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Product Design with Embodiment Design as a New Perspective

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1. Introduction

Product Design is the solving of a design problem from the assignment to the final product design. Many design methods may lead to a product design but also the design process which include embodiment design. The most time absorbing part of the design process is, in general, embodiment design: going from idea to realisation. In figure 1 a design process is drawn up, including embodiment design.
Product design is not business as usual, according to Kyffin (2007) of Philips Design. This statement has a presupposition that every product design needs an original approach of the design process to solve the design problem. Design needs to change, to enrich our cultures, to respond to the new world and new world economies, to create lifestyles, to develop quality life and explore innovative technologies in relevant new products.
First the answer should be given on the question "What is embodiment design?" Embodiment Design will be understood as the design phase where ideas get just some matter added and consequently a product structure, a product layout and a working principle. But the physical aspects should be meeting the requirement concerning the use, interaction and the ergonomics: the emotional aspects. During the design process the amount of uncertainty decreases and the amount of certainty increases. Every step in the design process is generating design information which reduces the uncertainty. The tools used in this design phase are countless.
Problems are enclosed in the assignment; at different levels and stages of design. Recognized problems can be transformed by the designer to a solution at certain levels and different stages of the product design process.
Every time a designer makes a choice, he also has to look at the method that will lead to the most ideal product design solution.
The goal of the product design is creating a product that fulfills its functions, looks beautiful, can be produced economically and is sustainable. The new perspective will be reached by the designer with methods that may bring embodiment design to the conceptual stage.
The key aim is to understand the alteration that is needed to move Embodiment Design to the conceptual phase. This is the new perspective for Embodiment Design which be researched in the near future.

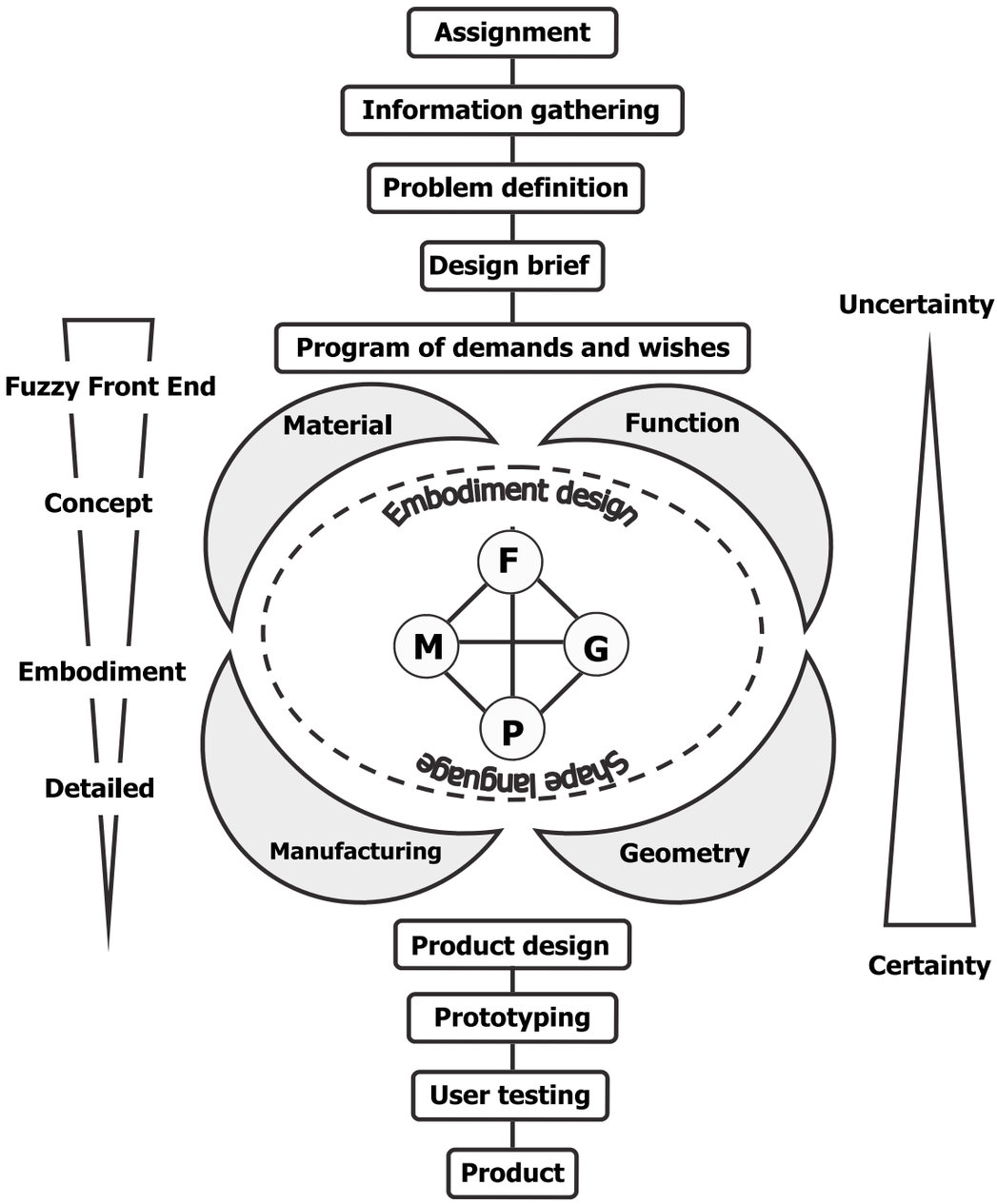

Fig. 1. The product design model, with the embodiment design model enclosed.

A product is assembled from components, sub-assemblies and parts into a working whole. The product has a structure with different levels. The product aspects can have constraints for certain parts that exclude parts form the product layout, for instance heating components in the area of plastic parts.
For a matter of fact all the product designs could be designed with the design aspects which may contain a number of embodiment design elements such as: design with X, engineering database, the designer needs, product structure, product layout, creativity, designer role, education, culture.

A designer has knowledge of technology and the design process. But the designer wants to develop himself by means of experience. Projects are excellent for the knowledge development and practice experience. Learning is inherent to the development of knowledge and experience.
Embodiment design should be educated in such a way that students realise this already in the early stages of the design process as far as the impact of the decisions is concerning on the embodiment design possibilities. During early stages could be taken decisions about solutions. These could be physical and emotional aspects such as: material, working principle, etc. which implicit determine embodiment design aspects. If the student is not aware of this then he limits the possibilities of embodiment design unintentional.
An engineering database has been developed to collect quantitative and qualitative information about products which stimulate the knowledge of products and experience with products at students during designing including the embodiment design phase. The stimuli come from incentive that is fed by the engineering database just during embodiment design. The three main goals of the engineering database are within the context of embodiment design education:

1. storing of design information
2. quick retrieval of information
3. the retrieved information should inspire the industrial designer

The embodiment design education takes place during the whole bachelor and master program of industrial design engineering. It is not an explicit course but integrated in many design courses in the bachelor and master program.

2. Problem definition

Product design concerns the solving of design problems from the assignment to the final product. It covers the whole design process. In the literature you find many design method, but every method has the same goals; a product design that works and solves the design problem. The design method to use depends on the design problem, the designer's knowledge and experience and the needs of the user. The main issues in the design process and embodiment design are creativity, innovation, performance fulfillment and high design efficiency. The design efficiency is an expression of assembly time and number of parts which is an index number how efficient the product design is done and how much design space is left for optimisation of the product design.
Embodiment design is a part of the whole design process, but in this phase of the process, the product concept gets concrete form and material, which includes certain manufacturing processes. But sometimes you want to focus on the main design aspects for instance implementation of a new material in a complete new business area. This means that embodiment has to take place already in the conceptual phase of the design process. The real problem is "how do you move embodiment design to the conceptual phase?" in an efficient way. This question should be answered in an ultimate manner, which gets gestalt in a new definition about embodiment design. Embodiment design can move to the conceptual phase by focusing on design with X, one of methods within embodiment design. The focus on the innovative product solution within embodiment design will make it easier to answer the question.
The idea of "the first time right" is also giving a new perspective to the whole design process and to embodiment design. Of course this includes the embodiment phase in the

new perspective by avoiding the iterations in the design process. This can only be reached when all stakeholders have the same goal in mind. This opportunity will seldom occur because collaboration requires compromises in a design team and in the organization, but it counts also for embodiment education.

3. Objectives

Product Design develops itself in a direction which may solve the design problem into product concepts and finally to a product design that will be prototyped and tested before starting a new manufacturing unit. The manufacturing unit may be equipped with a product oriented unit, a process oriented unit or a combined unit, a combination from product and process oriented unit. If during the design process the realization of the product was ignored, there is a good change that design iterations are necessary to enable an appropriate manufacturing method of the product. If embodiment design has moved from embodiment phase to the conceptual phase then the focus may be on designing or on making. This could be reached by looking for an innovative design solution. Time is often spilled by working on irrelevant and conservative design solutions also in the embodiment design stage. This spilling can be avoided by performing a good analysis phase in which mixed and innovative design solutions are found.
Design with X occurs to the new definition of embodiment design. But seeking for applications in a new domain can be done on focusing for innovative design solutions and in lesser view for the mixed design solution.
For a new perspective of embodiment design there is always one goal to be reached by going for innovative design solutions with more design in the solutions. It has to be efficient and creative manner to come up with design solutions.

4. Product design

Product design is the process of planning the product's specifications, according to Industry Canada, in their glossary of automotive terms.
Product design can be defined as the idea generation (Tassoul, 2009), concept development, testing and manufacturing or implementation of a physical object or service. Product Designers conceptualize and evaluate ideas, making them tangible through products in a more systematic approach.
Product design is concerned with the efficient and effective generation and development of ideas through a process that leads to new products, according to the book the fundamentals of product design (Morris,2009).
Product Design is defined (Walsh et al, 1988) as: the activity in which ideas and needs are given physical form, initially as solution concepts and then as a specific configuration or arrangement of elements, materials and components.
The above definitions and the one's who are still coming show the weakness in the realisation of the products and service but the designer should involve the stakeholders in the development of products or services to come to a good product including the embodiment design. Products are objects or services which are the results of designer activity. Before manufacturing, every part has to be detailed with, material, manufacturing and geometry. Additionally marketing, advertising, product introduction and distribution have to be done. Embodiment Design can help with problem solving and choices in the

stadium of concept development (Otto & Wood, 2004). During idea generation it is to avoid irrelevant designs solutions and conservative design solutions nevertheless but focus on mixed design solutions and most on innovative design solutions, see figure 2.

Product design is the process of defining all the product's characteristics which affects product quality, product cost, and customer satisfaction. A product design could be designed badly than quality, cost and satisfaction go downward. Product design approaches regular need adaptation, because lifestyles change every decennium. Sometimes it is even going much faster for instance the use of computer, iphone, ipad, etc. So product design is not business as usual, because the process should be suited to the actual design problem. In most cases researching the design problem is the best way to start the design process. (Shih-WenHsio & Jyh-Rong Chou, 2004) The design team is often formed after the design research in which the boundaries are defined and all the design tasks that should be performed until the product is detailed and the prototype tested.

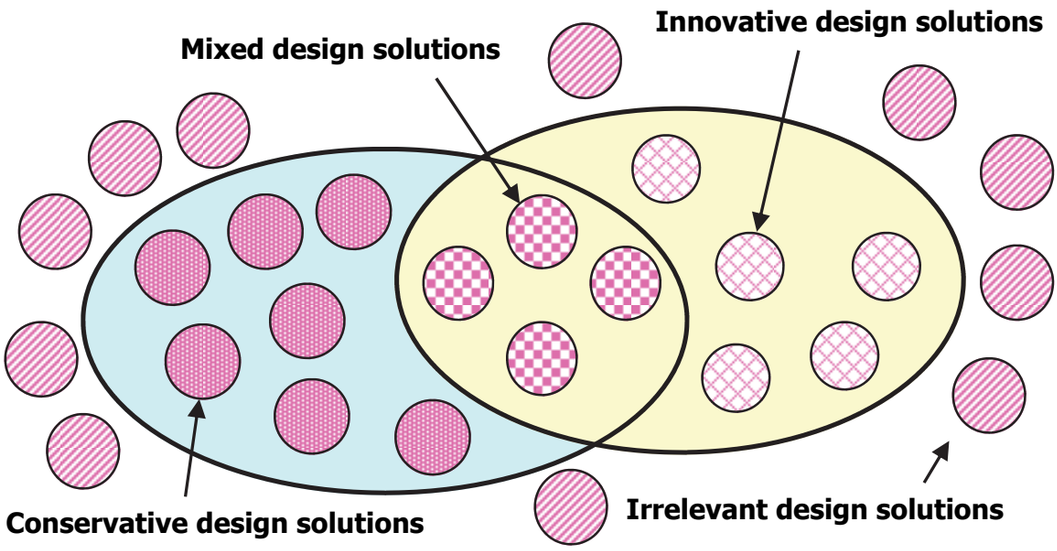

Fig. 2. Possible design solutions

The product design process contains at least the followings activities:

- Identification of 1market needs
- Problem analysis and formulation of the Design Brief
- Product Design Specification
- Concept development
- Embodiment design
- Detailed design
- Design for Assembly
- Life Cycle Assessment
- Evaluation

The above activities occur at different design levels and different stages. For instance evaluation should be done on the end of the every design stage. Competitors products should be researched for ideas which may be used in own product design. Here it is six of one and half dozen of the other such an important activity may be benchmarked, before starting the design process.

In figure 3 the product design model demonstrates the whole process from assignment to finished product. Embodiment design in practice is spread through a large part of the design process. The steps distinguished in the design process which in reality is not taken one by one, section 6 will explain more about this. Innovative product designs are realized by a creative process development which diverges from the classic step process.

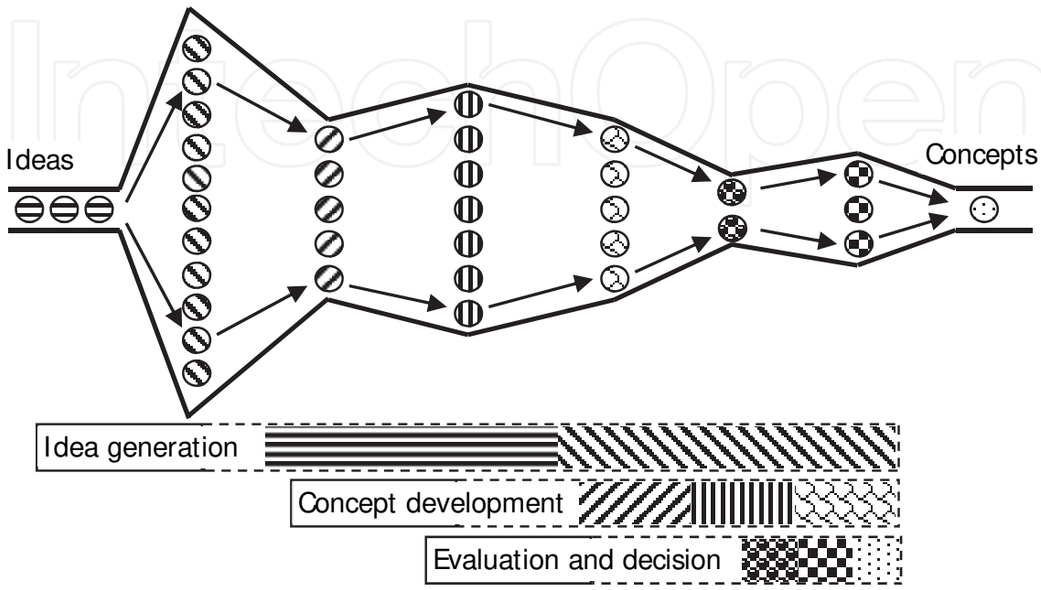

Fig. 3. The funnel model after Eekels and Rozenburg & Ullman and Eppinger

Concept development needs innovative idea generation, this includes the embodiment aspects. This bubbles up during the process from ideas to concepts. Evaluation and decision making are essential, because not all ideas can be developed into a concept. The funnel model is defined after Eekels & Rozenburg(1995), and also after Ullman & Eppinger.(2004)
The product presentation is a way to communicate with the prospective costumers. The embodiment of a product is an important part of this communication. There are many possibilities for presentation such as: projection, perspective, netting, time line, star, exploded view sketching, cross section, prototype, movie, 3D –views, e-drawing, etc. A nice example is given with 3D – view for housing parts which are just different on a small detail in figure 4.

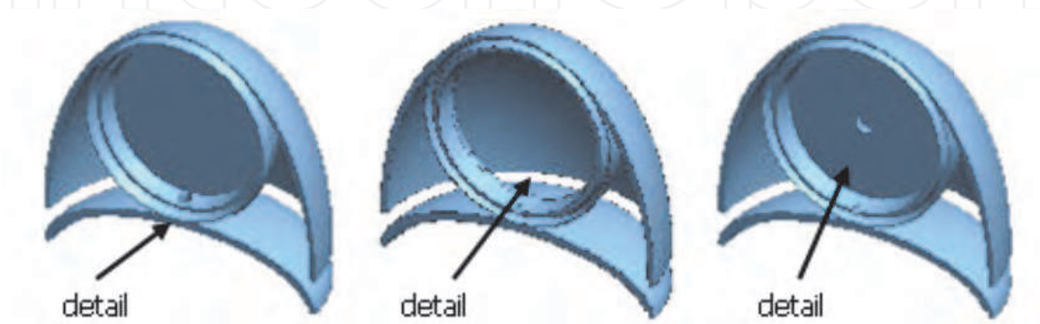

Fig. 4. Three housing parts in a 3D view with little differences in details

Product planning helps the company to realize the opportunities of product design and invests in the most likely product design. The product plan has to deal with the product development, product strategy, marketing, product portfolio which include embodiment design for each aspect. More specific, the product plan may be used to: product strategy and selection, defining target market or better competitive strength, distinguish from product competition, establish priorities in project development, high levels schedule, embodiment design, estimation of product cost and balancing product resources.

Embodiment is inherent to product design because in the design process you may take already decisions about embodiment during different stages of the design process such as conceptual design. Product planning is a process that runs parallel to the design process either embodiment design. Therefore preferably the planner and designer do the decision making together about the steps to make in the design process and in particular embodiment design. The planning process is necessary to identify and stimulate redesigns and new product designs with embodiment design as main concern, which can lead to new products. The goal of product planning and design should be avoiding investing in any chanceless product ideas. Market knowledge and product knowledge with a great share of creativity are necessary for the planning and design with a number of milestones just for the decision making on the right moment. The decision making must be on the right level in such a way that the decisions are not made about apples and pears.

There are still companies that have a formal product planning which lead to inflexibility in the embodiment design phase. Only the successful product ideas should be embodied, all the other ideas consume senseless time. This makes it hard to come to compromises in many cases.

The practical approach of embodiment design is shown in figure 5 with the physical main design issues of a product. This rocking chair is built with the material bamboo and is realized by transforming the bamboo in such forms that the parts can be used for the chair. The geometry concerns about the desired shapes, the interaction and the person who will sit in the chair, with are derived from a drawing or an explanation by the designer. In some cases, the designer is also the maker of the product.

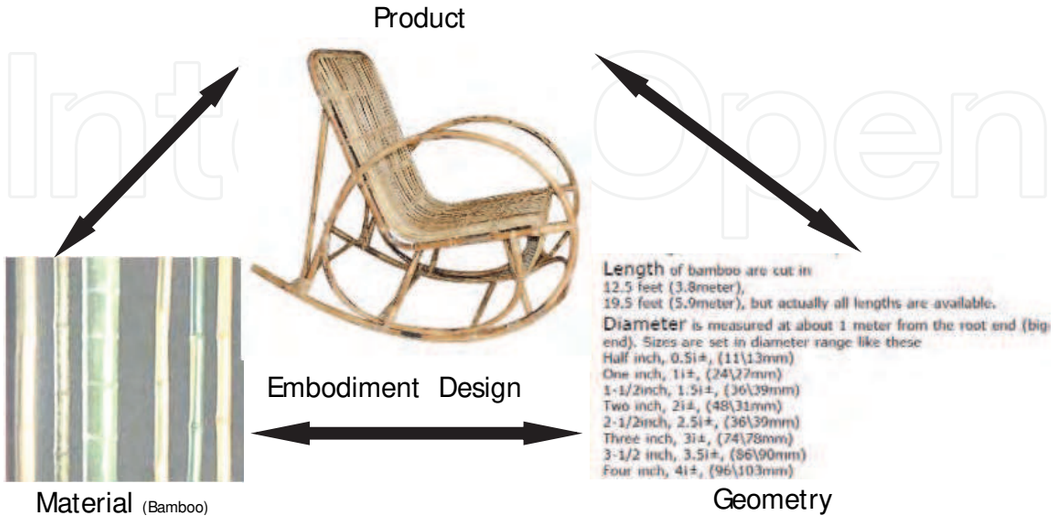

Fig. 5. Product, practical model

5. Embodiment design

Embodiment design is well known in product development. Kesselring (1954) was the first to refer to Embodiment Design and introduced a set of principles: minimum manufacturing costs, minimum requirements, minimum of weight, minimum losses and optimal handling. These principles are often calculated at the end of the design process and are typically used as verification.

The definition of embodiment design according to Pahl and Beitz (1996) runs as follows: "Embodiment Design is the part of the design process starting from the principle solution or concept of a consumer product. The design should be developed in accordance with engineering and economical criteria". This is a pure technical and economical consideration of Embodiment Design. But a product has more aspects than only the technical and economical ones. A product can also bring aspects about emotion, beauty, appeal and happiness the other values in live. People like to pay for these values if the earnings are higher than the cost of the basic needs.

The Embodiment Design phase is the part of the design process which is concerned about the production of the product concept, the engineering and the economical feasibility. The production contains the parts making and the product assembling.

However this doesn't open the new perspective of embodiment design. We propose a new definition of embodiment design and it runs as follows "Embodiment Design is designing with material, manufacturing and geometry to fulfill a new function or updating of the function". The emotional aspects such as: use, interaction ergonomics, etc. have to meet the requirement with the physical aspects.

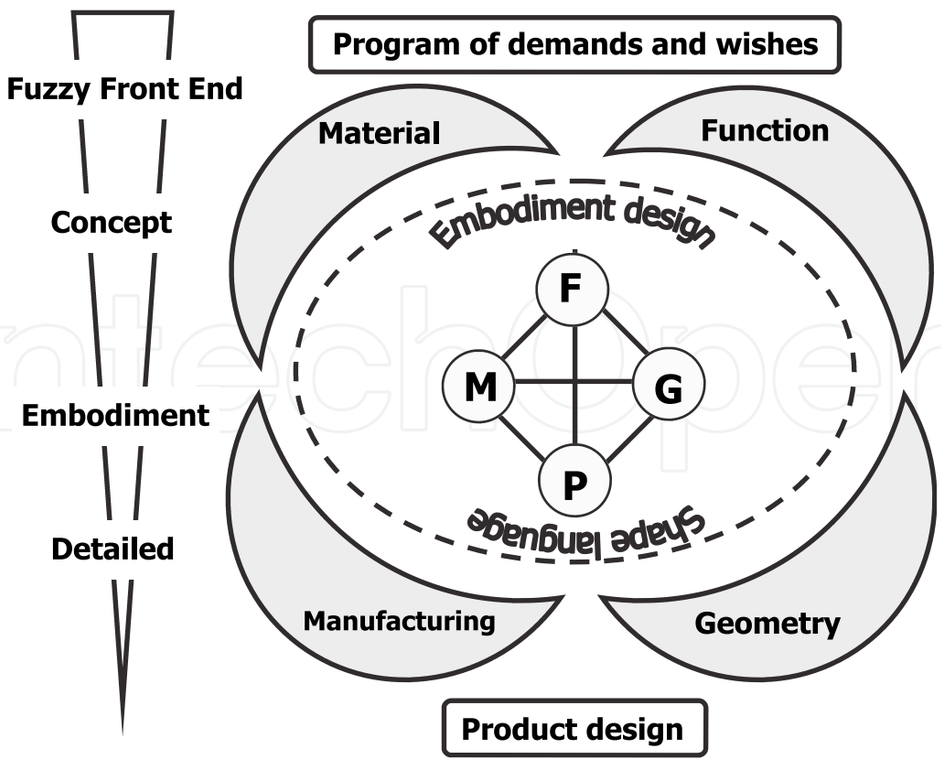

Fig. 6. Embodiment Design Model

Embodiment Design is giving matter to ideas, so a body is created in headlines, which will be detailed during the continuation of the design process.
The design aspects Function,(F), Material (M), Geometry (G) and Production, (P) in the FMGP-model have relations which are defined as design activities, see figure 6. These design activities can enrich existing products or product design concepts into innovative design solutions. The direction of an activity from the design aspects to a function is called Design with X.
All the product designs can be designed with these design aspects which may contain a number of embodiment design elements such as: design with x, engineering database, the designer needs, product structure, product-layout, the role of the designer, creativity, education and culture.

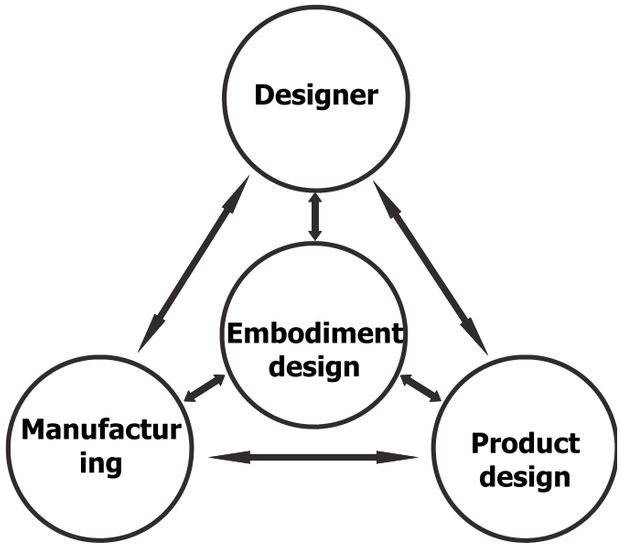

Fig. 7. The domains of making and doing

Embodiment design is a process of many different aspects in order to come to a product design. In figure 7, the domains of making and doing are provided which their mutual relations. Designers use embodiment design to follow a structured process, which depends on the design task.
The result of their doing is a product design which can actually be produced. The designers have to build their knowledge on manufacturing and even broader, on production. The product designs are related to the facility of manufacture systems and planning, the strategic and innovative aspects.
Embodiment design isn't an exclusive course, but part of advanced product design projects and other design courses in our bachelor and master program see figure 8. The assignments for advanced product projects are brought in by companies and institutes, so the 'design problems' are realistic. After the design brief has been formulated, the student groups start with embodiment design and finish the project with the testing of a functional prototype. Each group presents the results in the form of a report and a presentation for the other groups. The results must be in the area of a new working principle, cost reduction, new materials, parts reduction, use or other manufacturing processes, etc. These are all

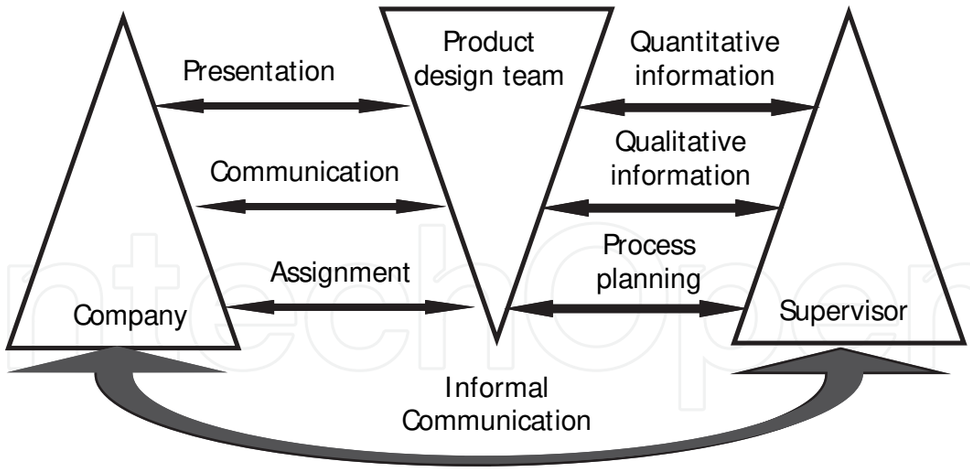

Fig. 8. The cultural difference between the stakeholders should be aware at project with companies

engineering aspect in which embodiment design can be of great assistance. Still, industrial design engineers have a tradition of simulating, calculating and testing the prototype.
A design aspect is an independent item that can be influenced by the other aspects.
Embodiment Design can start with the program of requirements and wishes of an existing product or concept design as shown schematically in figure 9. Either alone or in combination, the design aspects, material, function, geometry and process have to contribute to innovative design solutions. Designing with one design aspect for example process is called Design with Processing. The innovative design solution can be reached for 100% by process, geometry, material or function; that is called Design with X. Of course design with X could be design with anything however talking about design it is dealing with the main design aspects. This created an opportunity for embodiment design to penetrate into conceptual phase.
Ideas are transformed by a designer into bodies, which can be resulted in products, components and norm or standard parts. However the designer must avoid to do senseless

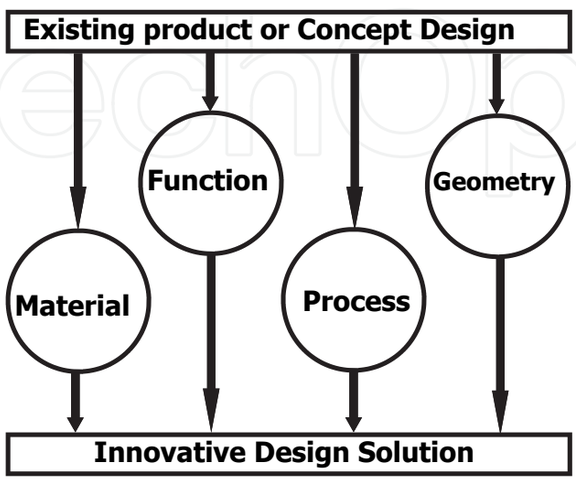

Fig. 9. From existing product to an innovative design solution

work so the designer has to recognize the irrelevant ideas and the conservative ideas and should not embodied them (figure 10) to bodies. The more the designer recognizes by doing how more efficient the design can be the designer is gradually getting more experienced. One idea may be realized into one body; this transition takes place in the head of a craftsman or artist, it could be art but it is craft. Embodiment design needs a plan that is not necessary for craft. Systematic design and engineering design occur but their results have lost the chance which lead to less solutions.

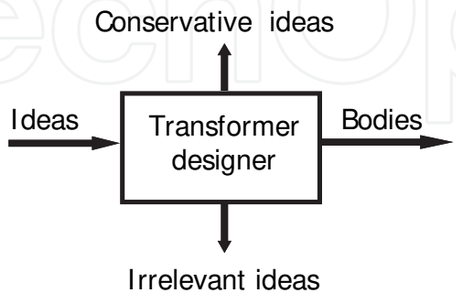

Fig. 10. Ideas transformed into bodies

No detailing takes place during the embodiment design phase. Detailing should take place at the moment that it goes over in engineering. In engineering, experience plays an important role. It is favorable to lay down the geometry, material and manufacture information on the technical drawing. For parts this information could be not sufficient, however the relational information may also necessary for instance for two moving parts.

Embodiment design could be brought to the conceptual phase, that could be led to more efficiency. Innovative design aspect could be taken as goal for the product design project with a main concern on embodiment design which leads to the innovative product design solutions. Stay to your design problem; do not run away to engineering and detailing. Then the design brings easier a product design solution which can be successful by using innovative design aspects or combinations. Innovations could also be done for items in the product organization or business financing. This does not have influence on the design of a product. Seek for the honest innovative design aspects, but concentrate on the design task because embodiment design gives a protected environment to do the design task on a creative way. The analytical approach of the design tasks influences the innovative power in the number of product ideas.

Decisions have to be made in the embodiment design phase at different moments in the process. In the Delft Design Guide (Boeijen & Daalhuizen, 2006) the following decision and selection methods are described: C-Box, Itemised Response/ PMI, vALUe, Harris profile, the Datum Method and Weighted Objectives Method. However for product design and part design no specific method is dedicated to product and design. We have filled the gap by creating a design decision matrix based on: who, why, what, where, how and when, see table 1. However the decisions and selections have indirect influence on the shape language. The design decision matrix (see tabel1) is a tool to identify how the design decisions are taken. It was inspired by the internet weblog learning journal from Lombardozzi, (2009) named Design Decisions.

Design Decision	Product Design	Part design
Decision making (Who)	Who decides which function could be fulfilled by product design? How might the product design be subdivided (but still a whole remains)?	By whom is the component or part being designed? What are the critical characteristics of part design to take into account?
Objectives (Why)	What are the goals and the performance objectives?	What are your goals and the performance objectives, concerning components and parts? How complex are the relation between objectives of the part?
Content (What)	What knowledge and skill areas need to be "covered"? What aspects of these topic's in the scope and out the scope, are important?	What information, procedures, skills, models, etc. will be shared with team members? What is in scope and out scope for the parts?
Delivery Method (Where)	Which will be the best delivery methods to accommodate the needed techniques, the overall preferences? What are the units' interfaces?	How are you going to deliver the part? What tools will be used to develop the part?
Techniques and Activities (How)	Which technique supports the best promotion of the product design?	What techniques will best contribute to the achievement of the objectives? What is a high level for part design?
Structure and Timing (When)	Which aspects of the product design need to be self-directive (pulled) vs. need to be instructed (pushed). How do you organize the research and design aspects of the product design? What is the intended time planning of the product design?	How do we organize the parts design in time? How are products broken down in parts? How do we represent the content (graphics, sound)? How long will it take to complete individual activities or components? What is the intended design time of individual parts?

Table 1. The design decisions matrix for product and part design

Within Embodiment Design the decisions are made by the designer, but at Detailed Design the part properties are established such as dimensions, material, tolerances, geometric tolerances, surface roughness and the volume (the number of parts in one product). In every stage of embodiment and detailed design the uncertainty will be decrease and hopefully come close to 100% certainty every time. Shape language should be used during this path

from uncertainty to certainty, for the parts and product design. At part level most parameters are fixed and the manufacturer should deliver the part with the required performance so that the assembled parts will fulfill the estimated performance of the product. Detailed Design is the final touch of the product design and should be 100 % correct for the assembled product to fulfill the expected performance.

6. Product

Product are the red thread through embodiment design because the designer has to create something new, what it means for the designer need about product knowledge which he has to learn from existed products. Design experience shall do grow the product knowledge such as: material, manufacturing processes, aesthetic, interaction, use, appearance, etc.
A product structure can be made by tearing apart a product concept or an existing product to learn and gaining knowledge of products which be good for use in the embodiment design stage. The product will be split up in functional units, sub-assemblies or components, parts and raw material, see figure 11. In general, the raw material is not found in the product structure because raw material is another business than designing and manufacturing products. Design and manufacturing can take place also in different business units such as design studios and manufacturing plants, depending on business size, skills, quality, technical knowledge, total products costs. The business activity is only successful when all the ingredients are positive for product development.

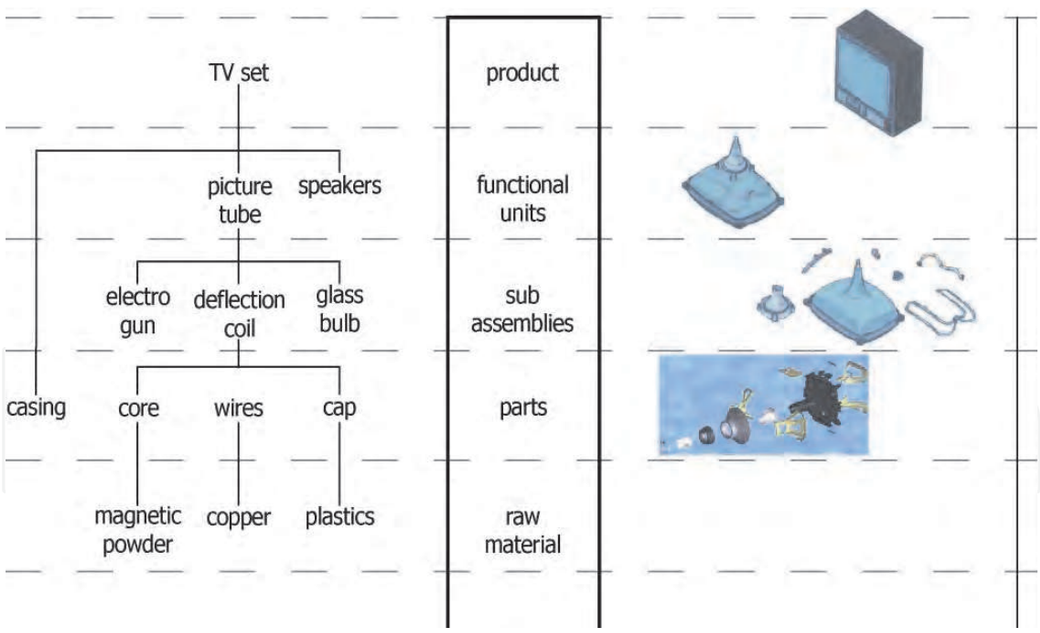

Fig. 11. Product structure of consumer product, which starts with raw materials

Product levels are acting as abstracting of the task in the product creation process. All product levels need their own approach; for example raw material require quite a complete other knowledge, skills and creativity than parts production.
Product layout arranges the assembly activity for manufacturing. The manufacturing may be organized in line systems of which the operations are sequential for a particular product.

The assembly system can also be organized as single point. Together they enable all kinds of arrangements, for instance a line system with sub-lines and a single point workstation.
Product aspects are identified as activities which are essential for a successful product. The hot topics for product aspects are sustainability, integration, embodiment design, healthy environment, feasibility, inter action, sound, etc. The topic embodiment design justify the possibility of making and the decisions are made in the uncertainty stage where it gets more certainty.
Time is money; however, the time available to create a successful product is always under pressure. But the "the first time right" principle is only possible if during the creativity and making processes, sufficient time is available for design development and manufacturing. Individual interests and short term successes are undermining the development of a successful product.
Product Management is about managing your products; manage what you offer to your customers at more or less fixed conditions. A product involves a more or less fixed outcome which encounters more or less stable, but at least pre-agreed terms to your customers. A product manager has the responsibility for the success of the product that means all the stakeholders will be served with the right tasks and budgets to get the product on the market in competitive way. Embodiment design is the base for an efficient product design process, but the product management should be on the same quality.

7. Design

Ulrich and Eppinger (2004) assign the next meaning to design: the design function plays the lead role in defining the physical form of the product to meet costumer best needs, these are also the embodiment task. The design function includes engineering design (mechanical, electrical, software, etc) and industrial design (aesthetics, ergonomics, user interfaces, etc.).
Design changes the world, however, before that happens many strategic product development decisions have to be made and the bodies are getting the form and geometry of the parts and product with embodiment design. But the design on itself does not change the world. The designer has the human instinct that every problem could be transformed to a design problem which may enclose a design revolution solution.(Pilliton 2009) mentioned in the book "Design Revolution". A great number of design solutions that have changed the world in different areas such as: water, well being, energy, education, mobility, playing, enterprises, etc.
In the innovative Design Solution model of an existing product or concept design, the main design aspects can adopt the innovative character of an aspect or combination for embodiment design. The goal will be a new product design that is needed on the market. For innovation in application of materials, the easiest way is to search for successful design applications, because experience with innovative material use starts at that moment.
The trade-off between design time and money evokes questions such as "how much time is available for Design?" The available design time should be used efficiently, also for embodiment design stage. The time management is a prerequisite to put the products to the market in time and within the budget. Time management involves time to market and time for designing and embodiment design for a good design. You have to plan and manage the whole embodiment design. It is necessary for the overall process as well as the design process. Time management costs time and money. However, a good balance between financing and designing is a must for a company. More design time may lead to better

designs because the solution can be considered in more depth. However, the deepening should be done on design aspects that request this, for instance deepening of manufacturing process by mechanical process modeling.

8. Designer

The designer is a human being with the ability to create products which the market needs with embodiment design in mind. The industrial designer needs input from art, social, cultural and technology knowledge and experience to be able to make a product design see figure 12.
Furthermore, the designer should have creativity, inspiration, motivation and emotion. These qualities enable an energized transition which can be done by the industrial designer who is using embodiment design aspects that may lead to a predictable product design.

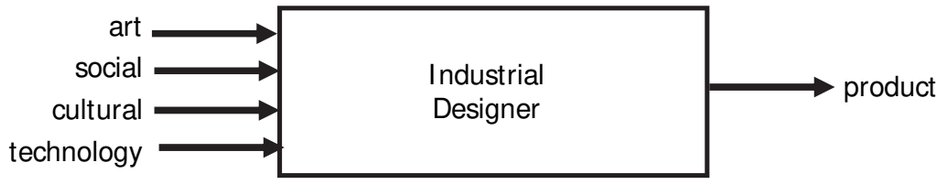

Fig. 12. Black box model of the industrial designer

The fundamental needs of the designer are conditioning and contact. For every need, we can distinguish three levels of interaction, which are shown in table 2. These needs are expected from the prospective designer during his or her education. Embodiment design demands all relational needs to meet on a well designed product with high expectation, these relational needs should be fulfilled.

	conditioning	contact
biological	Need of expression by sketching Need of making	Search for design project 3-D-Model making
psychosocial	Need of being designer	Need to contact other designer
existence	Need to design consumer products	Search to sense of design

Table 2. The matrix of the designer relational need (after interpretation of Nuttin, 1984)

These are all design elements which bring the designer in an environment where he can create the innovative product designs in the embodiment design stage. Knowledge, experience and skills are the qualities of the designer which are fed by personal designer needs, inspiration which stimulates creativity; structure of design process plays, an important role in the designer life, education of developments on different design areas and the culture of living and designing. The hierarchy of designer needs have also been defined on Maslow (1970). It starts with the basic needs (knowledge, methods and tools) and the highest need is design research, see figure 13. Nowadays embodiment design is used on conceptual design level so the designer has to follow education that trained on the level of acting. The prospective designers have to develop themselves to fulfill the needs of concept design, which is mostly found in design programs at university level.

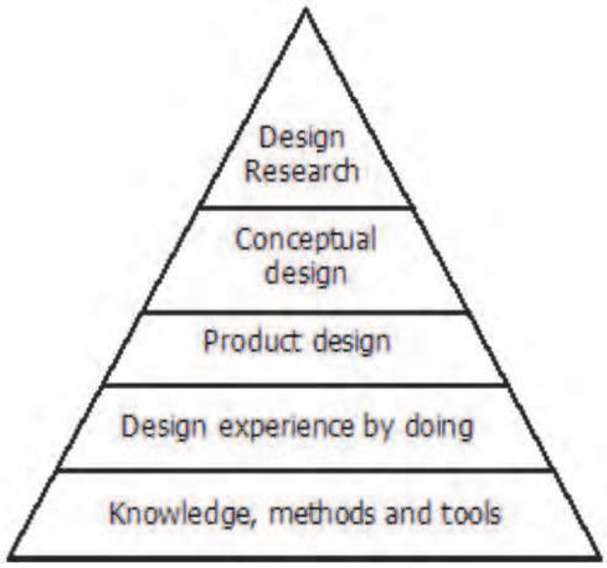

Fig. 13. Hierarchy of designer needs based on Maslow

The industrial designer can follow a certain path of education at a design school. During the educational program the industrial designer typically starts with the basic knowledge and progresses step by step in the hierarchy of the designer needs. An autodidact can follow these steps in his or her tempo, but gaining an overview of the right competences from each step costs much more time. Nowadays, the advice is to take a design course or apply for a design program, which is a more effective for the development to be a designer.
Embodiment design is mostly not offered exclusively but in the form of design courses with accents on embodiment design for example Advanced Design Project in master program of the industrial design engineering school in Delft.
The prospective designer applies for a degree in Industrial Design Engineering. He follows the program and has certain expectations of design education. These expectations are based on three main design capabilities: knowledge of design, communication of design and training, see figure 14.
Sometimes there is a great difference between the design program and the expectation of the prospective designer. If a selection is necessary by abounded of application, the offered program will match better the expectations? The applicants are more motivated for their

enrollment and have the opportunity to their skills. However, the designers have to form themselves during the design projects which they are following in the bachelor and master program.

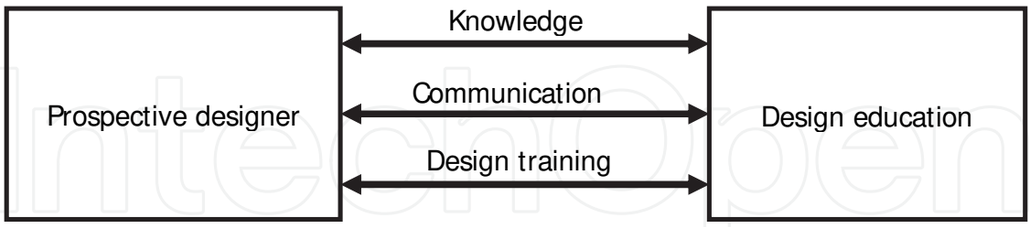

Fig. 14. The relation of the prospective designer and design education at his institute

9. Engineering database

In the embodiment design stage it is a possibility to orientate on the design problem to solve the design problem with knowledge from an engineering database that can inspire the designer.
The engineering database has three main goals within the educational context:

1. storing of design information
2. quick retrieval of information
3. the retrieved information should inspire the industrial designer

In design education enormous quantities of design information are generated in all kinds of courses and design projects. This information can be useful as an inspiration source for future design assignments. Thus, storing this design information is practical, if it can be quickly retrieved. Quick searching of design information is a need, if a designer wants to use the information for fulfilling a new design task. The data processing should be fast and reliable. For this reason, the input of product design information must be correct. This intensifies the need for structure and unambiguous data in product design information.
The stored design information must be reviewed regularly to check whether the information is still up-to-date. The size of the database may be large; however, it is only useful if the information is up-to-date. The search time should not be too long, otherwise the chances of inspiring the designer will decrease, which is shown in figure 15.

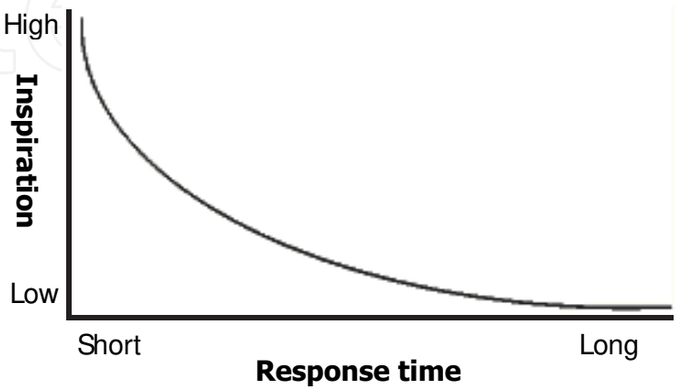

Fig. 15. Curve of the response time versus inspiration

The design education operates under high pressure, because the right information should be chosen from all the information offered for a specific design task. The present design assignments are so extended that no time could be spent on searching for the necessary information. Sources like the internet can deliver some information, but the amount of data is often overwhelming. Each day it is getting harder to find useful information on the internet. The engineering database can also fill up quickly.
Finally, the use of an engineering database in design education can prevent design students from aimless searching on the internet or in other information sources. The goal is to allow designers to find the needed information in the database, so that he or she is inspired. The engineering database can be consulted for inspiration in all phases of the design process. Inspiration gives motivation and inspiration challenges the creativity and inspiration challenges the creativity. The inspiration should be conceptual inspiration and detailed inspiration, see figure 16.

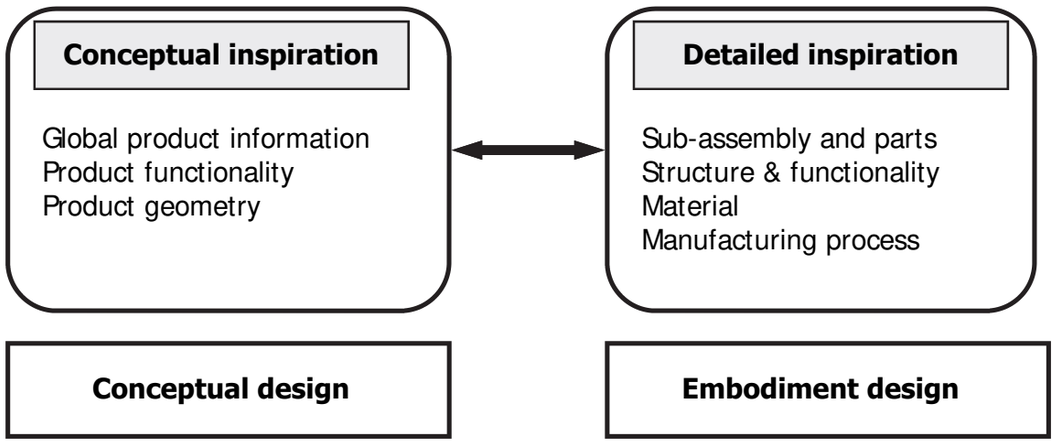

Fig. 16. Conceptual and detailed inspiration

Products have a structure that describes mostly how they are composed, with the relations out of the FMPG- model.
The product structure, figure 17, distinguishes several levels: product level, sub-assembly level and part level. The FMPG model is applied at the part level, but the design aspects change at component and product level
Components and sub assemblies can be bought or outsourced, depending on company strategy, volume on year base, uniqueness. Components are not made in the fabrication place itself. Sub-assemblies can be made inside manufacturing plants or produced on record.
Parts are manufactured in special shops to keep the cost to a minimum. The biggest part makers in the world are India and China, but they are also under pressure about the labour costs. Shipping the manufactured parts towards the place where the assemblies are done is relatively cheap in spite of the large distance between the part manufacturer and the assembly site. Parts which are assembled can be manufactured separately. So manufacturers of parts and sub—assemblies can be found all over the world.
Standard and Norm parts are produced in mass production; in this type of production, nearly all labor cost is cut away. The production of washers, for example, can be done almost fully automated.

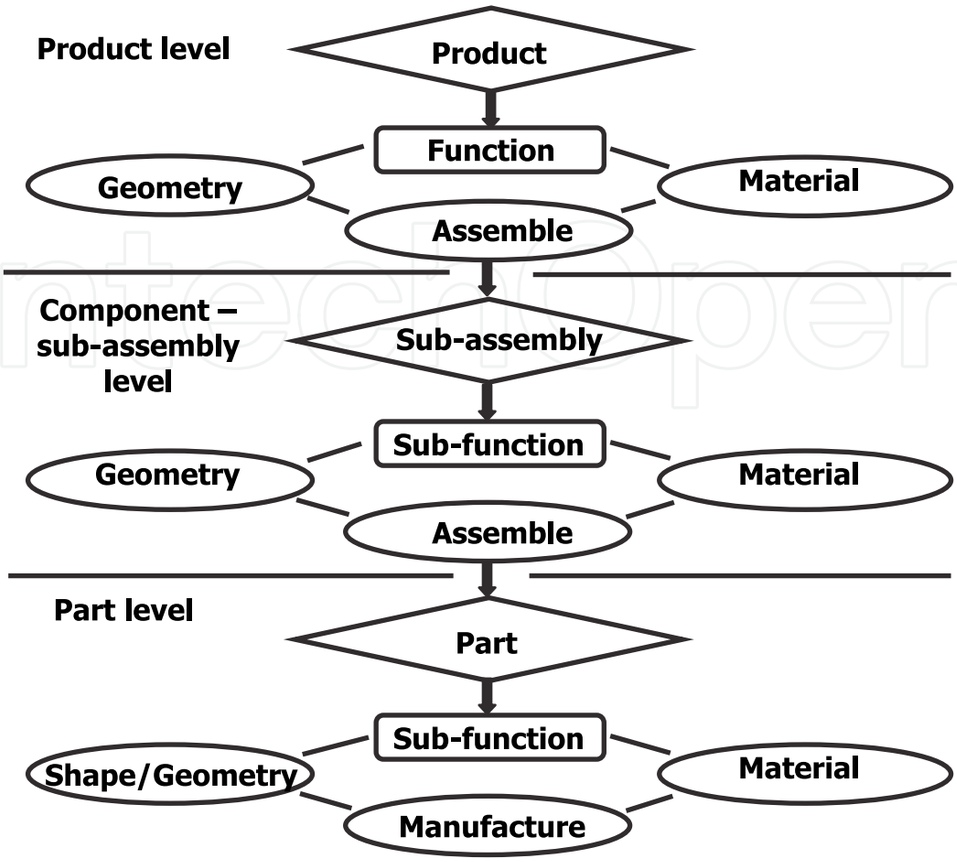

Fig. 17. Product structure on product, sub-assembly and part level with the design aspects

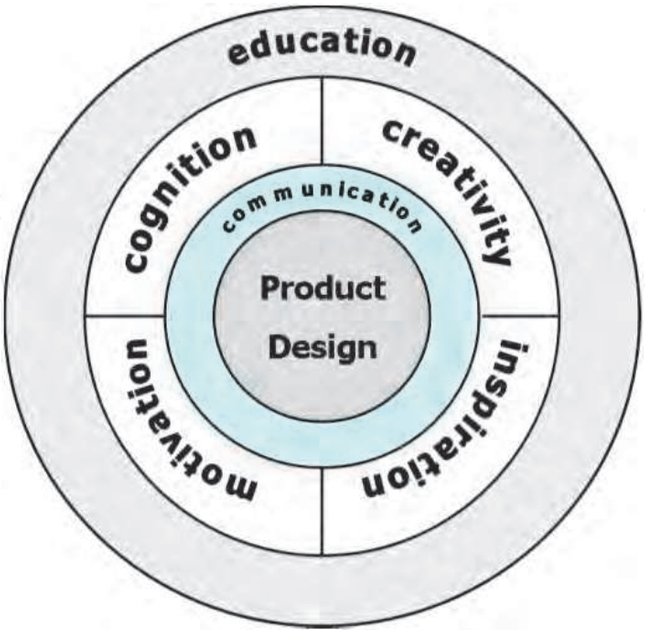

Fig. 18. Product Design Education model

Obviously modeling in 3D-systems comes up with views, sections, rendering as expression in visual images but e-drawings are also possible. This means walking around the product and check out or it is visual correct or wrong.
Calculation on parts, components and products may inspire the designer to optimizations. This is useful detailed inspiration information that is retrievable in databases.
Estimation of costs, market potential, appearance, color, etc., are necessary to become from uncertainty to certainty at the moment that every aspect is detailed and the production may start at this moment. But embodiment design is always searching to a solution that comes closer to certainty in spite of the uncertainty. Estimations help to increase uncertainty until it fits within the bandwidth that gives confidence about the solution area.

10. Embodiment design education

The education product design model shows the condition how an institute may arrange an education program to Industrial Design Engineering on Bachelor and Master Level, see figure 18. The cognition, motivation, inspiration and creativity are main properties of the product design program which should translate into design courses and domain courses which should support the design courses. Embodiment design is covered in divers design courses of many design programs in some design courses lay the accent on different main aspects of embodiment design.
Shape language is such main aspects just as a part of the communication which has to be taught in all product design courses. Cognition is more used by courses which are engineering orientated such as product in motion, technical product optimization, industrial production, technical modeling, etc.

Fig. 19. Cycle :model of creativity and inspiration

Creativity and inspiration are stimulating each other, as shown in the cycle model in figure 19. It is possible that no creativity may lead to less inspiration, what means to stop for a while with designing until the inspiration is coming back. Motivation comes from different areas principally with a lot of energy. This energy is picked up by designing with inspiration and creativity. Motivation or better feeling well is a must for a designer in the embodiment design stage. Education should focus on conditioning of the designer and offer all kind of tools for the embodiment design phase so the motivation stays on right level. The communication should lead to motivation and creativity of the students, because the knowledge they have to learn and to create by their selves.
A product design is the result of communication between a designer and his client, only good communication will lead to error-free product designs. Embodiment design is a part of product design with a new perspective that needs some revision for design projects. The design projects and courses, with the focus on embodiment design, should be further

improved, because embodiment design should be learned efficiently and also experienced by applying it in the new perspective.

Embodiment design will also be communicate where the technical engineering language plays a connected role in the whole. The shape of a product should be communicated by different designers which may lead to misunderstanding but if they have the same goal then it leads mostly to success.

The communication goes verbal and visual; every designer has his own means to communicate his design work.

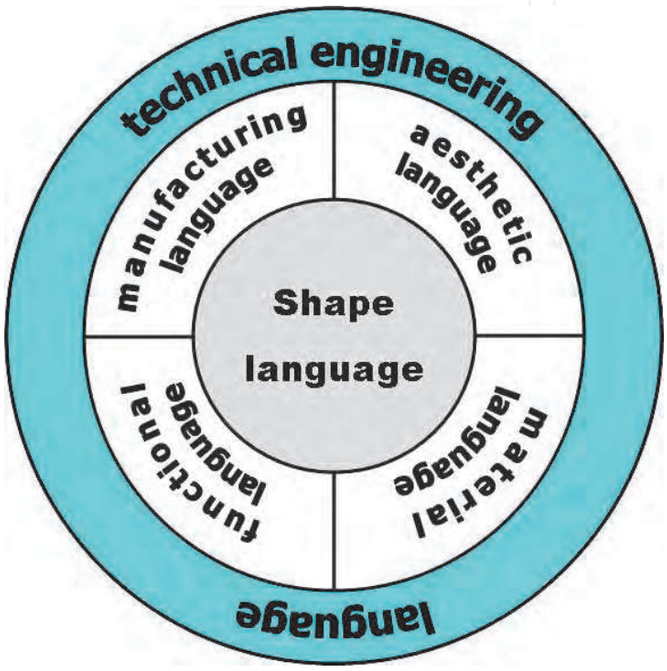

Fig. 20. Technical Engineering Language model which contains shape language

Communication is a way in which product designs respectively embodiment design become their gestalt by means of technical engineering language see figure 20. We need a language to transforms ideas into product designs. Within this technical engineering language, we can distinguish four more specific domain languages:

- Functional language
- Manufacturing language
- Aesthetic language
- Material language

Manufacturing language contains specific manufacturing terms. For instance volume is the number of pieces made in one batch; yearly volume goes about the production in one year.

Functional language indicates with specific terms how a product can fulfill its physical principle. The specific term contains always an activity which fulfills the product function or sub function, for example, coffee making.
Aesthetic language expresses with specific terms how one experiences the form and what the form does with you. For instance, a natural form may please you quite well, because of recognizing the beauty in nature.
Material language is giving specific terms about the physical properties of the material and how you can make and assemble the parts into a product.
Shape language has the specific terms to express the shape in a general way of material, function, manufacturing and aesthetics in the engineering way.
Realization of functions is always engineered by physical appearance; however, emotion can play a role, too.
During the embodiment design stage should be practiced the technical engineering language to come to a successful design solution. Every kind of education is lagging behind the facts in industry, including academic education. When education does not introduce innovation in their design projects and courses, the students will get far behind the reality when they get graduated. About embodiment design is it the same. Poor education does not have the capability to develop any education program with a focus on embodiment design, design projects that stimulate the student to realize an innovative product design.

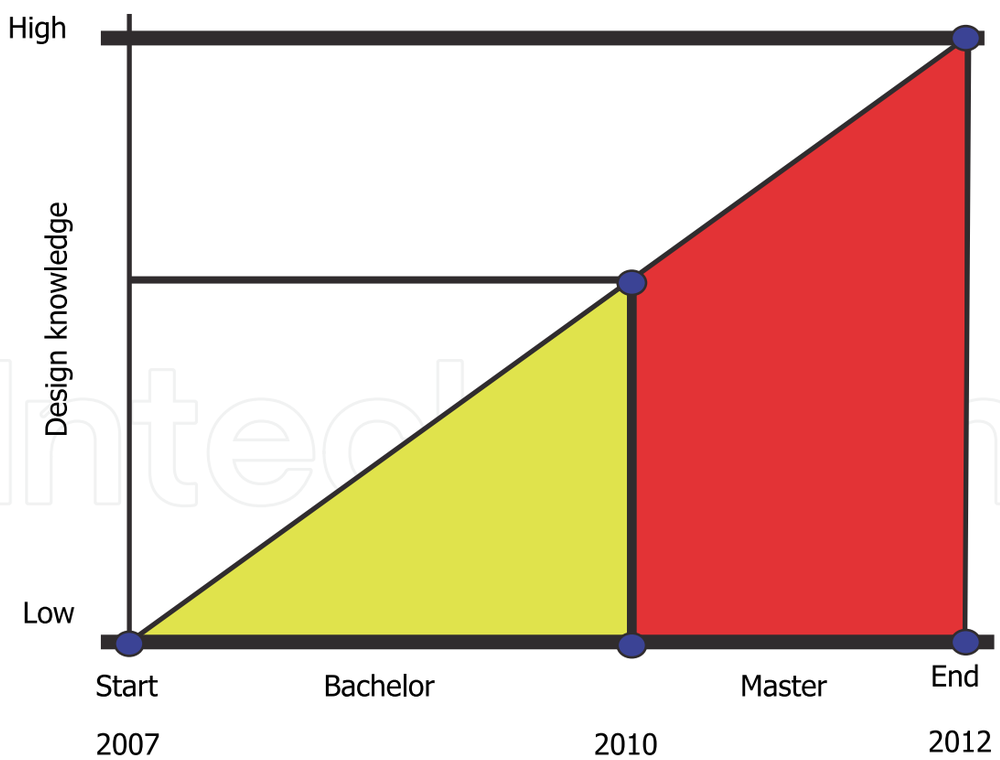

Fig. 21. Design knowledge during educations programs

A design staff must recognize the innovative product concepts which are elaborated into a product that has an innovative character, also in the embodiment phase. Here you need the use of embodiment design in the new perspective. The academic Industrial Design programs, at the moment, have a bachelor and master structure. At the end of the bachelor the design knowledge including embodiment design should be on a sufficient level for a bachelor to look for a job or do the master, see figure 21. The design bachelors should have the capacity to develop their own identity from junior designer to senior designer. The design knowledge has to be the foundation for the independent identity development. It is only one pillar of the successful Industrial Designer, because creativity and social skills are also essential elements to build on the designer to be as a personality. All this could be trained with embodiment design. The design schools have to offer design programs that give the possibility to be conspicuous in industrial design. This does not mean that the other regular design programs are not good enough. Attention should be paid to embodiment design in the new perspective just for opening perspectives for creating of the design identity.
The master program should not be more of the same, but provoke design knowledge that motivates and stimulates to do excellent design projects and courses. This design knowledge is gained from the results of design projects with predominantly industry design problems. This offers new perspectives for embodiment design, but also for product design. The real knowledge generator should be identified and developed to an education development system. Valuable knowledge should not be thrown away, even if it is not directly science knowledge.

11. Discussion

Product design includes embodiment design, but this is the strength and at the same moment the weakness of it. Embodiment design is included in the design process which is from assignment to the final product design. In the embodiment design phase the ideas get the physical form by the transition of ideas into concepts by the industrial designers. However the emotional contribution should be also transformed into the physical form. The physical form is an extension from material, geometry and manufacturing. Design with X is useful for many design processes with the goal of a product design. To promote a new material, first an amount of mechanical, electrical, thermal properties have to known or tested before you used the method successfully. The design process can take place on so many manners: sequential, cycles, spherical, random, etc. So the designer chooses the design process that fits the best for solving the design problem. All the processes have a moment that ideas have to transform into preliminary design, the first stage of embodiment design and after that detailing takes place. The new perspective brings embodiment design to the conceptual phase of the design process. When the designer wants to do the design effectively then a concentration on one of the main design aspects may be applied with design with X. It may happen that design with coffee making, could be solved with an innovative solution for example the Senseo coffee maker from Philips, a design with X solution.
With design with X conservative and irrelevant designs solutions can be avoided, they do not show up in number of possible solutions. If the designer looks for innovative design

solutions then there is no space for the other design solutions. Focusing on one main design aspect helps to solve the design problem in an efficient way.
Decision making is an embodiment design activity that may be pushed forward during the embodiment design process, but if the decision is taken on the right moment in the process then the result gives a new starting point to gather information for next goal in the design process. The design decisions have to be made on who, why, what, where, how and when for product and part design. The questions are very helpful to support the decision making for that specific area. It provides a new perspective to embodiment design; it is a tool that has to be experienced by using the design decision matrix during a number of design tasks.
A product has a structure which is depending on the number of parts, components or sub-assemblies and units. The levels take care of items for that specific level. However design research on embodiment design, product management, design time, layout and feasibility are efforts that help to indicate the new perspectives for embodiment design and product design. These aspects are mostly in the area of organization and technology, where the creating process (Prabir Sakar, 2007) is supported with creativity as main driver.
Design is the most difficult phenomenon because it means everything, but time and products are concepts that give content to product design. The content may be innovatively, quality for money, beauty, sustainability, etc. The context of the product design problem has the power in itself to make a transition from ideas to a product design by an industrial designer.
The designers should have a certain aim of life for their eyes; creating products that make the life comfortable. The designers have a need that is depending on their education and capability. It may be on different designer need levels according to Maslow. Education can only support the need of the designer in his development, the industrial designer he wants to be. The support contains design training, communication and design knowledge. All the called aspects should be optimized for the junior designer. Experience in design does grow with experiences so they may grow out to a senior designer. In daily life the designer generate new knowledge, design ideas, product designs, part designs, etc., all valuable information If this is collected in a structured engineering database then it is shareable with all designer world wide. The base for such database is mentioned as engineering database with an ordering that can inspire the designer by means of the designs examples on conceptual and detailed level.
All the generated design information also the abounded information after a decision can be useful for sharing it. So the valuable information of alternatives principles, ideas, concepts and product designs have to be judged before putting them into in the database.

12. Conclusions

Embodiment Design is a part of the design process with a new perspective that is expressed in the new definition: “Embodiment Design is designing with materials, manufacturing and geometry to fulfill a new function or updating of the function”, but the emotional aspects of the product should be met the requirements about: use, interaction, ergonomics, etc. Embodiment Design is giving matter to ideas, so a body is created in headlines, which get

detailed by continuing of the design process. This takes place on different levels which depends on the place in the design process.
Particular embodiment design aspects of an existing product or concept product design should be avoided iterations to come to an innovative design solution. Right choices occur not always for hundred percent, this will still lead to iteration as compromise of the design aspects.
Designing and decision making are the main activities of embodiment design but decision making could only be done by means of feasibility studies, estimation of cost, implementation of ergonomics data, and physical calculation such as; strength and stiffness, sound intensity, thermal effects, etc. However designing is using the designer skills to solve the design problems which are formulated in the design brief.
Design decisions have always to be taken on the right time, on the right place, and with the right knowledge. However the design decision should be taken in the right stage of the embodiment design phase. But time pressure disturbs a good design decision, because the designer can not research sufficiently all the aspects of design decision. If you get enough time to analyze the design problem then embodiment design can prevent iterations based on the principle "First time right"

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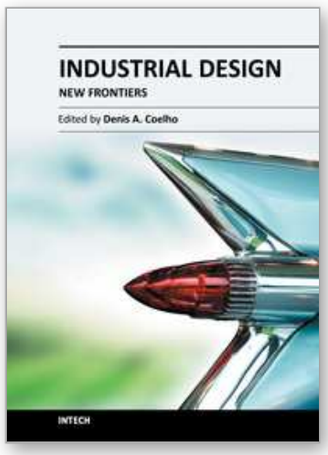

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A new breed of modern designers is on the way. These non-traditional industrial designers work across disciplines, understand human beings, as well as business and technology thus bridging the gap between customer needs and technological advancement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

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