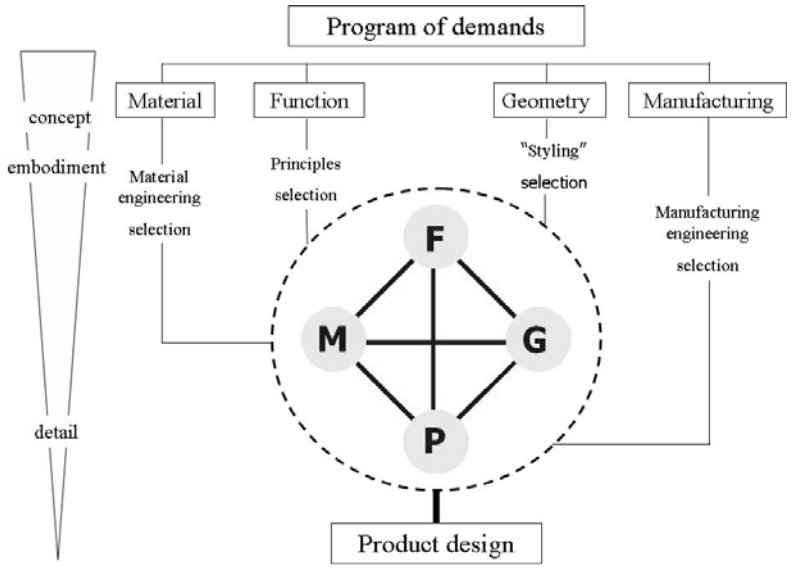

Figure 2. The design process from program of demands to the product design with the FMGP-model

The FMGP-model can be used in the design process from the program of demands to the product design, see figure1. After the program of demands you start with Design ***with*** X at the front end of the design process. You will find Design ***for*** X mostly at the end of the design process in the detailed phase.
In our course Project Advanced Products students can define their design task after e gathering information about the project. The projects are brought in by companies and institutions in the form of assignments; this is a guarantee for real design problems which need an innovative product design solution. The innovative product design solution is an objective for the students and can be reached by picking up the best familiar design method for solving the design task. They can follow the design process from the conceptual phase to the tested prototype or they can also start with the design with X method. This method is focussing on the manufacturing process, material or geometry. The project groups that take the method of design with X have the advantage of shortening time with innovation as a driving spirit of design with X. The students can reached another objective shortening design time or within the project time more depth. A few examples of student also choose, instead of shortening design time, more depth within the project time. Some examples of student projects are given about shortening time and more depth within the project.

2. Literature review

Embodiment Design has been discussed for the first time by Kesselring (1954). He formulated a set of principles: minimum manufacturing costs, minimum space requirements, minimum weight, minimum losses and optimum handling. These principles are mostly checked at the end of the embodiment phase. When one of the checked outcomes isn't correct, you have to go back in the process and start the process again, until the solution is sufficient to go further with the detailing. About 50% of all the designs aren't completed at all and from the other 50% about 60% goes directly to the detail phase. The other 40% needs a redesign, if the product designs will become manufacturable.
The method used by Pahl and Beitz (1996) starts from concept to detail design. They try to use the set of principles in an earlier stage of embodiment design for the feasibility of the product design. When following these design steps, first of all the designer determines the overall layout, the preliminary form design and the manufacturing processes. A feasibility study is of enormous importance to come to the desired solution. The design process, in particularly the embodiment design phase, is untransparant:

1. many aspects choices are simultaneously

2. repeating design steps on different product levels
3. changes on different product levels have repercussions for product design in the detail phase.

Design ***with*** X opens new ways of approach in the beginning of the design process; you can concentrate on the method and you don't have to worry about other aspects that lay outside the scope of the method, Langeveld (2006). This is possible because the argumentation starts with a product and not as usual with the design process. The product have aspects and that is implemented in the design process.

For Design ***with*** X must still develop methods that give a designer tools that can be used at the right moment to do certain design tasks. One must look for example with designers' eyes to the production method and these experience is applied in the design process.

Design ***for*** X is the activity that can be used as a verification tool mostly at the last stage of the design process. It represents the activities from function to a design aspect. Then you have already the situation as mentioned above. For instance DfA, the Boothryd method, is used at the end of the design process, as a verification tool. The detailed cost estimation is another verification tool. This is rather late in the design process.

Otto and Wood (2004) have based their Product Design versus Product development on front-end activities such as: new technology, new materials, new geometry and new manufacturing process. If these are research and development activities then they can be developed to the point that innovation could be encapsulated into a new method for product design. This is a step forward in comparison with Pahl and Beitz and can bring the process to strategy level. It does not necessarily include the management, distribution and financial activities.

3. New Approach

Design ***with*** Material, Geometry or Manufacturing is a new approach by applying these activities during the Embodiment Design phase or already in the Conceptual Design phase. The activities between the aspects depend on the aspect you start from. The activities are given in table 1 for all the relations between the aspects: function, material, geometry and process.

Table 1. The relation between the aspects of FMGP model with the described activities

From Aspect	to Aspect	Activity
Function (F)	Material	Material engineering
	Geometry	"Designing"
	Process	Design for Manufacturing
Material (M)	Function	Design with Material
	Process	Material selection
	Geometry	"Styling"
Geometry (G)	Function	Design with Geometry
	Material	Aesthetics
	Process	" Tool making"
Process (p)	Function	Design with Manufacturing
	Material	Process selecting
	Geometry	"Making"

Between aspects are relations and these are described as activity which depends on the aspect you start form. The activity, for example design for manufacturing, is a relation from aspect function to process. For the relations from material, geometry and process to function there are activity describe as Design ***with*** X. So design with X is a valuable method for the design process. A greenfield product design is

exceptionally, because a redesign of an extended product is the most common design task. The design task must be done with special attention to an innovative aspect; this means: design ***with*** X is an innovative method.

4. Design with X

The design aspects in the FMGP model have relations, are called activities and are showed in figure 3. When you start from the aspects material, geometry and manufacturing process to the design aspect function, then these activities are defined as Design ***with*** X.

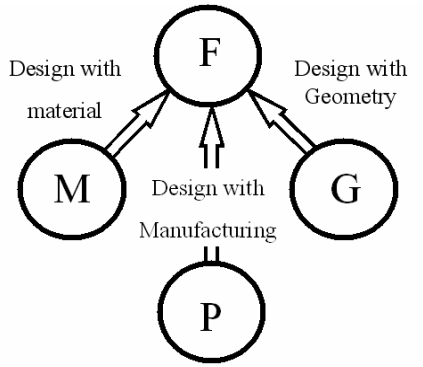

Figure 3. In theFMPG-model qualified the activities from a design aspect to function

Design ***with*** Material is well known under product designers with knowledge about innovative materials. With an innovative material you can start up the design process and you are looking for new product design solutions. For example you have to design with natural fiber and a biopolymer, because you find in the gathering phase information that possible accommodates the product design. During the design process you generate alternatives with this new material and deep it out for the most promised alternative.

Design ***with*** Manufacturing shall be undertaken by the designers, who are also familiar with new manufacturing processes and systems. They are designing with the constraints of innovative machines and processes and create alternative product design solutions. For example you take laser cutting and welding as innovative processes in mind. The design process delivers of course alternatives based on both processes and after the selection one or more alternative is deepen out and one is being tested and that one can be the new bicycle concept in the future.

Design ***with*** Geometry has embraced the opportunity of the vision for the future product design towards: form, colour, surface conditions and human interface. The designers must have experienced a vision that could fit to a certain period. They are designing the alternative product designs that belong to a certain period. For example a water cooker is deepen out and is being tested to the harmony of geometry, colours, surfaces and human interface.

Design ***with*** X comes always up with new or updated product design solutions. This means there is an innovative base with the design aspects within the context of the assignment. Thus Design with X is a real efficient method, because you avoid all kinds of irrelevant designs.

In product development education you can let students get gain experience with this method. So they can make a choice between a design ***with*** X method to use and the regular design process with the risk of loosing time for the possible irrelevant designs.

5. Working method

At the project, Advanced Product, students get the assignment from a company or institute. They can follow the method of embodiment design; this isn't forced, but strongly recommended. The assignment is the start of the working method that ends with a presentation of the results during the embodiment design (Langeveld and Kandachar 2001). After the information gathering that is pointed

to the assignment, follows the problem definition that could also be called the design task or research task. Alternatives can be generated with Design ***with*** X.

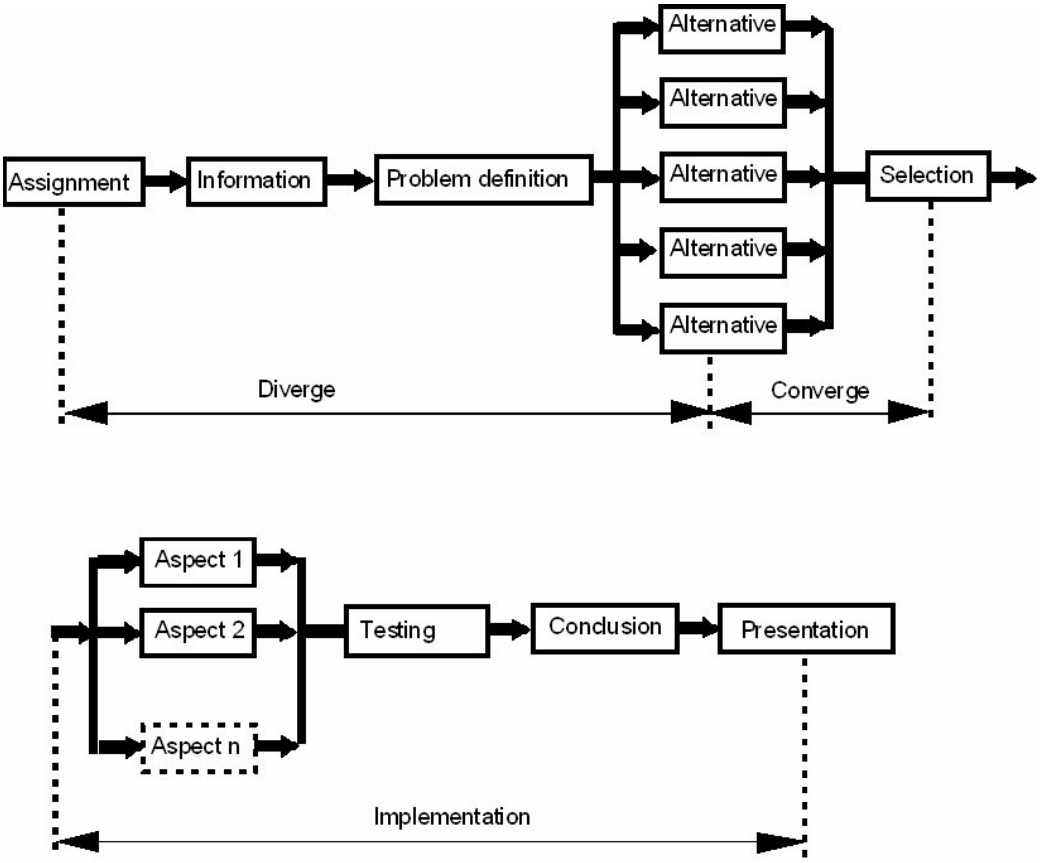

Figure 4. Working method of Embodiment Design

The X can stand for the different design aspects of a product such as innovative materials, manufacturing processes and geometry. The potential alternatives are selected by the converging methods and called Aspect (1, 2, 3, ….., n); they carry the opportunity of a satisfied solution. The aspects are worked out to alternative solutions in more detail. There is mostly not much time to deepen out all the aspects, so the team tests most of the time one aspect by simulation, experimental or solid modelling. Drawing conclusion out of the results of the tests must be done on an quantitative and qualitative manner. Also the relation to the other aspects is very important for a good judgement of the conclusions. The final results must be presented in a written report and in a mini lecture, see figure 4. A poster is also made for the exhibition by each group and can be shown to every visitor and faculty member.

6. Results

The results of two projects of the Project Advanced Product shall be analysed. The project teams are formed out first year master students of Industrial Design; a team exists out 5 or 6 students. During the first half of the course there are guest's lectures from specialists in area's related to projects. Of course some course aspects must also be explained to the students by our course owners in the form of a lecture. At half time the groups have to present their findings and to show the plans for the second half of the course. This is also the moment that the project groups hear a go or a no go of the project. When the group fail to explain the results half time and do not have a clearly plan to finish the assignment

task than the coach give them no go. This happen not so much, because the course owner have to find an alternative solution for this students so they can finish with another approach the same assignment task. The projects shall be finished with a presentation for their co-students of about six groups, their supervisors and assignments owners from companies and institutes.
There is used the observation method for description of the remarkable activities during the embodiment design.

6.1 Standing Knee Chair

Standing Knee Chair (SKC) has improved as the quadriceps training machine that is used by physiotherapists. The SKC trains the quadriceps in natural standing position with the use of resistance. With built in software the patient guides through a specified therapy program. In the product design are solved the main problems. The group uses the Design ***with*** Manufacturing, because the parts must be produced in small batches and a number of 500 on year base. The result of the redesign is shown in figure 5 with a number of updates and added design solutions. In table 2 the product development activity of SKC are described for the design process steps.

Table 2. Product development activity for the design process steps of the Standing Knee Chair

Design process steps	Product development activity
Gathering information	Analyse the extended product and identify the design problems
Problem definition	Design an improved SKC with the method Design with Manufacturing
Generated alternatives	The standing and foot support can be adjusted by a gas spring Two separate adjustable footplates The setup of rotation with the air pressure cylinder drive Use brake system, speed and force reduction of backward rotation
Selected alternatives	New way for rotation the air pressure cylinder drive, find out the right stand of the cylinder, this can avoid the dead point
Testing	The dead point problem is solved
Conclusion(s)	Which a simple new setup angle of the air pressure cylinder drive, you get a right working principle for revalidation of injuries

Figure 5. Redesign of Standing Knee Chair with updated and innovative design solutions

6.2 Airless Tyre Nuna

To conclude the probability of a flat tyre during the World Solar Challenge 2005 in Australia, the Nuon Solar Team, asked for an airless, puncture proof tyre. The wheel should hold out at least the 3000km from Darwin to Adelaide. Improvement of the rolling resistance and wheel that are exchangeable with the original air tyre believe in the winning time. In the product design of an airless tyre a number of alternatives are developed for solving problems of the rolling resistance. The group used the Design ***with*** Material because the part must be produced in small batches of ten peaces year base and they got the rim from a tyre company in the Netherlands. The result of the redesign is shown in figure 6 with an innovated design solution. In table 3 the product development activity of the airless tyre 3 are described for the design process steps.

Table 3. Product development activity for the design process steps of the Airless Tyre

Design process steps	Product development activity
Gathering information	Analyse the extended air tyre
Problem definition	Design an airless tyre with the method Design with Material
Generated alternatives	A tread of different materials (compounds), spring of arimid composite
Selected alternatives	A tread is developed by and with Vredestein
Testing	The tests were simple, but a global view give the spring works as designed. Only making by hand of the tyre spring give weak places by air inclusions arise from to much tolerance on vacuum body
Conclusion(s)	Overall feeling of agreement in the group that the airless tyre has saving time potential

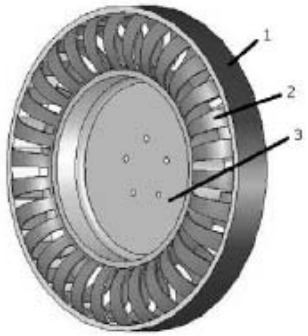

Figure 6. Airless tyre for Nuna 3, the Solar Wagon of Delft University of technology: 1. tread, 2. tyre, 3.rim

7. Conclusion

Embodiment Design is a complex process with many activities and decision moments that influence the product design result. The activities that are called *Design with X* are used in the two assignment mentioned as: Design with Manufacturing and Design with Material. The Design with Manufacturing method asks decisions in an early stage of the design process about manufacturing process, batch size, weight, logistics, etc. that influence the embodiment design. The use of Design with X shortens the development time by avoiding the irrelevant design solutions.

The first time right is an utopia, however the designer can't do it right the first time so he have to make use of iteration steps and recalling earlier decisions.

The design with X method gives the designer the opportunity of saving time or deepening out the result, so he does possible his design task first time right.

In education Design with X gives the possibility to get higher quality and quantity courses by avoiding time loss on irrelevant designs and paths. We want to do further research on quantitative aspects of these observations the coming years.

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