DEVELOPING IDPEO – A MULTIDICIPLINARY APPROACH TO PRODUCT REALIZATION

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ABSTRACT
On the background of a changing industrial landscape and key elements of the realization of complex integrated products, this paper discuss and explore an "innovative" approach towards product concept development methodologies by focusing on creativity, multidisciplinary teams, and decision-making. Throughout 2006-2009 a product realization methodology, the idPeo methodology, has been developed in a university/industry collaboration milieu. Based on a briefly reported literature review, the paper presents the methodology, briefly the three generations of conducted cases and the evolution of the methodology over the years. It is argued that the approach for innovative product realization in concept development, if implemented correctly also into companies' product development process, could contribute to increased flexibility, creativity and tolerance for change. It could also decrease lead time, increase product performance, and decrease uncertainty.

Keywords: Product Realization, Development method, University/industry collaboration

1 INTRODUCTION
Long term growth and future jobs rely on to what extend industry is able to realize new sustainable product ideas and develop these to profitable products in the market. Competence is needed in both product/service development and in product/service introduction. This encompasses both short time-to-market and continuous development and adaption of existing products and processes to improve productivity.

1.1 A changing industrial landscape
The industrial landscape is changing. Recent data on Swedish industrial structure illustrated in Figure 1 show a radical increase in value-add from knowledge intensive company services during the 1996 – 2007 in combination with a still strong manufacturing industry.

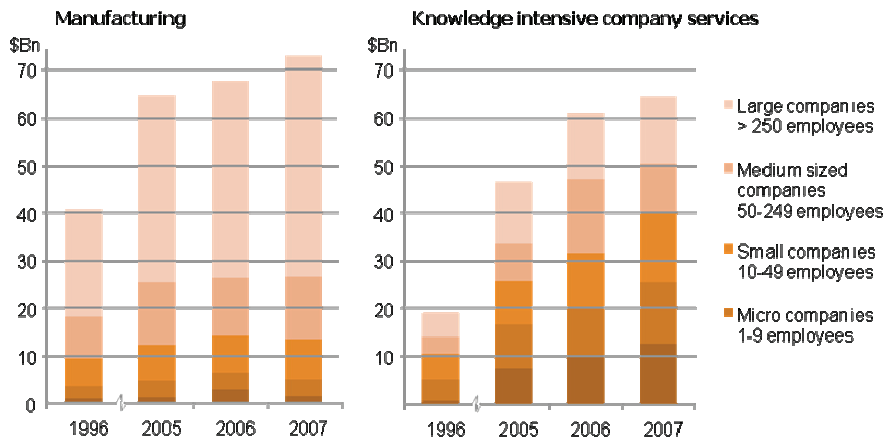

Figure 1. Sectorial contribution to Swedish GDP. Accumulated value-add in current prices from Swedish companies within two specific sectors. Source: Accumulated data from Swedish companies' financial reports.

The fast-growing sector of knowledge-intensive company services relies upon a strong industry as customers, and is heavily engaged in the increasingly complex product realization. Another typical dimension of this industry-related service sector is the size of the companies. As seen in Figure 1, SMEs are highly represented in this fast-growing sector, while the industry is typically dominated by large companies.

1.2 Product characteristics in successful industries

As reference, Fujimoto concludes in his analysis of Japanese industrial success [1], that integrated products (such as cars, small electrical appliances, game software), have been the key sector for the world leading Japanese manufacturers. Here competence centers on capabilities in transferring design information to solutions, in contrast to modular product architectures (such as mainframe computers, PCs, bicycles), where Japanese manufacturers are notably absent among the global leaders. Designers of modular products only require good understanding of the rules for interfacing the modules and the designers of the modules do not to think much about how other modules work. Integrated products on the other hand, are a complex optimized architecture where single components relate to multiple functions and single functions are solved by multiple components.
A brief analysis of the Swedish manufacturing sector indicates similarities with the Japanese industrial landscape. Big industrial companies have been built on individual innovative and often integrated products or services. Integrated system solutions within automotive, aircraft, machinery and automation have been the basis for much of Swedish industrial competitiveness, founded on teamwork, innovation and a system perspective.

1.3 Some success factors for developing complex, integrated products

Fujimoto [1] further points out the typical characteristics of the product realization for integrated products, which have been the winning abilities for Japans world famous production philosophy:

- A focus on short lead time in product development by minimizing waste and a concurrent engineering. Apart from efficient use of resources, this has raised the accuracy in targeting demand, a critical ability in product development.
- By higher productivity more development project are possible with the same allocation of resources. This has lead to a broader product flora and addressing a growing diversity in demand.
- The development teams are generally smaller and the multi-skilled team members have broader responsibilities and broader perspectives on the project. The Toyota-specific ‘Product managers’ with very strong mandate and broad competence from market to production leads the development teams.
- Close collaboration between product designers and production engineers builds a basis for less efficient product realization and short lead times.

Worth noticing is the absence of pointing out formal product development processes. Research within product development is often focused on a technical engineering perspective and is manifested in descriptive and normative models for product development. We argue however that, especially for development of integrated and complex products (which will be the most promising path for high-cost nations), it is not enough with traditional subject-specific development processes. It is even more important in addressing a multi-disciplinary approach incorporating various competences and functions. Diversity is a true key success factor for the product realization of the future.

2 RESEARCH SETUP

2.1 Objective

On the background of the changing industrial landscape and the key elements of future product realization discussed earlier, the objective of this paper is to discuss and explore an “innovative” approach towards product concept development methodologies by focusing on creativity, multidisciplinary teams, and decision-making.
The approach have been developed and adjusted in a university/industrial collaboration center. However, the objective has been to develop an approach for innovative product realization in concept development that, if implemented correctly also into companies’ product development process, could contribute to increased flexibility, creativity and tolerance for change. It could also decrease lead time, increase product performance, and decrease uncertainty.

2.2 Methodological considerations

In order to detail a multifunctional and innovative product realization process a sequence of industrial cases were carried out during the 2007-2009. Different project teams were set up, running in generations of parallel projects with a synchronized phased project scheme in order to exchange experiences.

The research has been based on industry cases, leading to a big impact from the temporal, cultural and social context of these cases on the results. This is however always the case in this kind of case-based research, where analytical generalisation is used in contrast to research based on statistical generalisations.

Yin points out four criteria for judging the quality of case study research: Construct Validity, Internal Validity, External Validity and Reliability [2].

In this research, being an exploratory first phase towards a method to be further validated, the external validity (i.e. the possibility to generalise outside the studied cases) is not obvious. The reliability of propositions is also obviously not verified at this point.

However, these four aspects of validity and reliability are important aspects to consider in the total research setup, where this is in a first phase. The case selection is for instance central to span the solution space and in the end establish an external validity.

Finally, flexibility in the process and application is an important aspect, long discussed as contrast to rigid structured approaches. The possibility to adjust to situation, but not loose critical elements is an important aspect of a development method.

2.3 Aspects on university/industrial collaboration

One important methodological aspect of the proposed development process is that it has been developed in a university/industrial collaboration milieu. Industrial experiences from working together with university in development project are not entirely positive. Problems that have been pointed out in the setup of the university/industry collaboration center are:

- Universities do not have enough insight in companies' conditions regarding punctuality, delivery accuracy and reliability.
- Universities are not transparent enough so that external parties can orientate.
- Universities have not ability on their own to drive knowledge generation processes that are adapted to the industrial conditions.

These aspects vary of course enormously between different universities, but in contrast to this somewhat discouraging image of universities' ability, there is a positive component. That is universities' legitimacy as knowledge producers. So there is expectancy that universities provide an unrealized potential for knowledge building. It is also an arena for new ideas, new knowledge, new influences represented by competences and persons that industry is interested to get in contact with. All this give a process development environment that is neutral in interest but need close industrial collaboration in order to develop relevant processes.

3 PERSPECTIVES ON PRODUCT REALIZATION

Many are the researchers who have tried to characterize and structure design. The design process is often described as including both irrational phases of intuitive creativity as well as rational phases of calculation and evaluation. These two parts of the design process—the irrational and rational viewpoints—seems to separate more and more as the technical complexity increases and specialists tend to play a more important role in the design process. This impedes the development of good design, since both the rational and irrational parts are needed in the design process and it is often in the meeting of these two competencies that a successful design is created. The vision of merging the two worlds of design is not new. The Renaissance main idea of the complete human; engineers as painters and architects as engineers, supports this vision. Today, however, it is not possible to create the "complete man", instead this merge must be created by communication and co-operation within project teams where competencies with insight in each other's core competencies together creates a successful design team. Wikström [3] elaborates through a theoretical review of current literature on a number of important factors for conducting a multidisciplinary approach to product realization, detailed in the following.

3.1 People involved in the process

The development of complex integrated products is especially dependent of multiple competences for true innovative steps. Fujimoto characterizes this type of development as "rubbing things together" [1], which well points out the need of communication, multi-capabilities and teamwork. It stresses the importance of a multidisciplinary team, where people differ in their roles, have the freedom to think big in a creative and innovative environment. Another witness is Florida, who describes how technology, talents and tolerance for diversity are closely connected. In the research and in the company world, more often than not, are multidisciplinary teams responsible for successful innovations [6]. In a longitudinal study by Hoegl *et al* from 2004, 39 teams in product development project in the European automotive industry were studied [7]. The study show that interteam coordination, project commitment, and teamwork quality, as rated by team members early in the project, are significantly correlated to project managers' ratings of overall team performance at the end of the projects. There is also a positive relationship between interteam coordination, project commitment, and teamwork quality in the studied cases. These findings complement the long-time established importance of team-internal processes for smaller scale projects, and focus collaborative processes between teams in large-scale multiteam projects for the development of highly complex products.

A way of looking for the right people or creating the right people is described by Gardner [8]. His "five minds" is a starting point when forming a development team for a new project. It indicates the knowledge of minds that is demanded to be able to take part of the future, not only as passengers but as drivers. He stresses individuals to be disciplined, synthesized, creative, respectful, and ethical.

3.2 The Medici Effect

Johansson [9], points out that today increasingly more innovations originate from a phenomenon, the so-called Medici Effect. It is the cross-road where ideas, or disciplines, from different knowledge areas and cultures meet, resulting in an explosion of innovation. "When you step into an intersection of fields, disciplines, or cultures, you can combine existing concepts into a large number of extraordinary new ideas".

The "Medici Effect" has reference to what the Medici family accomplished in Florence in Italy during the 16th century. By sponsoring people from different disciplines – architects, scientist, artists, sculptors, philosophers, and bringing them all together in Florence, they made it the epicenter of the Renaissance - one of the most creative eras in Europe's history.

This is tightly linked to the earlier discussion, that by combining different knowledge areas and supporting the work with innovative tools and methods, it is possible to increase creativity. Use of idea management, ethnographical studies of customers, rapid prototyping, and other creative tools, can inspire integrated development teams explore opportunities they otherwise would not.

3.3 Design Processes

The design process is no straight forward path. The paradox of how to decide the whole, without knowing the parts, while the parts in turn depend on decisions of the whole, is evident. At is often described as being solved by a constant iteration between the whole and the parts, but how is this solved in a large organisation, designing a complex technical system? Here the use of work structures and efficient tools must be emphasised, supporting the creativity and iteration in the design process.

Balanchandra and Friar have made an extensive survey and mapped success factors in product development literature [14]. Categories such as market, technology, environment, and organization were found to impact the success of product development. Organization was found to be the category that contained the most important factors which influenced success.

One problem in communicating this model is the complexity of the iterative process that characterizes the design process. However, that is partly solved by communicating on a linear stage-gate-model, adapting to the Analysis-Synthesis-Evaluation paradigm, but applying an iterative process when designing the solution. As pointed out by Utterback et al: "Swedish design firms claim that they follow processes that are mostly standard and linear: some firms use specific tools and metrics. (In reality processes are not always linear, but there is a feeling that clients wish to see understandable logic.)" [15]. A further witness on the use of stage-gate models are: "The use of stage-gate-models is actually built upon the assumption that one actually learns gradually as the project develops, however, gate decisions are often applied as locking mechanisms for the end result from the very beginning.

During high-uncertainty projects the gate model should be used to set up hypotheses that are tested and evaluated in the next coming phases." [10, translated by author].
Lifting the reasoning to a higher level, Dobni [16] points out that the design process rests upon three parallel sub processes:

- The creation of a satisfied customer
- The knowledge about team processes and multidisciplinary work
- The continuing development of processes and ensuring of an efficient and well carried out process.

3.4 Communication

All kinds of communication have to be effective and efficient. First of all, an external representation can carry understanding in multiple interpretations, in terms of creating a common mental image in the project. Communicating this mental image between different parts in a development process is hard and demands a dialogue that does not flinch for analogies and metaphors, and that the receiver interpret from his or hers experiences. The challenge is to among the co-workers create this common, mental image of the project, not only of the result, but the way to the result [10]. The lack of information and the need to communicate this "mental image" of the project to the next group of people, who continue the work process, is considered a difficult step - a handover situation described by Eckert et.al. [11].
When we discuss different strategic decisions, it is important to have tools designed for understanding. From an information designers perspective deep knowledge in perception, cognition, and esthetic is important. This itself speaks for a cross-functional development team.

3.5 Visualization

Visualization is vital for a common understanding of concepts, problems and solutions. Successful external cognitive tools compensate for limitations in human memory and information processing, at the same time that they take advantage of these limitations. [12]
The creativity is enhanced by allowing designers to interpret sketches. The designer views this as interacting with the sketches as in a conversation: the designers see more in their sketches than they put in when they drew them, and these insights drive further designing. [13]

3.6 The innovative culture

Dobni [17] describes a number of areas that are of the highest interest for organizations to become operative innovative. The model supports the theory that there are four general dimensions of innovation culture, that being:

- the intention to be innovative;
- the infrastructure to support innovation thrusts;
- influence, or the knowledge and orientation of employees to support thoughts and actions necessary for innovation; and
- an environment or context to support implementation – which invariably has inherent risk and reward tradeoffs.

As Dobni concludes: "The innovation blueprint describes the environment and behaviors necessary for ongoing innovation in an organization. The innovation environment, being management-centric, describes the context in terms of intentions and infrastructure that must be created by management to support innovation. Behaviors, on the other hand, are employee-centric, and identify the temperaments and characteristics necessary to drive the market orientation of employees and the implementation of innovation" [17].

4 IDPEO – THE PROCESS AND STRUCTURE

The process presented here has been built upon an general design process and focuses in the three different areas of competence within the Centre for Product Realization: Engineering design, Innovation Design, and Information Design. From these areas and from evaluating the cases above we have created a new process that not only focuses on the process itself, but also supports areas like collaboration and team development, and we are also suggesting a physical environment that supports our process with special care of the mental environment. We also have a concrete proposal for the

system that is required to carry out product development projects in collaboration between academy and organizations.

4.1 Key considerations

Regarding an "innovative" approach towards product realization, it was argued that there is a need to establish multidisciplinary teams of people, with different skills and frames of reference on the innovation ideas as a result of the backgrounds, experiences and activities.
Examples of possible competences are mechanical engineering, information, product and industrial design, business and marketing, innovation management, ergonomics and applied psychology.
This formed the initial ideas and problem statements on a model, including planning and manning the team. The research then continued through two new projects were the aim was to explore and identify gaps in the model and to form the management of projects. After that a literature review within design theory, project management, and product development processes was carried out. A total of eight semi structured and open interviews was held with PhD students and researchers at the university to identify a common model for product development according to the differences in competence. These results were then incorporated into the suggested model, idPeo, illustrated in Figure 2. The name is a play with words where the university department name resembles the well known company for innovative product development, IDEO.
All key activities are supported through developed workshops, dedicated to focus on shared key factors and decisions for successful product development. Some of these key factors/decisions are common in design theory, but they are being researched and developed continually. In contrast to other product development methodologies, idPeo is composed by workshop packages and does not constitute a continuous full process, but is rather a complement to various product development processes.

Figure 2. Ilustrated aspects in the IdPeo-process.

The model is workshop-based to fit into the diversity of development processes in industry today and has a broader focus on the decision-making process itself. It manages the focus of shared decisions, organization, and creative tools for exploration and decision-making. Decision management together with creative thinking and tools – idPeo – is an option to a wide range of industries engaged in, e.g., product innovation and service design.
The composition of the development team is the single most important factor for the success of the idPeo model. idPeo encourages diversity of expert knowledge within the work groups and is consequently a great and flexible tool for use in Concurrent Engineering and Integrated Product Development. The process leaders should have extensive experience within team management, creative methods/tools (idea management), and decision management to facilitate an effective and efficient product development process.
The goal is to eliminate traditional barriers and to foster good communication and cooperation. The process should be made explicit to facilitate development and the possibility to become increasingly flexible and creative, as well as robust to changes in the market, organization, task, and team.

4.2 Process steps

The suggested approach, called idPeo, is a methodology for innovative product development and successful cooperation. It focuses on management and flexibility of creative product development within organizations that are dependent on creativity, quality, and time-to-market. The process consists of the following eight key activities, illustrated in Figure 3;

1. Analysis and Assembly of Team – Analysis of necessary expertise and knowledge areas for the project, assembly of development team with necessary skills.

2. Project Plan Development – A generic plan for important shared decisions in the project at hand.
3. Project Definition – This is where the collective goal is visualized and described to serve as common direction throughout the project execution.
4. Knowledge Gathering – Need finding and benchmarking etc.
5. Analysis of Information – The interpretation of the gathered material so it may be translated from the language of the customer to the language of the engineers. Use of creative tools for decision making.
6. Concept Development – In this phase "design thinking" dominates the process. Concepts are generated which corresponds with the needs of the customer. Idea management is utilized.
7. Evaluation – Evaluation and selection of appropriate solution to the customer need. Use of creative tools for decision making.
8. Final Presentation – In this phase the final selected product is visualized and described to best show the advantages.

We have divided the model (idPeo:s eight steps) into three areas:

- Preparation
- Realization
- Reflection

Where step 1-3 is the preparation area, step 4-7 is the realization area and step 8 is the reflection area. Although the reflection area mainly is in the last step, it is of highest importance that the reflection is a part of all steps in the process.

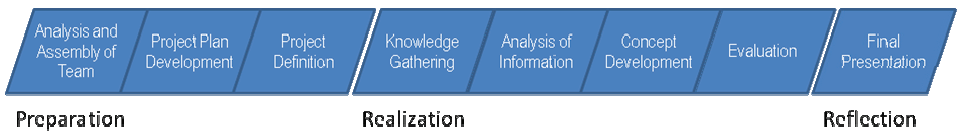

Figure 3. Principal structure of the project process

4.3 Supporting structures

The environment is important for supporting the process. It is both the physical environment and the mental environment. Important supporting structures are the lab environment, both the user experience lab, the rapid prototyping lab, the robot lab, as well as the wood and metal workshop. These labs support the process in a concrete way and give substance to the projects.

The physical and mental environment is important to create in such a way that they support the process. It is important that this environment is unexpected and "clean". To be able to set the mindset for each purpose, having mobile solutions for everything and possibility to change the environment quickly or move to a completely different room, next door, use senses to stimulate and inspire the team by music or humor. In the mental environment we mean that it is important to make the team members trust each other and to have fun.

A reference library inspires, as well with literature, supporting the steps in the process and material samples to feel and test along with a library of form. This library is for applying known form to new applications, turning things upside down.

5 CASE EXPERIENCES

The idPeo-approach has been developed throughout the last two years, by a number of case generations.

5.1 Process prototyping

The basis of the approach was first developed through a workshop after the first step in a project during 2006. The aim of the pilot project was to make design concepts of multi sport wheelchairs and an exhibition to show the wheelchairs. The exhibition was supposed to be mobile so that it could be taken on a aircraft and only weight 10 kg/person. The multisport wheelchairs should easily be adjusted to at least two different kinds of sports and for many different people. Today one sport wheelchair costs about 2000-5000 EUR and is handmade for one person. The goal was to create a wheelchair for 1000-2500 EUR for several different sports and people. The students and researcher involved in this project were from different areas of competence, the aim of the workshop was to explore the common

approach in working with projects and how to execute the projects. The result of the workshop became a model of how to execute projects like this, containing six steps:

1. Project Plan Development and observation.
2. Creative work based on observation.
3. Making concept and rapid prototyping
4. Refining the concepts and modeling
5. Prototyping and development
6. Presentation of concept

5.2 First generation of cases

During the fall 2007 the first real product realization projects were carried out. Three industrial cases were chosen where a team for each where formed, consisting of complementing competences overarching the entire realization process. Each team worked through the idPeo-process for four months and consisted of 5-8 persons with a dedicated project manager.

5.2.1 Case A1

The company was based on research from a larger Swedish university, dealing with bacterium and virus elimination in air. The technology decreased the risk for infection in areas where many people are and the risk for infection is high, such as airports or hospitals. The commercial potential was regarded as high and the product was based on development of novel micro-porous material. The project team showed how to realize a commercial viable product on the basis from a research-based innovation. Potential target groups were analyzed and their respective information, product and design needs were defined.

5.2.2 Case A2

The company was based on the idea of an autonomous robot primarily intended for hospitals as a service robot. The application exists, but this had specific unique hard- and software features. The project team worked with product functionality and design, information design with a graphical form and with manufacturing adaptation and material selection.

5.2.3 Case A3

The company is a entrepreneurial local manufacturer of high-end quality products, mainly different types of marmalade. The company was launched 2006 and currently have a production of about 50,000 jars of marmalade per year. Their resellers are carefully selected shops with premium products of high quality. In 2007, the company was contacted by a new large reseller. Due to lack of production capacity, the company had to turn down the large orders. Their current production method and system could not handle the large production volumes (four times the current volume). This episode became the starting point for an investigation of finding solutions for how to increase the productivity of the production process. An important aspect was that the craftsmanship must be preserved, while at the same time more efficient production methods, probably by adoption of new production technologies into the production system.

The project team analyzed potential customer groups, producability of the products, and ways to increase volume while preserving the brand image. A future factory solution was developed and a first step prototyped in 2008.

5.3 Second generation of cases

During the spring 2008 the second generation of product realization projects was carried out. Two industrial cases were chosen where a team for each where formed, consisting of complementing competences overarching the entire realization process. Each team worked through the idPeo-process for four months and consisted of 5-8 persons with a dedicated project manager.

5.3.1 Case B1

The project is based on creating and improving handling of assistive equipment for persons with functional disability. The starting point was a individual with a spinal cord injury. The project was built on using product development and design process tools applied on health care equipment. The project team analyzed current situation, solutions, and potential solutions. Some 150 ideas and focus areas were defined, where two were detailed as digital and physical mock ups.

5.3.2 Case B2
The company is larger automotive manufacturer with a need of visualizing information in the manufacturing environment. The project team developed a visualization system for relevant information in a manufacturing environment, on the basis of the user. For co-workers at the company this leads to increased understanding of the process as a whole as well as the individual activities. It supports process improvements, leading to motivation and understanding. For the company it leads to less defect rates, higher quality and increased overall equipment efficiency.

5.4 Third generation of cases
During the fall 2008 the third generation of product realization projects was carried out. Three industrial cases were chosen where a team for each where formed, consisting of complementing competences overarching the entire realization process. Each team worked through the idPeo-process for four months and consisted of 5-8 persons with a dedicated project manager.

5.4.1 Case C1
The company develops an electrical driven wheelchair system, with the purpose of enhancing participation and an active life style for persons with walking disabilities. The specific character is the ride comfort and terrain availability, solved through advanced hard- and software development. The project team analyzed potential users from a physical, cognitive and emotional perspective. The conclusion of this project was that freedom, flexibility and spontaneity are the biggest needs and what they miss the most. The company was provided personas that described three different persons with different needs and situation in life that the company could have for further development of the product and services around it.

5.4.2 Case C2
This project originated from one of the business incubators in the region and the product was a new instrument for improved performance and health by breathing the right way. The aim of the project was to find out how the product would look like and where the customer would wear it, a concept development project. By using the developed process the company received a concept of different places to wear it and new technical details they haven´t thought of before.

5.4.3 Case C3
This organization are working with a high risk project with massive media and engagement from government institutions and multinational enterprises, The aim of the entire project is to place a house on the moon. Our project started up as a communication project with the vision of making an exhibition of the project but developed to the need for teenager's information about technology and the need for new places to discover, explore and learn about technology. A new type of website will soon be released.

6 PROCESS DEVELOPMENTS
During the evolution of the idPeo-process over the case generations, some development areas are worth mentioning:

6.1 The development process
From a six-point, rather ordinary, project-phase scheme as it originated in the prototype project described in section 5.1, the idPeo-process has evoloved into a eight-step sequence. The eight steps are detailed with a specific concern to create an innovative and multi-competence using development process. The process is aimed at combining a formal delivery-focus with a flexibility and creativitity in its objective. It is not rare that initial objectives are changed during the development.

6.2 Support structure
The teams have a clearer support structure, both in terms of infrastructure as well as in senior mentors. An infrastructure in terms of lab environment and reference library is constantly under development in the university/industrial cooperation milieu. A more formal support from experienced coaches have been developed and will be further developed.

6.3 Project leadership

The project leadership has been strengthened and emphasized during the latest project generations. Delivery, budget and time plan are just some of the aspects that a product manager have to manage. Important aspects are to be able to communicate with different competences and visualize plan, objective and progress of the project.

7 CONCLUSIONS

This paper has discussed and explored an innovative approach towards innovative product development. To support the development of the next generation products and services within industry, it was concluded that there is a need to develop and implement new innovative methods and models that will support and strengthen industry to generate new ideas and realize these into successful products and improved processes. The need for a responsible process leader who can use the process with flexibility and make the team work together towards a common goal is of highest importance. The suggested model has been tested and proven. Further research within this area will for instance be the use of visualization during a concept design process that could be mapped upon this process.

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