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Transition Design

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1. Introduction

Sustainability Transitions are conceptualized as grand challenges that require radical change, as it is stated in the first paragraph of the most recent version of the research agenda of the Sustainable Transitions Research Network:

> The starting point for transitions research is the recognition that many environmental problems, such as climate change, loss of biodiversity, resource depletion (clean water, oil, forests, fish stocks), are grand challenges, which relate to unsustainable consumption and production patterns in ***socio-technical systems*** such as electricity, heat, buildings, mobility and agro-food. These problems cannot be addressed by incremental improvements, but require shifts to new kinds of ***systems***, shifts which are called 'sustainability transitions'... Therefore, a central aim of transitions research is to conceptualise and explain how radical changes come about in the way societal functions are fulfilled (Köhler, et Al., 2017). ***(Emphasis added).***

In one sentence thus: sustainability transitions require radical socio-technical changes at the systemic level. What professions are prepared to educate the needed experts to create and support these ambitious, big scale, long term, radical transformations? What kind of expertise is available to be put at the service of sustainable transitions? Or, is it necessary that, as a community of scholars, we too acknowledge that the dramatical unsustainability of current socio-technical systems is mirrored in the incapacity of existing professions and expertise to even imagine a radical way out and, therefore, we should be thinking how to create new professions and expertise? Is it necessary to produce new experts capable of facilitating new ways of collaboration among professions and across current sectorial divides?

To contribute to the emerging discussion of these questions, this paper discusses the following specific questions: How can design and engineering approaches contribute to whole system transformations? Can we apply existing design and engineering approaches? Or, is it necessary to transform these professions in order to prepare new types of practitioners that are able to understand and tackle the socio-technical, the systemic and the long term core aspects of sustainability transitions? To address these questions, the papers is organized as follows: first, we review the most recent literature on how can design and engineering contribute to sustainability transitons. Second, we present a current experiment called Sustainable Design Engineering at Aalborg University. And third, we conclude by outlining what we propose are the main shifts in knowledge and educational training of professionals needed to live up to the ambitions outlined by the STRN community in their research agenda.

2. Current Engineering and Design

Engineering

We claim that current engineering and design professions are not prepared to tackle sustainability transitions. Engineering in particular is uncapable for two reasons: the first, is that engineering professions are extremely focused on the technical aspects of any system and many specialities are conspicuosly intrasectorial and determined by historic domains of practice; the second reason, is that engineers around the world have to achieve competency in natural sciences and engineering sciences before they are exposed to problem identification and open design tasks and if they are lucky, to socio-technical challenges to engineering science. Even those specialities within engineering that do take up some kind of serious systemic approach do it as a tool to handle complex technical decisions.

The literature accounting critically for engineering education claim that these overemphasise problem solving of oversimplified quantitative problems with only one correct answer is extensive. To quote a publication from this year, John Leydens and Juan Lucena (2018) explain that the engineering curriculum is mismatched because

> ...Sputnik-catalyzed curriculum place primary emphasis on the engineering sciences and core math-based scientific foundational courses, with considerably less emphasis than previous engineering curricula on hands-on engineering design or humanities and social sciences scourses. (Leydens and Lucena, 3)

They go on to qualify that there are efforts to bring back into the curriculum opportunities for experimenting with socio-technical problem definition and solution. They are referring to engineering design, which is and should be the very soul of the profession...

> Unfortunately such courses are a small part of the overall curriculum, and research suggests that -in part due to the problem solving methods inculcated in the real science- students do not see them as “real” engineering. Furthermore, design courses suffer from the “kitchen sink” effect: they are loaded with meeting multiple assessment benchmarks. (Leydens and Lucena, 7)

In the United States this means meeting the program outcomes of the Accreditation Board for Engineering and Technology (ABET) that normally assesses engineering program in light of future challenges including climate change mitigation, sustainability and social justice. Although well intended, the ABET criteria are only attended in design courses which amount for less than 10% of most engineering curricula. This means that any attention to the practice of engineering as a socio-technical innovative engagement is marginal to an education that otherwise is entrenched in training innovators by focusing exclusively in existing established knowledge in the most deterministic parts of natural sciences and the engineering sciences. Dispite the emphasis on high tech topics in the advanced topics of engineering curricula these are from the outset reproducing the idea of an instrumental technical realm that is independent of social and in broader terms sustainability challenges.

Clive Dym, Alice Agogino, Ozgur Eris, Daniel Frey, Louis Bucciarelly and Larry Leifer, leading figures in the are of Engineering Design, in the United States had identified the same problems already during the 1990s where the first attempts to bring design topics back into engineering were articulated. After reviewing some of the by the time most recent efforts to bring back design into engineering education the following conclusion is illustrative stating that

> the most important recommendation is that engineers and academe, both faculty members and administrators, make enhanced design pedagogy their highest priority in the future allocation decisions. (Dym et. Al. 2005).

This has not happened in engineering as whole neither in the United States, nor in Europe. In part because what is required to re-incorporate and improve a focus on design, even in design engineering, might be at odds with the current paradigm of engineering education.

Dym et. Al. discuss the following skills engineers should be trained in order to handle innovative design:

- Tolerate ambiguity that shows up in viewing desing as inquiry or as an iterative loop of divergent-convergent thinking;
- Maintain sight of the big picture by including systems thinking and systems design;
- Handle uncertainty
- Make decisions
- Think as part of a team in a social process; and
- Think and communicate in the several languages of design. (Dym et. Al. 2005: 104)

Discussing in more detail the need to train students in system dynamics, they also recognized how difficult this is and the need for innovative approaches to it. In particular they noted that training in quantitative modelling of system dynamics (for example modelling electronic circuits or water circuits), could improve students' ability to tackle some system dynamics, but that they remained limited in their ability to "reason qualitatively about feedback, stocks, and flows in systems" (Dym et. Al. 2005: 106). Additionally, they claim, engineering "curricula greatly underemphasize the application of probabily and statistics in engineering...making estimates...and conducting experiments" (Dym et. Al. 2005: 106).

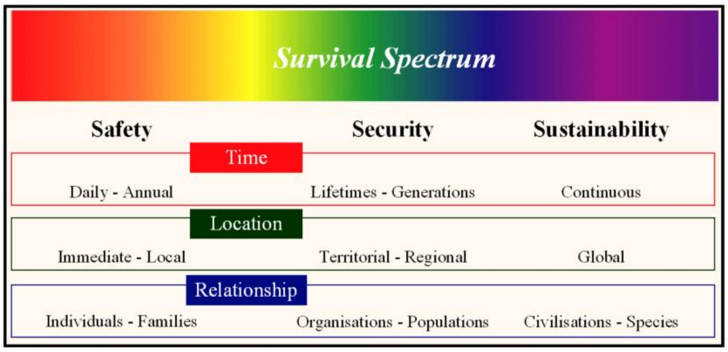

Figure 1: Continuum of safety, security and sustainability (Krumdieck, 2013: 315)

In a novel and thought provoking approach, Professor Susan Krumdieck from Canterburry University in New Zealands, proposes that "Transition Engineering is the research and application of state of the art knowledge to bring about changes in existing engineered systems in order to improve the odds of survival" (Krumdieck, 2013: 318). Sustainability is, thus the natural evolution of safety to security to sustainability in time and scale, as illustrated in figure 1.

For Krumdieck, and her colleagues of the Global Assocciation of Transition Engineers (http://www.transitionengineering.co.nz), tackling transition challenges can be achieved building on the succesfull example of Safety Engineering which exhibits a particular mix of being motivated by "public outrage over a preventable tragedy", which triggers "safety changes and adaptations which are not economic or market driven". Additionally, she underscores that "safety regulations came *after* safety engineering standards" (emphasis on the original) and that "no one asks, 'what do we mean by safety?'" (Krumdieck, 2013: 318).

The particular method of making operational the application of Transition Engineering is nevertheless, not clear. On one hand she claims that "accurate modelling and communication by Transition Engineers who find ways to include complex systems connections in their risk-benefit analysis will be vital to the successful adaptation of our activity systems in this century". On the other, she outlines a 7-step method as illustrated in figure 2.

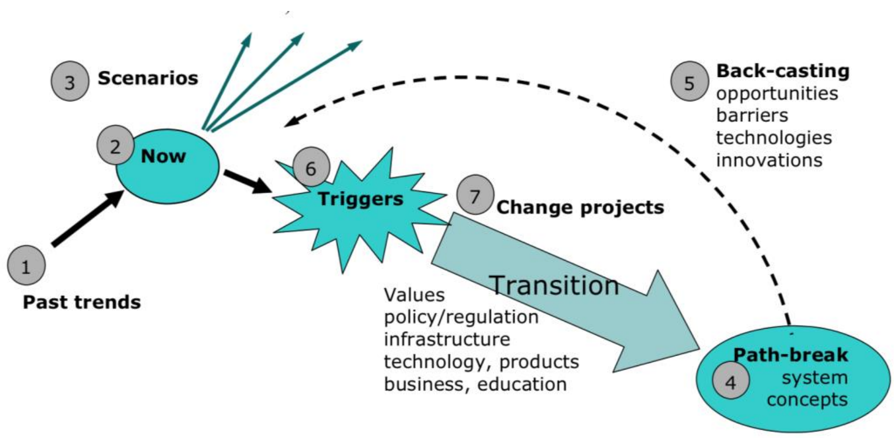

Figure 2: The 7 steps of Transition Engineering to model complex systems (Krumdieck, 2013: 319)

This approach takes into account the long term, adopts a back-casting approach and at least visually proposes a socio-technical approximation. However, as stated throughout the paper, it is about expanding and extending the tools and methods of research and innovation in engineering to incorporate also social and environmental aspects. In other words, the fundamental core of the engineering paradigm with its conspicuous appreciation of measurable variables and quantitative modelling is not challenged. Krumdieck also claims that some engineering specialities are already contributing substantially in the direction of tacking sustainability, as understood in the survival continuum. Particularly, she mentions explicitly that "Environmental Engineering develops ways to reduce emissions and waste, usually in response to scientific findings of the harm being caused" (Krumdieck, 2013: 318).

However, Valderrama, Brodersen and Jørgensen and Mulder have noted that environmental engineering has remained a subordinate discipline chipping in too late in investment projects and focusing only on modelling measurable variables The reproduction of existing, dominant domain of practice have shown to hinder or in substantive ways to subsume new societal challenges and reduce them to specialised engineering tasks within existing scientific and institutional frameworks. Recent studies on environmental as well as sustainability engineering at universities in Denmark and the USA demonstrate this. Even though engaged young scholars in several instansies have taken up environmental and sustainability challenges in curriculum reforms and even in building new departments and education they have experienced how existing domains of practice like sanitary and production engineering not only have taken up the new issues but also have subsumed and reduced their scope to fit into existing scientific and institutional frames (see Jørgensen and Brodersen, 2015). Also in consulting engineering firms attempts to intoduce the new topics and challenges have met serious obstacles and were forced to reframe their critique and efforts to comply with existing market requirements and practice domains making the change a long term and tedious effort.

In contrast to the entrenched obduracy of the engineering profession and the dominance of existing scientific disciplines and practice domains, the design profession has been taking up the discussion on long term, systemic, sociotechnical transformations. The head of Carnegie Mellon's Industrial Design school outlined in 2015 what she and her colleagues propose could be the foundation for Transition Design (Irwin, 2015).

This moves the critique of engineering beyond the question of re-introducing a design perspective to the engineering profession as a reaction to the growing dominance of a more and more theoretically dominated knowledge regime by raising fundamental questions to the devide of the sciences that has become foundational also for the engineering sciences and have aligned them with natural sciences. This supports the introduction of sociotechnical approaches that not least the STS field has contributed to and expands the critique raised within engineering.

Figure 3: A continuum of design approaches as presented by Terry Irwin (Irwin, 2015: 231)

In figure 3, Irwin (2015) suggests a continuum of design approaches. Not present in her figure is product design, which is still the main practice among industrial and engineering designers around the world and the one that determines the main elements in the dominant paradigm of what design is, how is conducted and what is the typical configuration of actors where it is realised. Design thinking and action has during the last four decades been feeding on the benefits of an increased focus on user centric design adding to the dominant focus on technologies the interest in use and use practices as inspiration and improvements in adapting design to markets by optimizing use. Due to globalisation, increasingly, products are designed for consumers all around the globe. The design for users in specific local markets has been taken over by ideas of design for world markets, which pose a number of interesting technical, aesthetic and logistical challenges as well as challenges on how to understand and frame who the typical global user is and what needs are to be served.

Over the last two decades the design of services (first to the left in figure 3) has emerged as an independent practice, focused on generating solutions that are not necessarily bounded to only one product as the main carrier of the design solution. These types of practice still operates under the narrow configuration of provider and consumer/user, although shifting the emphasis from the product itself to the services it offers.

Design for social innovation, at the center of figure 3, is a more recent development, where designers engage with wider groups of actors, ranging from public institutions to grass roots groups, to support more complex processes of interaction that can not be reduced to a service provider-user interaction. Many of the challenges addressed by social innovation initiatives, thus, require re-thinking dominant contextual conditions like markets, economic relations and power relations. They are opportunities to address taken for granted conditions and to think alternative modes of organization and generation of value like cooperatives, recovered factories, eco-villages, and many others that challenge to one degree or another the standard economic paradigm. Because of the very nature of the efforts, these innovation processes, where design might contribute, require longer periods of engagement.

Irwin's main contribution is the idea of transition design (to the right in figure 3). The proposal is that designers could and should get involved in creating, supporting and developing processes of transition towards sustainability. This requires, according to Irwin, that designers develop the capacity to engage in paradigm shifting processes by attending at least four areas: creating leading visions for transition processes; improving current understandings of how change is produced; being capable of changing their own mindsets and postures; and innovating in their own professional field by creating new ways of designing.

This all sounds quite positive and encouraging, but is it at all possible? Is it just a matter of adding to the existing knowledge in design, new ways of doing design? Or is it necessary that we all accept that the current entrenched un-sustainability of the world is also the result of the specific paradigm of product design? In other words, can designers transgress their role as providers of market ready and user adapted products feeding into existing and potentially new consumption patterns? Is it not necessary also to interrupt, question, get rid off old paradigms? These questions are not to be underestimated at a time when humanity and the planet is literally choking on designed products. In fact, Irwin's own choice of sources for inspiration for the envisioning part is telling: Boaventura de Souza Santos' sociologies of emergencies and Ernst Bloch's views of the Not Yet are all but just positive optimist discussion of what could be done, they are and build on sharp criticism of what is wrong with the current state of affairs in the world, including its production and consumption systems.

Irwin's reference to systemic changes is fleeting and to have a more substantial discussion of this key topic we turn to the work of Fabrizio Ceschin and Idil Gazuluzoy (2016). In this comprehensive discussion the authors provide a complete overview of the contributions the field of design has made to sustainability under an umbrella concept of Design for Sustainability (DfS). The review is synthesized in figure 4, which presents the evolution of the different approaches in time, and most importantly how do they relate to each other in two scales from insular to systemic and from technology centered to human centered.

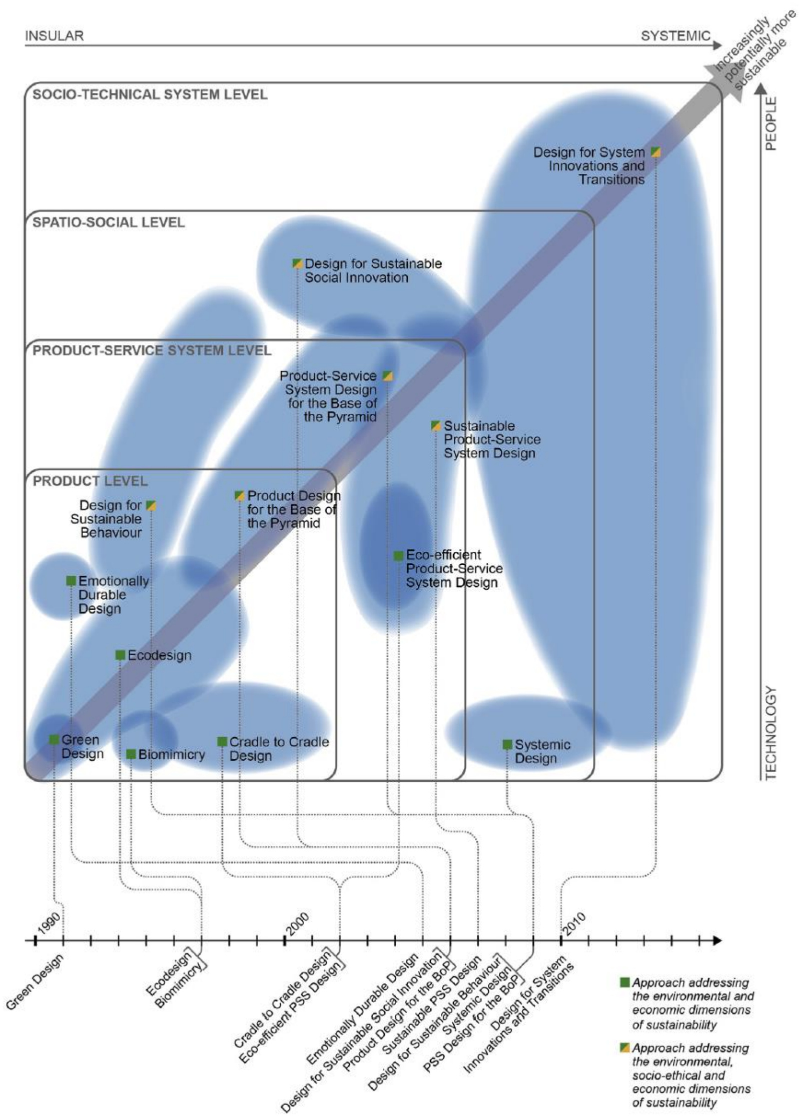

Figure 4: a typology and evolution of Design for Sustainability (DfS) approaches (Ceschin and Gaziulusoy, 2016: 144)

The authors qualify their analysis clarifying that many approaches are complementary, that others have evolved from one to the other, and that there might be more overlaps than those depicted in the figure. However, the most important clarification for our discussion, is that although the design of system innovations and transitions is presented visually as separated from product design, this does not mean that product design is not relevant. In their own words:

> ...each DfS approach should be acknowledged for its associated strengths and shortcomings, and should be utilised in conjunction with complementary approaches for any given project following a systemic analysis, because addressing sustainability challenges requires an integrated set of DfS approaches spanning various innovation levels. Approaches that fall under the Socio-technical Innovation Level demonstrate this requirement well. Design for System Innovations and Transitions focuses on transforming systems by actively encouraging development of long-term visions for completely new systems and linking these visions to activities and strategic decisions of design and innovation teams. Achieving these visions will require design and innovation teams to use a combination of the approaches in lower levels and use in development of new technologies, products and services (Level 1), new business models (Level 2), new social practices (Level 3) that can be part of the envisioned future systems. (Ceschin and Gaziulusoy, 2016: 147-148)

Given these considerations two questions follow in relation to the education of professionals capable of conducting Transition Design:

1. Is it possible to train professionals to cover all these approaches and therefore be capable of combining them?
2. And if that is the ambition, what is the sequence of training?

As professions evolve and their fields expand, these questions become relevant and even pressing. And educators have to take them up with care, because answers can lead to very differet outcomes. In Engineering the effort has always been to first add the new layers of required expertise to the existing core, and when this is no longer possible then new sub-disciplines emerge. This emergence happens in different ways, but normally first as research interests, then as specializations at the master level, and finally they crawl down into the undergraduate programs as tracks of specialization in the upper semesters.

When this happens, like it has happened in the bulk of engineering emerging professions, the core of what defines the profession goes unchanged. The specializations come after. If this is what is happening in design, which might also be implied in the visual representation of figure 2, then we have to ask: is it possible at all to educate professionals first in the art and science of product design and afterwards in transition design. Ceschin and Gaziulusoy (2016) point to several aspects to consider: green desing has focused mainly on lowering environmental impact by product optimization (120); ecodesign has moved on to make whole life cycle analyses to consider the whole process from raw materials to disposal but still focused “solely on environmental performance” (122); user-product attachment has focused on the emotional aspects of decisions about when to replace a product noting that “78% of discarded products still function properly when replaced” (123), but not necessarily focusing on the other aspects of the product; cradle to cradle initiatives shift focus to how a product plays on a bigger system of ressources and recycling, but might not attend the actual service that provides overlooking issues of energy consumption during use (126); biomimicry has focused on finding inspiration from nature to optimize form, materials and function in product, rather than creating complex eco-systems (127). In short, all the DfS approaches that are still bounded to product design seem to be uncapable of addressing the radical systemic changes that transition design require.

Product system design, they argue, seems to be going beyond mere product optimization. Maybe because of the mundane shift in responsibility over the performance of the products involved "since manufacturers keep the ownership of products and deliver a performance to customers, they are economically incentivised in reducing, as much as possible, the material and energy resources needed to provide that performance" (131). However they also note that PSS are difficult to create, maintain and specially bring to mainstream design. On design for social innovation, the authors note that designers have been more concerned with understanding the role they can play in scaling up initiatives that are already out there, rather than creating them. At the same time they state clearely that "it must be acknowledged that approaches solely aiming to generate technological solutions for sustainability problems tend to generate techno-fixes" (134). Systemic design has achieved considerable results at generating synergies between factories and companies in a given territory, but has overlooked the need to reduce consumption, remaining at the level of optimizing material flows and energy use in production exclusively (136).

Finally, Ceschin and Gaziulusoy (2016) review the origins and potentials of what they call socio-technical system innovation level. They place its origins in the projects "the Dutch National Inter-Ministerial Programme for Sustainable Technology Development (STD) (1993-2001); and the European Union funded Strategies towards the Sustainable Household (SusHouse) Project (1998-2000)" (136). These projects han a 50 year scope and used a backcasting approach that are consistent with the requirement of radical systemic changes. However, they note that despite the wide socio-technical ambition of these two projects, "the understanding about the formation of innovations was linear and one-way rather than co-evolutionary and the whole approach was explicitly techno-centric" (137). They also note that the most recent shift in transitions to projects and experiments in cities holds the potential of accumulating knowledge, and capacity for radical innovation, in settings were intersystemic dynamics are more visible.

In short, Ceschin and Gaziulusoys own balance of strengths and challenges of the Design for Sustainability approaches yields a result that can be summarized as designers are still good and confident in product design and willing to expand that approach to incorporate sustainability considerations, although there is clarity of its very limited potential. In contrast, product system desing, socio-spatial innovation design, systemic design and sociotechnical system innovation level design hold a bigger potential for sustainability, but are still underdeveloped non-mainsteam approaches in design.

Acknowledging this gap, they nevertheless propose that designers should "move from product thinking to system thinking and to become more strategic" (148-149). And to do that they proposed the following four key skills designers should be capable of:

1. "addressing sustainability operating on the integrated system of products, services and communication through which a company (or an institution, NGOs etc.) presents itself"
2. "creating clear, comprehensible and shared visions to orient innovations"
3. "contributing to create relations between a variety of stakeholders of a value constellation"
4. "acting as facilitator to stimulate a strategic dialogue and co-design processes" (Ceschin and Gaziulusoy, 2016: 149)

We agree that there is a need to move from product centred design approaches to system level approaches. We believe that this is a critical move when many of the hurdles to transition lay precisely in the current paradigm of product design. But is it at all possible to deploy an expanding strategy? As we will further discuss in the following section, our undergraduate program, has precisely the sequence of educating new professionals first in product design, then in service design and finally in system design. After six years of experience we wonder if this is working at all, or if the many chanllenges we experience lie precisely in the incompatility of product design and transition design.

3. Sustainable Design Engieneering

To illustrate the attempts to integrate socio-technical approaches and sustainable transition elements including a focus on engineered systems we use the arrangement of courses, projects and topics that constitute the undergraduate program on Sustainable Design Engineering at Aalborg University – Copenhagen Campus. The main objective of this program is to educate and train engineers capable of leading and participating in design projects of products, product-service systems and systems that contribute to processes of transition to sustainability.

The program is a combination of project studios, in yellow in Figure 5, organized in a Project Based Learning fashion in line with the pedagogical principles of Aalborg University and the tradition in training industrial designers and architects. The boxes with white background in Figure 5 present the socio-technical subjects that cover ethnographic tools and approaches like field studies; socio-technical understandings of change; science theories; fundamental education on the principles and applications of system visualization as well as discussions on what is sustainability and how to tackle sustainable challenges. The boxes in yellow present the engineering sciences that were considered best for the program. This is an accredited engineering program in Denmark and therefore it is approved by the Danish Association of Engineers. From the discussion on engineering above, perhaps the reader can guess what the attitude of the engineering association towards the program was: it does make sense to experiment with training engineers that can handle design and sustainability *as long as the engineering sciences are part of the program*.

All the three sets of courses and studios depicted in Figure 5 pose a challenge to the education of sustainable design engineers:

Design: As Figure 5 shows the program has a progression from the basics of desining in semester 1, to proper product design in semesters 2 and 3 to product-service system design in semester 4 to system design in semester 5. Students and teachers do acknowledge, after six years of experience, that there are difficulties in studying first product design and then system design, mainly because the knowledge, tools and methods of product design are not applicable to system design. It seems to be an entirely different endeavour.

A	B	C	D	E	F	G
	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS
1	Actor-oriented Design	Design processes and visualization		Fieldstudies and socio-material analysis	Modells, mechanics and materials	
2	Re-design for sustainability			Products, use and context	Vibrations and regulation	Thermo-dynamics
3	Design and use of prototypes			Co-design and user involvement	Logic and programming	Signal analysis
4	Design of product service systems		System visualization	Networks and change	Science Theory	LCA
5	Design of sustainable systems			Sustainability and Society	Fluid Mechanics	Applied Statistics
6	Final Project			Creative project leadership	Strategic concept development	Information gathering on physical and material phenomena

Figure 5: The program of courses and projects that constitute Sustainable Design Engineering undergraduate program at Aalborg University – Copenhagen Campus

Engineering Sciences: In a program structured around projects, there is a double challenge for the supporting courses. On one hand, they are expected to provide general knowledge applicable to the field. On the other, they are expected to support the semester projects. This places the teachers of the engineering sciences on the position of either teaching the standard content of a given course or making the effort of adjusting the content of the course to fit the program and the project semester. If the course is a service course delivered from another unit at the university, teachers have either no motivation or little ressources to attempt an innovation from the standard course. In our group, we have been able to obtain pesmission to hire an engineer that has taught the basic engineering sciences for a long time and is interested in adapting and adjusting them to the needs of our specific program.

Socio-Technical Courses: These courses draw on existing knowledge on Science and Technology Studies which are built mainly on historical cases of design, change, innovation and transitions. Students and teachers experiment that there is a wealth of lessons to be learnd from STS, but that it is difficult to transform those lessons into methodological tools to support decision making in design that are perceived by the students as understandable and as useful as those presented in the literature of product design.

But probably the most challenging part of the program lies in the fifth semester, when students should tackle System Design, which is to be understood here as what Irwin depicts as Transition Design if Figure 3 and Ceschin and Gaziulusoy depict in Figure 4 as Design for System Innovation and Transitions. The question is what is the unit of design of system design? This is a general question, which needs to be addressed also from a student perspective: after being trained in product design, and produc-service design, the first question students have when confronted with system design is: what is *the* system? We find this a critical question in general, which is also present in both taxonomies of design presented above: are we confronted with the idea that we can design a system? Or are we considering a systemic approach to a design process? Or is it a systemic perspective for a trasition process?

Classical presentations of systems thinking and approaches like those of Jay Forrester and Donnatella Meadows present both systems as an object of design or intervention. For instance:

> Folks who do systems analysis have a great belief in "leverage points." These are places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything. (Meadows, 1997: 78)

They are also keen on exemplifying dynamics of systems and its subsystems using as examples tightly coupled technological systems and insisting on some form of modelling, as illustrated in Figure 6.

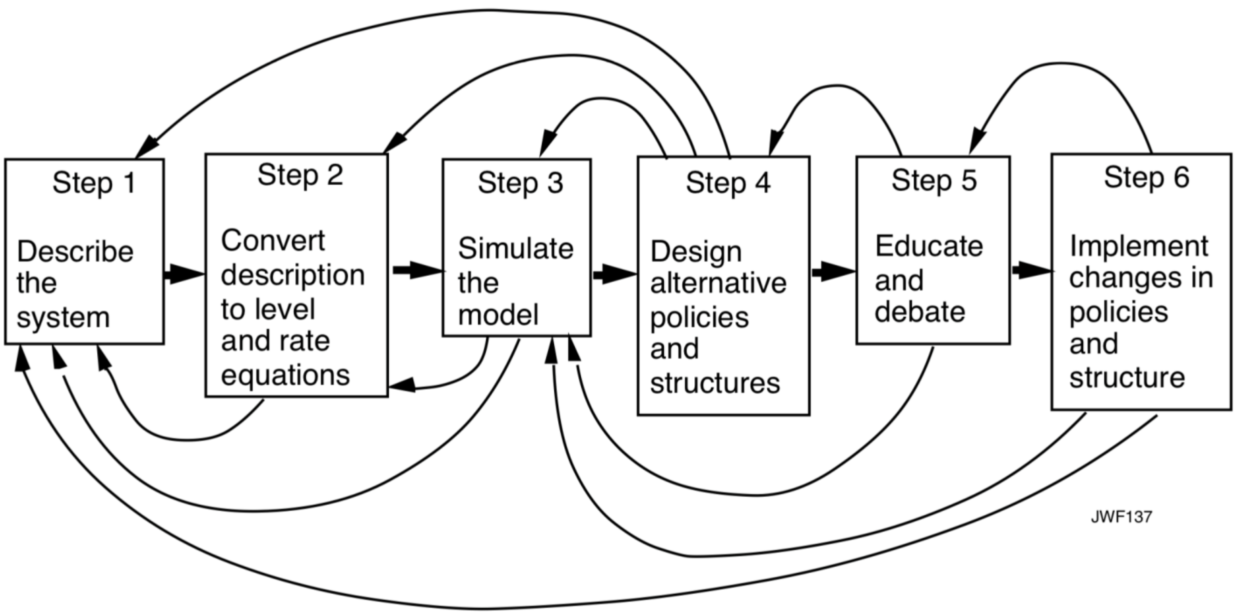

Figure 6: System dynamics approach to tackling system design from diagnosis to improvement (Forrester, 1994)

The fields of system dynamics, system analysis and systems thinking are intended to expand the scope of engineering and technological problem solving from a mere reactive task bounded by deterministic relations and short term scope, to a more holistic and long term approach. Its merits are undeniable. But what we find troubling from a transition perspective is the insistence of the system as in a singular knowable object that could and should be improved by using the appropriate modelling tools. It appears that these approaches are attempting to cope with complexity, uncertainty and scale by expanding quantitative modelling approaches.

We consider that some transition approaches might be suffering of the same problem. The Multilevel Perspective presents itself as a socio-technical approach where a regime or a niche are consistuted not only by technologies, but also by rules, norms, laws, social networks, actors, tacit knowledge and so on. However, the majority of the telling case studies carefully analysed in depth are organized around a technology or a sector. They do consider inter-systemic dynamics between a regime organized around a dominant technology and a strategic niche organized around a competitive technology. But they still approach this socio-technical systems as knowable wholes whose structure, behaviour and dynamics are knowable and thus, subject to controlled action. Technological Innovation Systems appears to have the same problems.

Transition Management recognizes that transition challenges are unstructured and highly complex.

> They are unstructured... and highly complex because They are rooted in different societal domains, occur on varying levels, and involve various actors with dissimilar perspectives, norms, and values. Solutions to such problems are not given, and purely analytical approaches will not suffice. The structural uncertainties surrounding future development necessitate more explorative, experimental, and reflexive approaches. (Loorbach, 2010: 164)

And its proponents invoke a Complex Systems based apporch to tackle them. Their hope and prescriptive aim is that...

> The transition concept tries to unravel the complex interaction patterns between individuals, organizations, networks, and regimes within a societal context, and how over time, these can lead to nonlinear change in seemingly stable regimes. (Loorbach, 2010: 167)

To address the intrinsic complexity, uncertainty and non-linearity of transition challenges and the potential solutions they propose a set of management types to cater for different scopes, scales and time frames in a backcasting inspired fashion as illustrated in Figure 7.

Transition Management Types	Focus	Problem Scope	Time Scale	Level of Activities
Strategic	Culture	Abstract/societal system	Long term (30 years)	System
Tactical	Structures	Institutions/regime	Mid term (5–15 years)	Subsystem
Operational	Practices	Concrete/project	Short term (0–5 years)	Concrete

Figure 7: Transition Management Types (Loorbach, 2010: 171)

In a nutshell, Transition Management proposes that some relevant actors agree to work together and conduct a series of activities in order to tackle transition challenges by conducting several cycles of the following recommended activities:

> (1) structure the problem in question, develop a long-term sustainability vision and establish and organize the transition arena; (2) develop future images, a transition agenda and derive the necessary transition paths; (3) establish and carry out transition experiments and mobilize the resulting transition networks; (4) monitor, evaluate, and learn lessons from the transition experiments and, based on these, make adjustments in the vision, agenda, and coalitions (Loorbach, 2010: 172).

The objective is that the iterative process among actors will produce the innovations and self-organization processes required for their success.

It appears that all these approached build on the idea that systems are identifiable and knowable. In contrast, central figures in the Design field claim that they are not. In the words of Robert Buchanan:

> By definition, a system is the totality of all that is contained, has been contained, and may yet be contained within it. We can never see or experience this totality. We can only experience our personal pathway through a system. And in our effort to navigate the systems and environments that affect our lives, we create symbols or representations that attempt to express the idea or thought that is the organizing principle (Buchanan, 2001: 10).

If we take this reflection seriously maybe we should rethink the role of designers and engineers as those who can contribute to transitions by providing the best possible expertise needed to account for all the elements, sub-systems, systems and macro-social dynamics involved. Maybe we should give up on the idea that Transition Design could ever be as Product Design on a bigger scale.

Then we should accepts that reality is not knowable, and that partial views, multiple accounts and controversies is what should be described and intervened. To act under this understanding is to accept that design has two phases: that of reducting complexity by doing partial mappings to reduce reality to a workable scale, and that of increasing complexity of a given solution by representing, prototyping and interacting. Helena Nowotny (2005) claims that we are always seeking to reduce and expand the complexity of the world in our intellectual and intervention efforts. She claims that

> we seek to reduce complexities – sometimes desperately so – in order to be able to describe and learn to understand the effects of the systems we construct, that is, the undesirable and unintended effects they may have (Nowotny, 2005: 19).

and that

> we seek to increase complexity in order to make objects or artifacts perform to the highest degree of complexity. We want to make them do things that less complex systems are unable to do. We seek to build complex systems in technology, because of their higher efficiency (Nowotny, 2005:19).

Her discussion the tensions between science and technology on one hand and social sciences and humanitieis in the other. The first one always attempting to reduce complexity by measuring, modelling and quantifying, while the second one increases it by attending issues of ethics, power, purpose and aesthetics. It appears, so that what is missing to make this tension productive is a full fledged transdisciplinary approach, but "transdisciplinarity as mode of knowledge production has taken modest roots also within academia" (Nowotny, 2005: 27).

System Design, we claim, might be able to make this tension productive. In very schematic ways, any design process has stages of opening up and stages of closing down as shown in Figure 8.

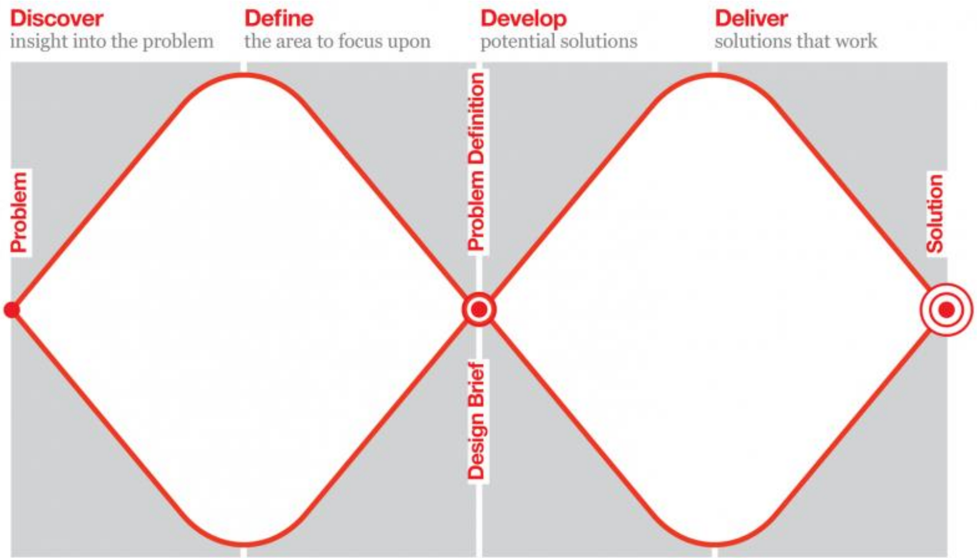

Figure 8: The Double Diamond of Design (https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond)

The phases of discovering and defining can be considered as stages of reducing the complexity of the world by first gathering, codifying and sharing among designers accounts of journeys into reality. And then by using these reduced traces to generate a problem definition. In other words, the first diamong of Figure 8 is a reducing complexity process. Once the problem is defined, then designers can move on to the phases of developing and delivering where complexity is increased by conceptualizing a solution, prototyping it, and sharing it among interest parties. Then, a proper design process, would enter in a phase of increasing the complexity of a solution by moving from simplified codified to reality where a design is accepted and incorporated.

This happens normally in a process of product design in different forms, but too often the whole process is a reduction of complexity which explains why too many products either fail or create major unintended consequences. In the case of System Design, we do not propose that this sequence should be only a reduction process, but precisely, what Nowotny proposes: an interdisciplinary process of conscious decreasing and increasing of complexity. This is not easy because it requires from disciplines that they shift the emphasis from the delimintation of their own expertise to what they can contribute in a given situation. In other words a shift from "theories, analysis and universals" to a focus on "context, practice, experience, common sense, intuition and practical wisdom" (Nowotny, 2005: 27 quoting Flyvbjerg, 2001).

For this to happen, it is also necessary to de-center the role of designers as those that accumulate knowledge to produce solutions, to become those who facilitate a reduction of complexity/increasing of complexity process by circulating, updating and making available different mappings of controversies among actors involved. This can only happen if designers give up the idea that they could play a managerial modernist role creating order by accumulating knowledge. They need to assume the role of designers as agnostic Prometheans supporting all involved parties in developing as much and as good knowledge possible on each other, the situation at stake and the controversies present, and the possible solutions (Storni, 2015)..

But this requires accepting that reality is multiple and that actors exhibit different modes of existence. The fact that reality is multiple requires that we accept that a thing like a product or a system is not a consistent object that can be known. It requires to accept things are collectives of different objects, which exist in different worlds. Therefore is necessary to give up on the idea of the objective representation as the main means of reducing the complexity of reality. Reducing the complexity of reality means creating as many mappings of a situation or controversy and circulating them to have actos themselves create the connections. Therefore, it is necessary to give up on the idea that there exist a preferred and more correct expertise or rationality (Storni, 2015).

In terms of systems thinking, this means, giving up on the idea that systems exist out there and can be known by proper system analysis. It means accepting that systems are multiple, and thus observing them is always both partial and an intervention done by particular actors. And that no one actor, not even the designer, or the engineer, has the best knowledge to do it. It means accepting that the knowledge that designers and engineers can bring to a design process is as good good and valid as any other knowledge including that which comes from other disciplines and other actors in a given situation.

We belive that this considerations allow to clarify what is required from transition designers. And to do that we add and qualify both the list produced by Dym et. Al. (2005: 104) and Ceschin and Gaziulusoy, (2016: 149). We do so adding our comments in **bold**:

- Tolerate ambiguity that shows up in viewing desing as inquiry or as an iterative loop of divergent-convergent thinking; **as opposed to problem-solving using deterministic methods.**
- Maintain sight of the big picture by including systems thinking and systems design; **bearing in mind that the contribution of these disciplines is as limited as any other.**
- Handle uncertainty; **perhaps account for uncertainty, make it explicit.**
- Make decisions, **because there is no rational process in design. At some points given time and resource contraints somebody will have to take a decision, which can only be as good as the knowledge it builds upon and the clarity the decision maker has on the uncertainties at stake. Additionally, in transition design there are multiple decision makers.**
- Think as part of a team in a social process; **Better be part of a team and a social process.**
- Think and communicate in the several languages of design. **Facilitate thinking and communication in all the languages that make sense for the actors involved.**

- “addressing sustainability operating on the integrated system of products, services and communication through which a company (or an institution, NGOs etc.) presents itself". **Yes, addressing sustainability as an emerging quality of the process and the interaction, instead of thinking that it can only be an external criteria.**

- "creating clear, comprehensible and shared visions to orient innovations". **Facilitating the creation of shared visions, which can be multiple.**
- "contributing to create relations between a variety of stakeholders of a value constellation" **Acknowledging that they inhabit different worlds.**
- "acting as facilitator to stimulate a strategic dialogue and co-design processes", **undesrstanding that this is a second-order objectivity process among actors that inhabit different worlds.**

4. Conclusion

It has been a long-standing discussion in the sustainable transition community whether transition management approaches based on systems reasoning have provided concepts and results or just use loose systems references to cover for gaps. One central critique has been that the frameworks provided on how to manage change processes have not escaped implicit ideas of centralised agency. Another has been that sustainable transitions per se are characterised by non-final goals and means and consequently will need navigational tools and changes in goals and means to be able to handle the complexities involved in the transition processes.

Recent developments in design (Irwin, 2015; Ceschin and Gaziulusoy, 2016) have been taking up the question of transition design as the possibility of developing design projects with the intention of producing paradigmatic system changes towards sustainability. This literature is keen on calling for an increased focus on the systemic aspects to be addressed in order to design with a transition perspective. This entails taking into account not only visions, new ways of production, but also long-term transformations, changes in life styles and mind-sets, transformation of social forms of organization, spatial issues and the importance of local place based knowledge and culture. At the same time, the field of design has taken over ideas from systems thinking that are inherently contradictory and run the risk of repeating the fields earlier traps and fallacies.

In line with (Willis, 2017), we acknowledge that transition design as an emerging professional practice should 'capture the extent of divestments needed for a significant cultural shift toward sustainment' (p. 70). This requires opening up to the controversies and the politics that entail a fundamental criticism to current existing knowledge, technologies and patterns of production and consumption. The claim here is that this can be achieved by design, but only if design is upgraded from a mere solution centred design practice to a focus on design processes that reflect the controversies and engage in suggesting how to navigate in a field of conflicting matters of concern and partial systemic clashes. These entails: dissociating, de-scribing, and critically dismantling the current systems as materialised in everyday object-systems of production and consumption. This also entails taking transition processes as clashes of partial system orders and the complexity resulting from these as central aspects of the socio-technical dynamics at stake. Complexity in this perspective goes beyond a cybernetics conceptualization of systems and operates with the heterogeneity of partial and conflicting systems conceptions as the most important aspect of complexity. This implies proposing new ways of re-arranging and re-conceptualising systems at different scales.

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