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The Consolidation of Design Science – A critical review of the status and some proposals to improve it

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1. Introduction

Since the mid-sixties Design Research has developed rapidly. Numerous contributions have been published in seminars, workshops and conferences, such as the ICED-conferences. At the latest, when globalisation became a major drive for the worldwide co-operation of Design Researchers, it was hard to keep an overview of the various approaches. Rare attempts were carried out to define a holistic fundament of Design Science as a basic structure of research approaches [1], but still the diversity of views and approaches and the specialisation of research work continued to grow. The current status of Design Research and the work contents of Design Researchers appear to be extremely fragmented and no endeavour at harmonising them can bee seen.
When the International Organisation *"the Design Society"* was founded in 2000, the specific objective of consolidation was written in its constitution. "The objective of the Design Society is… to create and evolve a formal body of knowledge about design" [2]. Since that time, the consolidation issue has been discussed and a small group of colleagues undertook different attempts to address this topic and to raise awareness for it in the Design Research community. First, in the AEDS-05 workshop and some months later in the Design Society's joint meeting of the Board of Management and the Advisory Board in Heraklion/Crete in March 2006, the topic of consolidation was explicitly addressed in written contributions. The boards decided to run an appropriate workshop prior to the conference DESIGN 2006 in Dubrovnik/Croatia in May 2006. This workshop was organised under the auspices of the Special Interest Groups "Applied Engineering Design Science" and "Design Theory and Research Methodology" and managed by Christian Weber (University of Saarbrücken, Germany) and the author.
This contribution summarises a critical view of the current situation presented by the author in previous contributions [3], the outcomes of the various meetings mentioned above and some proposals and ideas from the author on how to go forward on the long, steep and stony road towards a consolidated framework of Design Science.

2. An attempt at clear terminology

Talking about current deficits and desirable improvements within the body of knowledge, methods, tools, procedures, and rules in the area of design needs some clarification, especially if the topic *science and research* should be addressed. The following explanations do not intend to have the rank of definitions (they should be considered one "paving stone" on the consolidation road); rather, they represent working hypotheses that could prove useful for a better understanding of this contribution.

- *Design* is the (mostly complex) process of consciously creating models of artefacts (products or processes) which may be produced for use by customers. Design can be done in all spheres of human life, but is usually done professionally by designers in an industrial context.
- *Design Methodology* is a body of knowledge (like a repository), which comprises all rules, methods, tools, working aids, etc. to support the improvement of efficiency and effectiveness in professional design. Design Methodology is always application-oriented by nature; otherwise, the criteria of usefulness would not fit in.
- *Design Science* is the scientific fundament of Design Research (procedures, products and all related models). It is a body of knowledge which has to be founded on a theory (or theories). The theory(ies) can be proven by evaluation procedures using criteria, both of which must be accepted within the community of Design scientists. Procedures and criteria are not necessarily equivalent to those of other scientific disciplines, e.g. natural sciences, due the specific nature of Design Science.
- *Design Research* comprises all processes that produce knowledge, method, tools, models, characteristics, etc. by scientifically performed research work. Unlike Design, the output of Design Research is not models of artefacts but a body of knowledge about artefacts and/or related processes. Design Research can be done without any intention of application. It may be driven by pure scientific curiosity or performed with an interest in certain applications. A characteristic of Design Research and another difference from design itself is the generalisation of its approaches, which may of course be specialised to support design work according to a certain task or a specific design situation.

Based on these concepts, the following remarks should be taken note of.

3. Critical review of the current status of Design Science

Taking the view from outside (e.g., scientifically interested designers in practice, undergraduate or graduate students, Design Researchers at the onset of their research work), Design Science and the outcome of Design Research do not at all seem to be homogeneous and harmonised.

3.1 The rampant growth of definitions and models

Differences in Design Research become obvious when researchers try to find commonly agreed to definitions from their investigations of the literature. The lack of harmonised terms refers to terms defined long ago as well as current definitions like “upgrading” (figure 1)

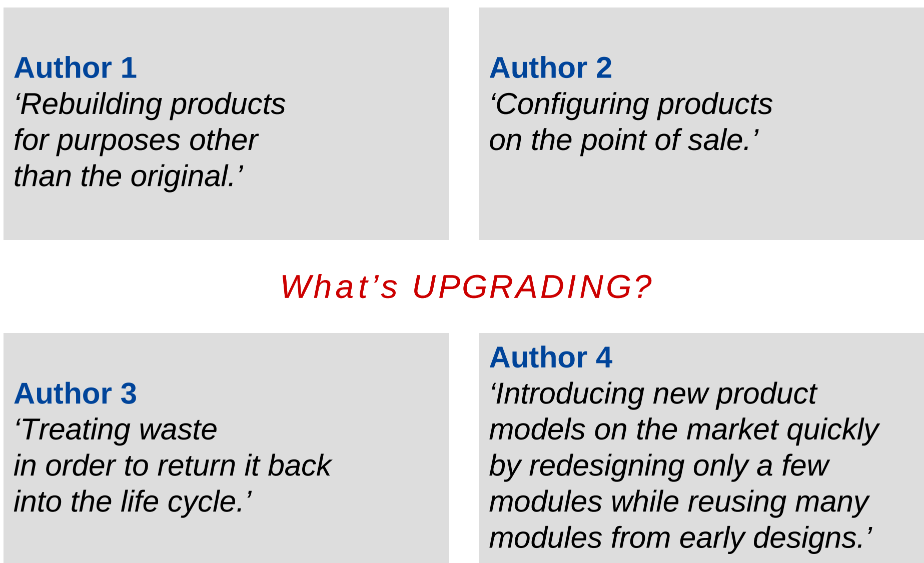

Fig. 1: Four definitions of upgrading

Although upgrading is an important term used within the context of life cycle design, the definitions do not match up at all. Rather, they mirror quite different views based on different aspects of upgrading and the different disciplines of researchers.
Analogous to the variety of contents one has to claim about a variety of styles, content is presented (figure 2)

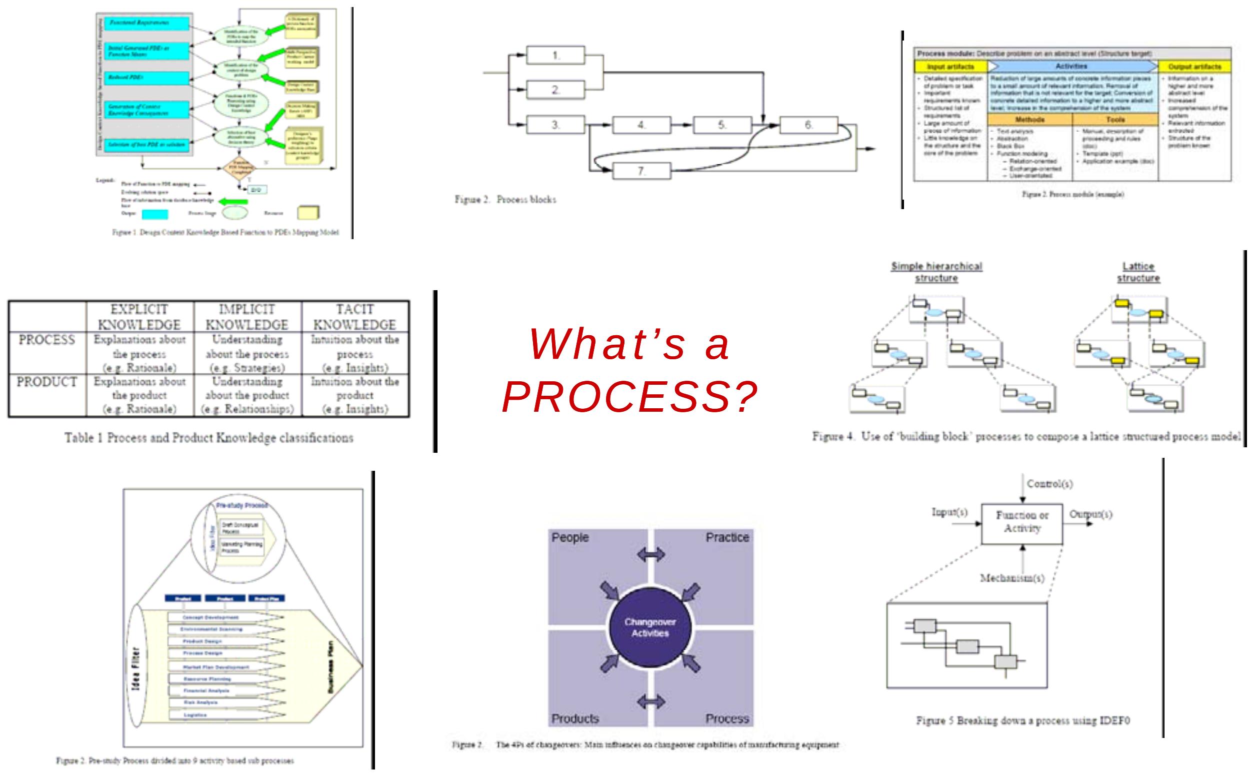

Fig. 2: Some illustrations presenting process models

Of course a specific content, such as a process, may be presented in different representations, e.g. flow charts, matrices, sequences of pictures. But compared to the presentation of models in mechanics, thermodynamics or electronics, for example, we have a distinctive lack of commonly agreed upon model representations in Design Research. This could emphasise the heterogeneity of the underlying concepts.

3.2 The uncontrolled proliferation of research subjects

The world is developing rapidly at a pace that seems to increase continuously. The same is true of design: products and areas of activities increase; new technologies arise and result in the adequate evolution and dramatic growth of research areas. As a kind of mirror the evolution of Design Research subjects may be seen in the larger context of the evolution of Design Research since the mid-sixties (figure 3).

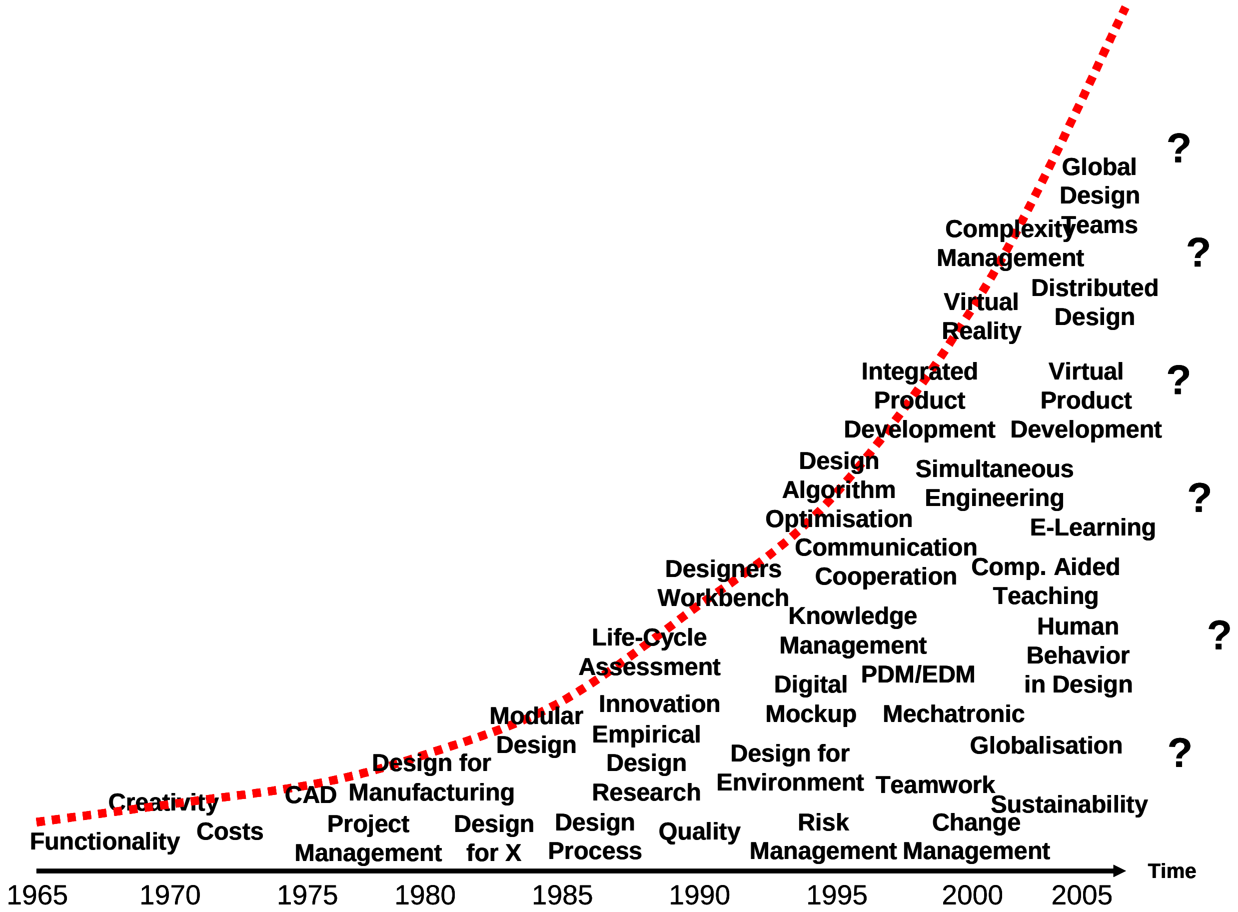

Fig. 3: The evolution of Design Research subjects

There seems to have been an explosion in the variety of subjects, which indicates a fragmentation of working fields and the fostering of poorly linked approaches. Perhaps driven by the explicit interest in innovative research subjects, or by the need to find funding for a true scientific innovation, there is a strong tendency among researchers - not only in the field of Design Research - to set off against competing researchers and stake out one's own research claim. Working in an isolated community and carrying out research in one's own hemisphere, not being bothered by outside communities or approaches is sometimes considered much more attractive than struggling with attempts at consolidating various definitions and approaches.

3.3 The diversity of conference topics

As a result of the increasing variety of subjects in Design Research, the topics dealt with in workshops and conferences vary enormously. Even global conferences like the International Conferences on Engineering Design (ICED) present a quite different set of conference topics over time (figure 4).

ICED 97	ICED 99	ICED 01	ICED 03	ICED 05
BBM	Acquisition of Knowledge	Aesthetics and Quality Methods	Change Management	CAD Tools
Computer Based Design	Artifact Theory	AI-based Methods	Collaborative Design	CAD Tools workshop
Design Education (DE)	Best Processes	Analysis for Design	Collaborative Working	Design Cognition
Design for Life	Communication, Cooperation	CAD	Computer Based Sketching	Design for Better Products
Design for Maintenance	Competitive Products	Complexity Management	Concept Modeling	Design for the Future
Design for Production	Computer Aided Teaching	Computer-aided Learning	Creating Product Families	Design for X
Design Process	Creativity and Innovation	Conceptual and Specification Phase Tool	Design in Industry – Methods Transfer	Information Management
Design Research	Design for Environment	Concurrent Engineering	Design Management	Design Planning and Thinking
Design Science	Design for X	Creativity and Innovation in Teams	Design Process Dynamics	Eco-conscious Design; Green Design
Global Engineering Network	Design Issues	Customer-centered DFE	Design Process Research	Engineering Design, Allied Disciplines
IMS-Global Research	Design of Product families	Design Education	Design Research	Engineering Design Tools with CAD
Knowledge Systemisation	Design Process	Design for X	Design Teams	Engineering Design - Mechatronic
Next Generation Manufact.	Design Process Theory	Design Teams	DFM, Costing	Failure, Risk and Uncertainty
Product Development	Designers Support and Training	Design Theory	ECO Design - How Do We Make It Happen?	Functional Design Analysis
SDS	Designers Workbench	Design Theory and Methodology	Educational Experiences	Global Design Teams
Theory of Technical Systems	Developing an New Product	Design Training and Industrial Education	Educational Practice	Global Design Teams (Research)
Oriented Innovation Strategy	Education	Distributed Design/Supply Integration	Engineering Design Programs	Global Design Teams
World Class Design	Empirical Studies	Domain Design - Medical	Engineering Design Research	Innovation Systems
	Enabling Technologies	Ergonomics and Human Factors	Engineering Education Philosophy	Knowledge Management
	Evaluating Engineering IT	Features	Evaluation, Optimisation, Decision Making	Long Term Issues in Design
	From Information to Knowledge	Functional Modelling	Industrial Design Engineering	Long Term Issues workshop
	Genetic Algorithms	Industrial Case Studies	Industrial Engineering, Methods and Tools	Managing the Design Process
	Handling Variants, Product Families	Information Managment	Information Retrieval and Reuse	New Product Development
	Human Innovation	Integrating Environmental Considerations	Inform./Knowledge Capture, Transfer, Use	Produkt Families
	Individual- and Teamwork in Design	Integration	Innovation	Development in Design Education
	Innovation Methods	Introduction of Methods into Industry	Innovation and Customer Demands	Professional Development workshop
	Innovative Products	Knowledge Management, Representation	Knowledge Management Reflection Learning	The Practice of Engineering Design
	Integrated Product Development	Learning Environments for Education	Knowledge-Related Design Theory	Tools for Design Innovation
	Knowledge Bases / Fuzzy	Life-cycle Assessment	Management of Complexity	Tools for Improving Design Process
	Knowledge Handling	Management Issues	Methods Application	
	Knowledge Management	Management of the Clarification Phase	Methods: Design Knowledge and Information	
	Machine Element Education	Material and Component Selection	Model Based Configuration	
	Man-Machine Interaction workshop	Models of Design Processes	Modularizing Products	
	Methods and Models	Modular Engineering, Product Platforms	Performance Assessment	
	Modeling	Modular Eng. - Industrial Case Studies	Procedures, Selections and Methods	
	Philosophies and Visions	Modular Eng. - Product Families	Product Conceptualisation	
	Plenary Sessions	Multi-criteria Optimization	Requirements, Specifications	
	Product Development	Nature and Philosophy of Design	Safety, Risk and Reliability	
	Product Modeling	Optimization	Student Projects	
	Proficient Designers	Performance Evaluation	Sustainable Design - Assembly, Disassembly	
	Representation of Knowledge	Product Data Management	Sustainable Design - Methods an Tools	
	Research, Methodology and Theory	Project Management	Sustainable Design, Legislation	
	SE and CE	Project Strategy and Management		
	Structuring - Configuration	Quality Methods		
	Systematic Design in Practice	Reflective Practice		
	Teaching Design	Research Methodology		
	Theory of Technical Systems	Risk and Uncertainty Management		
	Virtual Development	Sketching/Vague Models		
	VR in Product Development	Sustainable Design		
	Web-based Design - Globalisation	Virtual Reality		

Fig 4: ICED topics (partial listing) of the last five conferences with highlighted topics occurring more than once

The obvious diversity of topics indicates a lack of co-ordination and guidance. National or cultural preferences of the local organisers influence the choice of conference topics and the programs are not absolutely free from fashions and lifestyles. These individual characteristics of a conference program may not be seen as a weakness. It emphasises the currentness of the topics addressed and the specific interest of the organising university or host country. However, from a customer-oriented view (researchers who contribute), the variety and discontinuity especially of global conferences has to be regarded critically.

3.4 The influence of local and national preferences

It is also obvious that local or national preferences influence the research map within a country or a region. As one aspect of these preferences, the wording used in conference papers by members of different countries was analysed (figure 5).

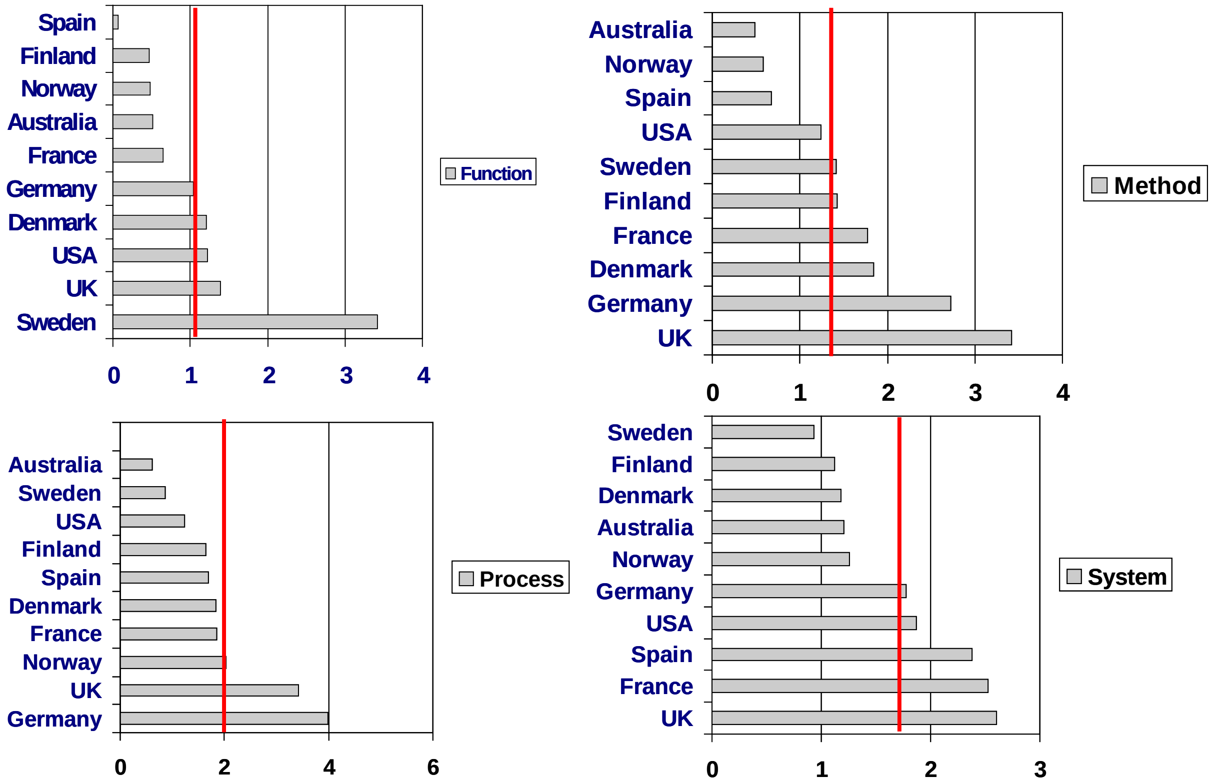

Fig 5: Most frequently used terms in different countries – an analysis of all ICED 05-papers

The frequency of used terms according to the author's affiliation differs substantially and mirrors the influences of local and national culture, industries, Design Research attitudes and schools, as well as science traditions. In terms of research, this may even be regarded as strength, but in regard to the vision of a true global Design Science, it also involves substantial complications.

3.5 The weakness of the scientific fundament

Last but not least, if one has a look at the scientific fundament of Design Research and compares Design Science with the so-called "true" or "pure" sciences, such as mechanics or thermodynamics, the weaknesses and deficits become obvious (figure 6).

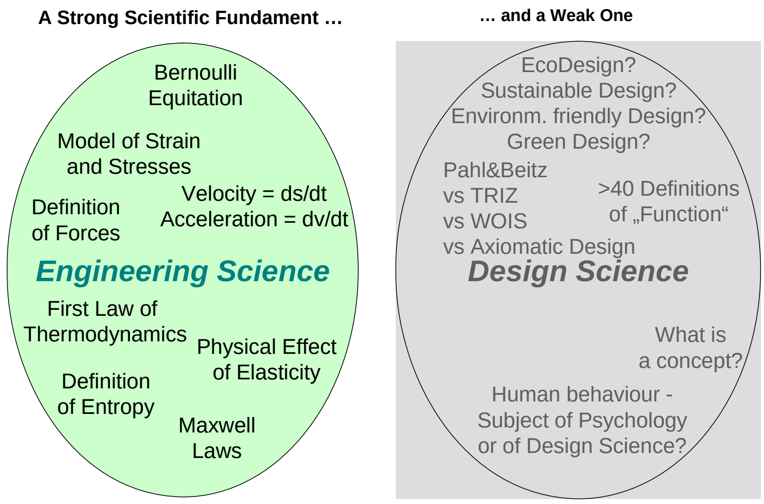

Fig 6: Comparison of the scientific fundaments of engineering science and Design Science

Even if it is claimed that engineering science developed over several centuries, whereas Design Science in its current status is mainly based on the work of the last 40 years, there is quite a lot of vagueness, ambiguity and variety in the models, terminology and ontologies of Design Science [4]. While imagining the work of especially young researchers starting with their research and looking for a strong and commonly accepted fundament for their own research, a huge amount of time and effort will be wasted on investigations. The outcome will probably be another island of research added to the thousands of existing ones.

3.3 Summary of the current status

As this picture of deficits and weaknesses addresses only some key points, it has to be assumed that it reflects only the "tip of the iceberg". Many more differences and obscurities can be seen "under the surface". In summary, the deficits and weaknesses mentioned above may be seen as characteristics of a rising but unripe technology. In coming up with new technologies, e.g. aircrafts, cars, engines and computers, a large amount of variants were sometimes created resulting in strange things. Due to the lack of knowledge and experience, variants are developed mostly by trial and error, and due to their weaknesses, most of them are born quickly and die fast.

There is no doubt - and this has to be emphasized here - that Design Researchers' work and Design Science on the whole seem to be in a kind of pre-scientific state. And, if this conclusion is accepted and understood, then the question that should be asked is: Is current Design Science really a science?

4 Findings of the latest workshops and discussions

Especially the joint meeting of the Boards of the Design Society and the subsequent workshop prior to the DESIGN 2006 conference gave a first impression of how the topic *consolidation* has been regarded and estimated within the Design Science community.

4.1 The assessment of the current status

It was generally agreed among the participants that the current state of Design Science and Design Research has deficits and weak points:

- Many approaches to design theory
- Fragmented world of Design Research and Design Researchers
- Disharmonic terms und subjects
- Poor referencing
- Dynamic change of topics and research areas
- Huge enlargement of research areas, e.g. in terms of computer support, mechatronics or adaptronics
- Severe gaps between the offerings of universities and the needs of industries

Valuable insights were articulated to the effect that Design Science encompasses a huge area of product and process modelling, and therefore has to include organisations, companies, branches and market aspects in its holistic view. A specific characteristic of Design Science is its integration of the actions and behaviour of human beings (designers, engineers, customers, etc.) in its scientific framework. Unlike engineering sciences, Design Science is a true "Action Science", which also has to deal with all the influences of humans on design work.

Besides the criticism, there was also a reasonable consensus among the workshop participants:

- The common core of understanding is quite bigger than it seems at first glance
- The consolidation of views, terms, etc. should be pushed, because it provides benefits for all
- But "consolidation" does not mean "unification"
- To clarify the relationships/references between different approaches and terms used in their contexts would be very valuable

- The consolidation of terms cannot be achieved by only focusing on linguistic aspects. It has to take into consideration the context of a theory (models, views, approaches, etc.) in which the terms that are derived are used.

A further and for the purpose of consolidation valuable contribution mentioned that gaps exist in all areas. A body of research without gaps is fiction. This remark represents a realistic estimation of what can be expected and achieved by consolidation.

4.2 Proposals on means of consolidation

Whereas the description of the current state was quite homogenous and quickly led to a remarkable agreement, suggestions for achieving better consolidation required a lot of discussion and were quite inhomogeneous:

- Build a world-wide but small core team of experts to make an action plan.
- It could be a task of the Design Society Special Interest Groups (SIG) to contribute to consolidation in their fields.
- Write joint keynote papers at conferences (e.g., DESIGN conferences in Dubrovnik, ICED conferences), which discuss and compare theories.
- Publish an annotated list of the most influential books and papers in the field (the realisation of this proposal already began at the DS's joint AB&BM meeting 2006 and has been published on the Design Society's web page).
- Enhance web-based discussions (Wikipedia-like system?)
- Progress in the field of Design Science with a bottom-up (case stories) and top-down approach (theoretical approach).
- Work out the customers, the benefits of a consolidated Design Science. What should be the goal?
- Try to answer the question: What should students be told about design(ing) in an optimally structured series of lectures? Especially: What should be said to them at the beginning of the first lecture?
- Use case stories as a "marketing instrument".
- Try to make progress by simple step-by-step approaches.
- Try to automate design processes using simple examples (e.g., a spring).
- Determine the shortcomings and flaws of theories when an attempt has failed.

The proposals reflect the "indecisiveness" of researchers in how to handle the weaknesses and deficits of current Design Research. Even though the deficits and weaknesses are well understood in themselves and the need for a consolidation is even moderately pushed forward, the problems in doing so appear as gigantic as the impact of every single researcher appears limited.

5 How to tackle the muddled situation – some individual remarks

Being involved in numerous discussions and presentations about consolidation, there is no precisely defined procedure in the author's mind on how to progress, other than an idea of the "general feeling" of interested researchers and a kind of suspicion of what may be practicable and what not. The following proposals should be understood more as discussion topics rather than steps of an elaborated consolidation procedure. They especially integrate many hints and proposals mentioned from workshop and discussion participants.

- Start with a carefully carried out analysis: Consolidation is a task with little glamour and a lot of resistance and difficulties. Therefore, a realistic estimation of the chances and risks has to be carried out before any consolidation objectives are formulated and any means decided. Similar to an ABC-analysis, the main topics in which consolidation appears successful should be carefully analysed to ensure the success of first attempts, even if these seem to promise only limited progress. At the same time, a consolidation project should be handled like an industrial project. As one has to expect a huge amount of work, set backs and frustration, the questions "Who are the customers of consolidation?" and "What are the benefits for them?" should be answered as carefully as possible.

- Go forward step by step. Considering the complexity of the research area, the diversity of influencing factors and the influences on design, the great amount of approaches and views, nobody can expect a holistic or fast solution. A persistent approach to progressing forward with small steps towards a consolidated Design Science seems to be much more promising than trying to achieve "the great success".
- Use the strength of co-operation. Consolidation of such a heterogeneous and dynamic area of science is a task not for individuals but for communities. Basically, there is a dilemma concerning individually carried out approaches of generalisation and consolidation. They are highly appreciated by researchers at the beginning of their scientific career, but the huge amount of valuable insights, definitions and remarks are neglected or even ignored when the same researchers progress with their careers. It is not malevolence; this happens on a daily basis, but it is the culture (nature?) of science and the culture of funding that forces researchers to be unique. Innovation is asked, not consolidation, which demonstrates weaknesses and deficits to a public expecting success and progress.
- Take advantage of the community. To motivate design researchers to work on the field of consolidation, the benefit for the people doing that has to be regarded, as well. A strong group of researchers making substantial progress in terms of consolidation and publishing the results (accounted for by their authors') worldwide could be a major motivation to join such a group and to associate oneself with the success of those results. Since a true global community met under the shelter of the Design Society, at last the chance to do so has substantially increased. This chance increased even more by initiating and founding the Special Interest Groups (SIGs), which focus on important research areas within Design Research. This could well be the most promising approach towards consolidation (figure 7).

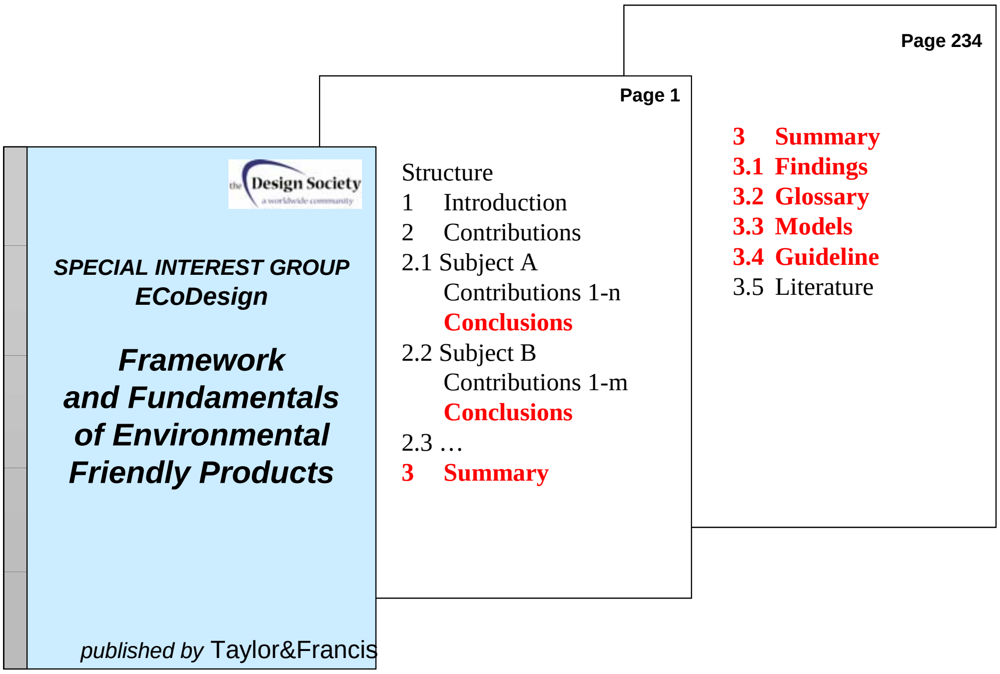

Fig. 7: Special Interest Groups as a key-factor in achieving consolidation within (limited) fields of Design Science

In addition, it has to be seen that especially young researchers are eager to be involved in such a development and are able, due to their lack of prejudice, to contribute substantially to the development. It might be discussed if PhD-seminars, such the ones coached by Lucienne Blessing and Mogens Myrup Andreasen, could be an additional and supporting element in the system of progressing consolidation.

5. Summary

The proposals mentioned above are not well elaborated; they may be weak, unrealistic or even utopian. The resistance and the difficulties of realising consolidation in Design Science are indeed overwhelming. Nevertheless, it is a good tradition in research to analyse the status, draw conclusions in regard to existing deficits and weaknesses, and create perspectives for improvements. As long as these perspectives are not proven unrealistic or even impossible, in principle I do not believe that design researchers should be allowed to neglect the current weaknesses and return to the "day's agenda". And to all those, who like to surrender, referring to the gigantic problems of consolidating Design Science, I would like to answer with the French saying: "Qui s'excuse, qui s'accuse!

Acknowledgement

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