NEW JOB ROLES IN GLOBAL ENGINEERING – FROM EDUCATION TO INDUSTRIAL DEPLOYMENT

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ABSTRACT
Product creation is facing the next level of fundamental changes. Global demands are growing substantially to achieve energy efficient and sustainable value creation networks for production, products and services without compromising traditional success factors such as time to market, cost and quality. To stay competitive within such an environment development partners in industry and public sectors will require new interplay solutions for engineering design execution, domain knowledge representation, expert competence utilization and digital assistance systems. Competition in engineering design is characterized by actors and stakeholders such as designers, engineers, OEMs, suppliers, or engineering service providers, by technical targets and economic factors within the field of application, and by higher level needs of regional and global environments and social equity. To face such challenges, new roles in engineering design have to be implemented in organizations and development projects. Otherwise new engineering design methods will lack deployment in industrial practice and finally fail. This paper addresses the need for selected new engineering job roles to deploy former made achievements in engineering design. The focused roles are “PSS Architect”, “Sustainability Mentor”, and “Virtual Product Creation Engineer”. Within the contribution requirements on teaching and the industrial deployment of the new job roles in a global engineering environment are presented.

Keywords: Engineering Design, Engineering Job Roles, Responsibilities and Competencies, Sustainability, Product-Service Systems, Virtual Product Creation, Education

1 INTRODUCTION

1.1 Characteristics of global Product Creation and Engineering

Globalization and international engagement of companies, segregation of markets, diversification, and verification of products, product-related service offerings, and contracting characterize today’s markets and trends. Networking engineers face an interdisciplinary development setup, complex development processes, and collaboration solutions, oftentimes distributed across company, country, and cultural borders. High *quality*, *time*savings, and *cost* reduction nonetheless remain being central targets in complex product creation processes to become or remain competitive, cp. [1].
Apart from that business oriented view global threats challenge competition in engineering design. W. Wimmer, for instance, provoked the engineering design domain at the DESIGN Conference 2008 by focussing on the three major threats “Climate change (Global warming)”, “Energy crises (Peak oil)” and “Food crisis”. There might be others but those three are tough enough to set hard design requirements in order to design more sustainable (product) solutions. It becomes more and more requested that design solutions (products and services) are sustainable, which in the words of the World Commission on Environment and Development [2] “meet the needs of today's generation without compromising the ability of future generations to meet their own needs”. Common sense is that the social, economic, and ecologic dimensions of sustainability have equal importance. Driven by politics, new regulations force companies to avoid hazardous materials and chemicals (see for instance REACH regulation) and inefficient working principles (e.g. sales-stop for conventional bulbs). To compensate the pressure, principles like “carbon trade” have been introduced. Moreover customers demand more sustainable solutions in selected societies and communities.

Private consumers and business customers request products and services in almost all life phases and situations. The degree of product and service consumption varies over time. Products and services are planned, engineered, produced, offered, operated, replaced and disposed in different types of business models and ownership conditions. Companies extend their product and service portfolio by "packages", which consist of combined or "integrated" products and services. Concepts like "Product-Service Systems" (PSS) become increasingly cited. Customers finally rather demand competence and solutions than ownership of products or service consumption. Thinking in "customer needs" and "added value" is vital to face this fact. Furthermore, PSS are considered a means to implement sustainability, cp. [3], [4] and [5].

Rising variety of products and service, customer oriented configuration, assembly-to-order process and the overwhelming complexity of technical systems integrating a multitude of technologies (for instance airplanes, ships, cars, plants, grid infrastructure, or distributed IT systems) drive a need for IT support in engineering design. Thus, IT penetration is rising enormously, reflecting the two opposites of the medal: (1) Engineers are relieved from batch work by automation and supported in many tasks. (2) The multitude of systems, which are not always well tuned/customized, hinders creative work and attracts two much concentration. Moreover, the amount of engineering methods rises continuously. New methods help designers validating their design alternatives in virtual environments before physical prototypes have to be build. CAD-Design, software programming, functional simulations, analyses of stress and strains (by FEM), computational fluid dynamics (CFD), or the use of virtual and augmented reality technologies for visual analytics and virtual validation are prominent examples. Process modeling and control, product data management, collaboration solutions and more request many IT skills of engineers today. Nevertheless, there is one characteristic dilemma: Lacking deployment of validated IT-supported engineering methods and tools in SMEs & broad variety and heterogeneous IT landscapes, including disliked IT solutions, in large-scale companies and groups.

Besides these challenges there is another fact of major importance. A new generation of so-called "digital natives" is now apt to enter universities and industrial practice. S.D. Eppinger established in his keynote speech at the DESIGN Conference 2010 the label "Generation Y" which addresses mainly the digital natives in engineering. Compared to older, experienced engineers such digital natives have different attitudes of information sharing, use of mobile IT solutions and acceptance or needs of permanently being linked to the world-wide-web and social networks like facebook. This, on the one hand, is an opportunity to exploit IT solutions more intensely. On the other hand, companies start to thinking how to attract such IT oriented generations.

1.2 Problem Statement & Motivation: Shortcomings in Organizational Structures

Successful application of new engineering design methods is not just a matter of their availability or customization to a specific branch or product type. To implement design methods and to assure successful application typically a driving "head" is needed. Such a "head" is a capable person in a company, combining competence (awareness, skills and authorization), budget, time and support (staff, acceptance, tools). To put in place such persons is a responsibility of a company in case it wants new management or design approaches deployed systematically and not by random.

A comparison with well-established processes shows that the aforementioned issues (mainly sustainability, PSS, and Virtual Product Creation) are not driven, controlled, or managed by dedicated roles. Companies have people assigned for quality, risk, issues, requirements management or processes specific engineering processes like car crash simulation. There are no people in most companies being assigned to trace sustainability, to plan and develop products and service integrated in a true Systems Engineering manner or to bridge the views of development engineers and IT administration specialists keeping IT support running.

To deal with sustainability, product-service systems and engineering IT applications in a quality matching the demands of global competition dedicated, committed roles have to be educated and put in place in industrial practice. The following sections give insight into specific tasks of such roles.

1.3 Research Approach

Basically, our work was motivated through experiences made in research an industry projects. Research on PSS and Sustainable Development has been carried out for several years and IT support in engineering is the core of our research projects. This contribution is a kind of statement reflecting experiences. Thus it doesn't base on a specific research methodology; it is a kind of finding that appeared between the lines.

2 NEW JOB ROLES AND COMPETENCIES

2.2 Sustainability Mentor

Importance of establishing a Sustainability Mentor

Values are created by society and politics forms the overall development. In this context, companies form strategic objectives to meet the needs of society and to fulfil political conditions. Therefore, they establish assessment criteria for product development projects (e.g. Key Performance Indicators) which will hopefully turn into success criteria. Apart from criteria that indicate whether customer requirements and laws and provisions are met the most important traditional criteria are development costs, development time and product quality within a company [6]. Due to that fact the competitiveness of a company is characterized by short time to market, low-cost and high quality innovation processes, whereas innovation in a narrow range is a matter of products or processes [7]. For that reason, companies deal with traditional parameters which are decisive for the outcome of a project and which stand to each other in direct competition as they consume the same resources [6]. Another important characteristic of successful product development is the development capability [8] or what we would call the ability of a company or a design team to develop innovative products. In a broader sense, innovation comprises organizational management, development process management, product distribution and resources supply [9]. Eventually, innovation is a matter of lifecycle thinking and values of a sustainable society [7, 10]. Figure 1 shows the development from traditional to future success criteria from a company's viewpoint thus the figure indicates an understanding of increasing product and process complexity.

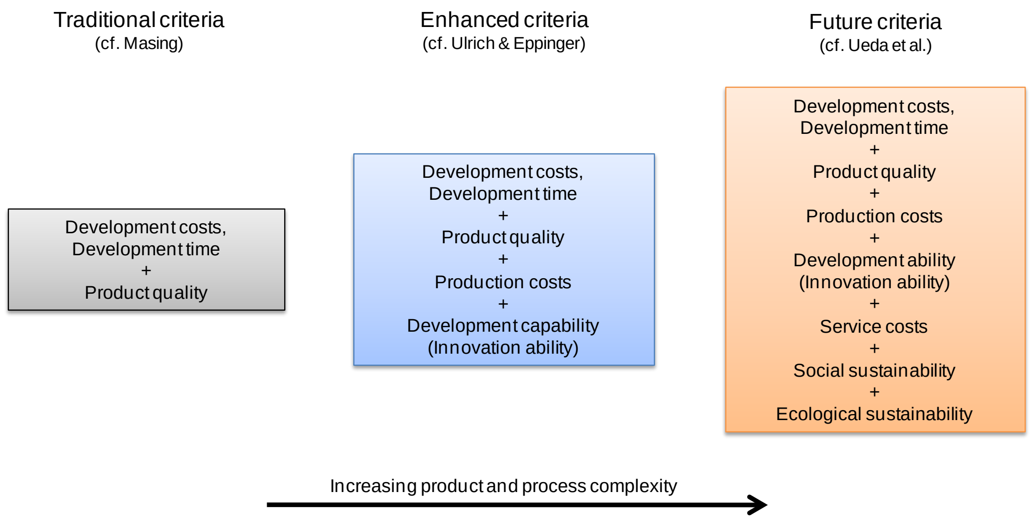

Figure 1: Development from traditional to future success criteria

Sustainability as a concept usually exceeds product development processes and is related to the broader sense of social, politic and economic development of countries and humankind. However, the term sustainability is also related to product development in the area of engineering and design. A large number of various tools and methods have been developed so far. They range from checklists and guidelines (e.g. material checklists, Eco-Design guidelines) to analytical assessment tools and integrated software systems (e.g. Life Cycle Assessment Tools). In this context, the following terms have been established: Eco-Design, Eco-Innovation, Design for Environment (DfE), Life Cycle Design (LCD), Design for Sustainability (DfS), Environmentally Conscious Design, Green Design etc. (cf. [11]).

Nevertheless, sustainability remains as a fuzzy concept. First of all, sustainability has no binding character. There is no actual statement on the distribution of benefits and burdens within companies and within the entire product life. Moreover, the concept of sustainable development is not suited for

guiding product development processes. Even if companies make commitments to voluntary codes and standards (e.g. Global Compact, Responsible Care), provide sustainability reports (e.g. Global Reporting Initiative) or if they are rated by third parties (e.g. Dow Jones Sustainability Index) there is usually no person in charge who has the authority to decide product development projects.
Although traditional parameters are monitored and even controlled, sustainable aspects are often neglected. The impact of sustainability on the traditional success criteria time, cost and quality is yet unclear. Research in this field leaves several white spots (cf. [12]). These are mainly the little practical relevance or testing of current tools and the weak linkage between the strategic aim of a company and the actual development processes [13].
However, there is a general public and political interest in sustainable issues and hence, due to ecologic and social as well as economic issues, a common shift in paradigm is resulting. Since previous job roles comprise only the traditional parameters new job roles like a Sustainability Mentor are needed to take future sustainability criteria aspects into account. The tasks and responsibilities of a Sustainability Mentor are described in the following as well as its position within an organization.

Skills, Tasks and Responsibilities of a Sustainability Mentor

Integration of corporate sustainability issues into product development processes

Currently there is no connection between the product manufacturers' sustainability reports and the actual development of their products. The major challenge in many product development projects is the deficiency in integrating sustainability issues into the context of product development processes. Due to this fact, four fields of information in corporate reporting can be distinguished:

- Company related information for internal use (sustainability targets, management reports)
- Company related information for external use (sustainability reporting to stakeholders and customers)
- Product related internal information (e.g. product policy, Life Cycle Assessment)
- Product related external information (e.g. mandatory product information, product declaration)

A Sustainability Mentor has to be aware of all four information fields and it is his responsibility to integrate and communicate the specifics of each product development project into the development process.

Derive design objectives from corporate policies and declarations

It is not always very clear which product features and characteristics are communicated to the customer sustainability information about a product. To remedy this situation a Sustainability Mentor has to derive design objectives and quality criteria from corporate policies and declarations. On the other hand, the Sustainability Mentor has to integrate specific project related sustainable aspects into design briefs and provide feedback to the strategy management. Hence, sustainable decision-making for both management and design would be increased and become more robust.

Increase the adoption rate of sustainability issues by designers and engineers

Design decisions made in the stages of product development determine the environmental, economic and social impact of a product at post product development phases. Therefore, it is necessary that engineers adopt a design paradigm shift from a focus on traditional cost and quality issues to a balanced future set of development issues which include sustainable issues as well. The Sustainability Mentor has to trickle down corporate sustainability issues to the design process. A consistent integration of sustainability issues into design briefs and quality objectives will improve the adoption rate by the designers and engineers. Furthermore, the Sustainability Mentor is responsible for the improvement of the company's sustainability tools and methods. Since available tools and methods are rather complex to use requiring specialized expertise and a significant amount of data input the Sustainability Mentor is responsible for training designers and engineers to work with these tools and methods. Additionally, he/she has to screen and select project relevant information and data.

Communication of objectives and reporting

Current approaches in supporting corporate declarations aim at improving the environmental information flow in their product creation chains. However, they do not provide eco-design modeling and decision making methodologies to reduce the environmental impact of new products and simultaneously achieve significant life-cycle cost reductions using the company and product sustainability information flow in a bidirectional way between reporting and sustainable design. As a result design objectives in most current practices are formulated in a narrow sense i.e. to only seek to fulfill applicable environmental legislation and directives instead of taking a proactive approach that will incur additionally a substantially improved competitive advantage, environmental impact and life-cycle cost reductions.

Position of a Sustainability Mentor within an Organization

A Sustainability Mentor is involved in every activity throughout the entire product development process and, additionally, is in charge of the different hierarchical positions. Due to his tasks and responsibilities he/she has to interact and communicate between different departments such as industrial design, engineering, styling, marketing and purchasing. This means a Sustainability Mentor needs, on the on hand, interdisciplinary knowledge of business activities and organizational structures and, on the other hand, specialized knowledge of engineering design methods and tools. In case of large companies and development projects, rather a team of Sustainably Mentors is needed instead of a single responsible person. The typical composition of a Sustainability Mentor Team should consist of a Sustainability Mentor leader and experts of all involved departments who act like key accountants or representatives. However, all people involved in the product development project have to become aware of the tasks and responsibilities of the Sustainability Mentor, in order to better understand the new job role and its principles. The Sustainability Mentor thus should be more a technical leader than a general manager.

2.1 PSS Architect

Importance of establishing a PSS Architect

Although research came up with methods for an integrated planning, development and operation of (foremost) industrial PSS some severe shortcoming hinder the deployment of PSS thinking and PSS design approaches. The situation in industry differs a lot from the state of the art in research. Academia still uses predominantly the concept of industrial Product-Service Systems (IPS^2), but it is widely unknown in industry. Nevertheless, solutions integrating products and services are attracting attention, as mentioned in the introduction. Many industrial equipment manufacturers consider themselves as solution providers, which essentially are offering solutions including products and services. However, the following shortcomings dominate the situation in economy.

- In general, there is a weak understanding of collaborative parallel / cross-linked development of products and services in industry.
- Multi-discipline interaction principles for successful coordination, cooperation, and collaboration in IPS2 development are rare.
- Service engineering approaches as already taught at some engineering chairs have not found their way to engineering and product creation processes.

In detail, this means that there is little service engineering in common engineering disciplines, at least in Germany. Real interdisciplinary approaches are missing and one might ask where and who service engineers are. There is a weak understanding of how service really does or has to affect a product’s design. So far, no consistent guideline helps to Design-for-Service (Checklists etc.).

Skills, Tasks and Responsibilities of a PSS Architect

The new committed role could be a “PSS Architect”, performing at least the following selected tasks.

Moderation of PSS idea generation and PSS planning

PSS design caters to be customer needs and value centric. The first step is to spread the proper mindset, before design tasks and methods are changed. The PSS Architect has to moderate workshops or trainings to plan PSS with customers and/or development engineers. He/she is a moderator and interface in a dialog between customers and development engineers. Important is that he/she is able to transfer PSS thinking to the “language” of the engineers. Often, there is a branch, company, or product specific terminology used that has few room for PSS issues as discussed in research. Thus, the PSS Architect has to find a proper level to introduce the PSS mindset.

Documentation and management of PSS ideas, requirements, and concepts
The PSS Architect has to document PSS ideas and concepts in a form that includes PSS relevant issues apart from technical requirements (cp. Figure 2). He/she has to assure that customer needs, expected customer values, lifecycle activities of the PSS and involved actors, main actors, core products, periphery (needed infrastructure), contract design, finance models, and the entire business model become captured in an adequate form. This is vital to identify the core elements of the future PSS and to break down the requirements form a system or value level to a deeper, domain specific level. Requirements on subsystems and components then will be considered by product designers, process designers or IT developers contributing to the future PSS.

PSS development project management
PSS are foremost carried out by networks of many stakeholders. The PSS Architect should manage component manufacturers, service and MRO (Maintenance, Repair & Overhaul) supplier integration. This is not trivial, because the project management can easily becomes multi-side, dynamic and thus complex.

Quality and PSS validation management
Tracing the requirements in solutions implemented has a higher degree of complexity than in normal product development. The PSS Architect has to trace whether the expected customer value is realized by the solution designed or not.

Such a role is missing so far. This hinders the PSS design method deployment, a holistic discussion of PSS ideas and concepts, and an adequate requirements and quality management. Such a role is necessary to implement a skilled project owner to drive a PSS development project.

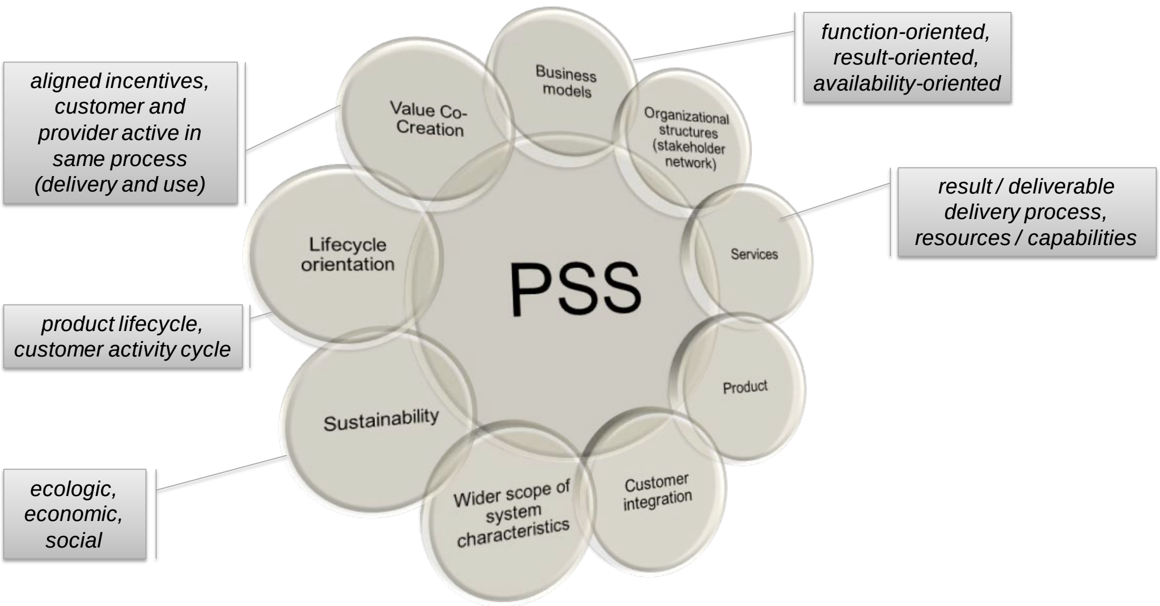

Figure 2: Issues related to PSS Design

Position of a PSS Architect within an Organization
The PSS Architect could be installed as a program or project manager. Compared to sales engineers he/she has to have a much deeper integration into development projects and requirements management. The PSS Architect should be a mentor and trainer to drive a transition of PSS engineering methods in running development projects to minimize the overhead of additional trainings etc. A detailed elaboration is given in [14].

2.3 Virtual Product Creation Engineer

Importance of establishing a Virtual Product Creation Engineer

Virtual Product Creation (VPC) addresses IT support for engineers and (project/program) managers in all lifecycle phases from product planning through development to virtual production planning [15]. Authoring, verification and validation are supported by modelling and simulation applications (CAD, CAE, FEM, MBS, CFD, etc.), project management software, collaboration systems and Product Data Management (PDM); *(abbreviations are explained at the end of the paper)*. Applications are integrated or merged and the variety of features is growing. The integration of virtual and real environments enables new ways of experiencing and validating product designs. Figure 3, for instance, illustrates a virtual real-time simulation of the physical interaction with a car back door. The person interacting with the virtual prototype has a haptic force-feedback interface. This is an example of cutting edge research achievements and showing that there are other competencies needed than "only" CAD or PDM knowledge.

Figure 3: Virtual real-time simulation of the physical interaction with a car back door

In industrial practice it is not unusual that particular groups of engineers just need some few functions of complex VPC systems. As there are many different groups collaborating on the same back-bone systems (e.g. a customized version of PDM Systems) such a system in total has to offer various functions from requirements management, over CAD integration, product structure management to resource management for digital factory applications. The users feel flooded by complex user interfaces and workflows not matching their particular engineering methods and thinking (e.g. platform design, bill of material structuring, requirements management). As such systems require global access and consistency, people managing IT infrastructures, system customization and installation have to find the least common denominator to set up a solution. This leads to a point where development engineers request particularly customized solutions (sometimes particular for their local group and design task) to remain competitive and where IT people at the same time fight back such claims. Reasons typically mentioned are high costs to implement and maintain specific features or that a realization would technically not be possible. It is not uncommon that engineers don't have deep knowledge about systems before they are deployed and at the same time software experts don't fully understand the engineers' needs. Virtual Product Creation Engineer, being familiar with the bandwidth of the most relevant applications, and understanding the engineers business are needed at this point. They are capable to understand the engineering methods in business and to understand at the same time the methods implemented in new applications. Such experts can help to find workarounds or transformation methods to bring together business and new IT solutions. Today, key user concepts are applied to fill this gap, but even though such key users usually have their familiar solution in mind and not the potential of new ones.

Skills, Tasks and Responsibilities of a Virtual Product Creation Engineer

The major task of such an expert is to track and trace new development of VPC applications and to bridge the views of users and IT administration and deployment teams. This means to "translate" the engineers' needs for the IT teams and to establish workarounds and methods for a successful use of new software features. Furthermore, the VPC Engineer has to take care for issues like transparency, traceability, interoperability, connectivity, security, reliability, and trust to moderate the discussion between user groups and software deployment teams. Another important task is to support decisions on segregation vs. integration of IT solutions and landscapes. The complexity of many systems leads to very tough programming for integration (e.g. after the merger of two companies). Even harder is segregation after a split of a company in two separated companies. A more design-oriented task is the planning, preparation, and execution of virtual validation and testing in specialized IT environments.

Position of a Virtual Product Creation Engineer within an Organization

Today there are few experts in place to perform the above mentioned tasks. Mainly consultants take over such tasks often being too far off from the engineers' daily business. Very specialized digital simulation and verification methods each are just applied by few highly specialized engineers having no "lobby" within their companies.

The new expert should be installed at a middle management level to consult upper level decision makers. This expert should have direct contact to development engineers in daily business and also with the IT teams. In case of deployment projects he/she should have a central role in decision making and solution development.

3 FROM RESEARCH TO INDUSTRIAL DEPLOYMENT

The coexistence of research and teaching has become an applicable model for universities all over the world. This coexistence is also known as the Humboldt's educational ideal and can be interpreted as the unity of research and teaching. This includes both the transfer of knowledge from the spirit of research and the idea of research-oriented teaching. In order to critically examine traditional bodies of knowledge and to advance learning students and teachers lively exchange knowledge and ideas.

In order to achieve this lively exchange of knowledge and ideas we integrated sustainability and PSS topics in our lectures and exercises based on Virtual Product Creation and Industrial Information Technology. In that way, Sustainability and PSS become additional views in design tasks for the students. Even though their primary task is to develop a product using cutting edge means of Virtual Product Creation they have to design for Sustainability and PSS, as well. This is an approach to let them feel how hard trade-offs in design are. It generates awareness and puts the students in charge. Figure 4 shows a typical design review situation where students have to present and validate their design solution in front of lecturers. To train what it means to represent a certain team role, the students have different tasks in their group work. Project managers, development process designers, industrial designers and development engineers can be typical roles working together in interdisciplinary groups.

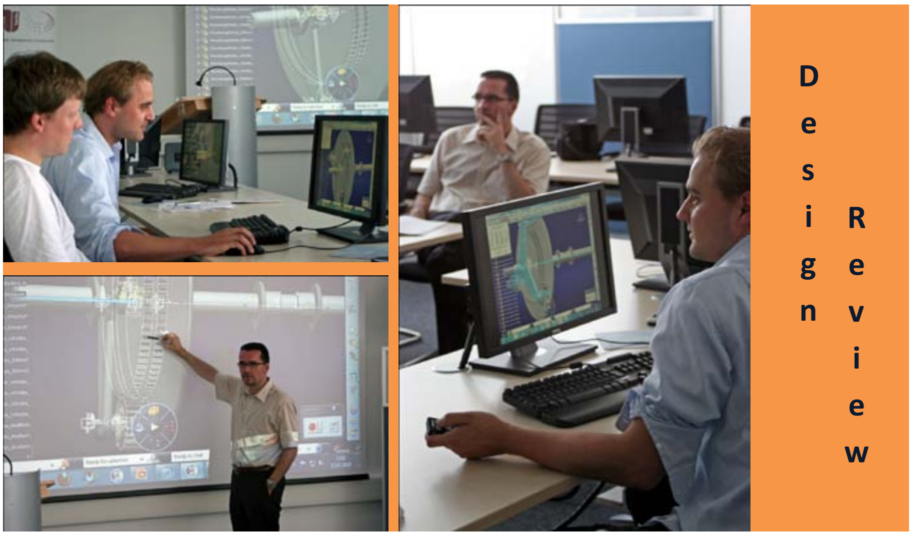

Figure 4: Design Review Situation

Teaching scenarios are built on today's industrial practice and prospects of future design offices (addressing the digital natives). Figure 5 gives an impression about the result a team of students worked out in four months. Given the environmental challenges faced by today's mobility systems, the task was to develop emission-free solutions for short-distance and inner-city transport of passengers or goods. Besides the basic requirements to be met by electric vehicles further factors such as the formation and storage of electrical energy and the vehicles integration into city logistics concepts had to be taken into account.

Figure 5: Student project for improvement of inner-city distribution of goods and parcels

To offer an adequate set up we built the Virtual Engineering Learning Center (VELC), a teaching and learning facility equipped with modular workspaces and high end virtual engineering applications. The facility can be reconfigured within a few minutes to train situations like group work, interdisciplinary design reviews or collaboration. Figure 6 provides an overview of the landscape of engineering applications which are taught and used in the VELC.

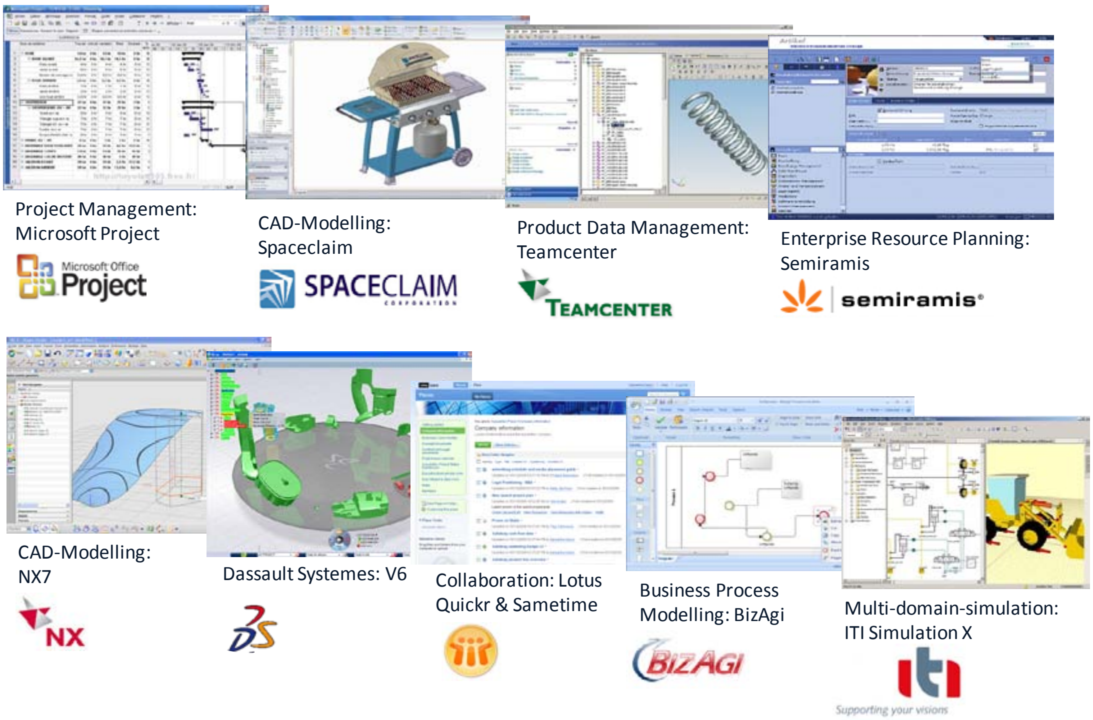

Figure 6: Landscape of Engineering Applications in the VELC

CONCLUSION, SUMMARY AND OUTLOOK

Against the background of sustainability awareness among customers and politics it is of growing importance to establish a person in charge of sustainability issues within a company. A so-called Sustainability Mentor who is following the tasks and responsibilities described in this paper can make significant contributions to both sustainable product development and corporate sustainability policy.

Due to the interaction between different departments throughout different hierarchical levels of an organization the education and training of a Sustainability Mentor represents a desideratum in research, which has to be investigated further (cf. [16]). To support PSS development in industrial practice and especially to deploy at least some of the manifold PSS design methods a PSS Architect would be a proper means. Companies should adapt this view to make the next step of product-service integration and to mature their offerings. To train virtual product creation high investments are necessary. Establishing our VELC was cost intensive but necessary and the students value this modern training facility and the teaching concept. As a next step, Sustainability and PSS should become committed elements in new curricula. We expect that mixed forms of such roles will appear in the future. For Sustainability and PSS, this would be "quasi-natural" form a research perspective as PSS is often considered being a means to implement sustainable, lifecycle-oriented solutions. The superior form could be a "System Architect" incorporating all three aforementioned roles and having additionally profound product knowledge. At least this role definition will depend on recent research results in the domains of Systems Engineering and Engineering of Systems.

SELECTED ABBREVIATIONS

CAD: Computer Aided Design; CAE: Computer Aided Engineering; CFD: Computational Fluid Dynamics; FEM: Finite Elements Method; MBS: Multi Body Simulation: PDM: Product Data Management; PLM: Product Lifecycle Management; PSS: Product-Service Systems; IPS^2: Industrial Product-Service Systems; VR: Virtual Reality; AR: Augmented Reallity.

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