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ECO-INNOVATION IN THE VALUE CHAIN

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1. Introduction

It is well known that companies face challenges integrating environmental considerations into their own product development processes, and there is an established body of research focusing on ways and means to aid this. Today the approach for integrating environmental considerations in companies and their product development processes is often reactive, resulting in a retrospective and insufficient approach.

It is also known that environmental impacts can occur throughout the whole product life cycle, either due to the attributes of the product – which are a result of considerations in product development, or due to activities of stakeholders in the value chain – which can be a result of lacking communication, low motivation, lack of awareness, or misinformation, among stakeholders. The area of value chain environmental considerations is relatively uncharted in the realms of design research, and furthermore a neglected field of potential consideration in companies.

Earlier research states that the role of the product developer must change and develop in terms of considering environmental issues in product development – ecodesign [Johansson 2002]. It is professed that the product developer ought to take responsibility for both the product *and* its lifecycle through ecodesign and that the design object should be expanded to include total life cycle and value chain considerations (both upstream and downstream), all affected stakeholders and the systemic modes of product or function delivery [McAloone 2001]. This broader view of the product developer's task leads to the necessity to seek supplementary support in the development activity, which is covered by the theoretical literature base around the field of innovation. Understanding that the early decisions in product development dispose for many of the environmental (and other) attributes of the product, it is widely agreed that the product developer should consider environmental issues as early as possible [Olesen 1992]. The paradox here, however, is that the early stages of product development are the areas where there is least insight into the product's future environmental footprint, as the product concept is immature. This has led to a long stalemate situation in the ecodesign and life cycle assessment (LCA) research domains, with occasional attempts at stopping gaps in methodology toolsets, by means of abridged tools and the 'recycling' of earlier products' life cycle data.

However, building on the concept that both the product developer's role and the design object should be broadened, there are a series of elements and considerations that easily can be addressed in the early stages of product development. Looking towards the opportunity of creating environmental improvements by involving other value chain stakeholders, early in the process of product development – often called the front-end of innovation, it is interesting to address the opportunities and barriers for collaboration, creative synthesis and knowledge sharing, early in the innovation process.

Given the above-named opportunity to create eco-innovation in the value chain the research project described in this paper set out to identify the mechanisms, opportunities and barriers for the actual

realisation of value chain based eco-innovation. This was carried out through a number of industrial studies, where a (limited) number of stakeholders were brought together to create concepts in a collaboration across the value chain. Our hypotheses for this work were (i) that there must be one dominant stakeholder (company) to allow the value chain innovation activity to be successful, and (ii) that it was necessary to describe and develop two life cycle systems to be able to create sufficient insight into the pending product development's environmental footprint, namely the life cycle of the physical artefact, and the user's activity cycle [Matzen and McAloone 2006] – describing the relationship between the providing company and the end-user.
Our method, which was built on the basis of a detailed literature review and a stream of interventions with a number of industrial companies, was designed as an action-research experiment. In this paper we have chosen to focus on two cases from a longer list of empirical interventions carried out. In both cases the supplier company was the same, allowing for a comparative analysis between the two cases, despite the small sample size.

2. Theoretical background

Earlier research has charted the needs, tools, barriers and experiences with the implementation of environmental considerations into the product development process [Johansson 2002]. Olesen reports that the early stages of the product development process are the most vital stages in terms of deciding the product's environmental profile throughout its lifecycle [Olesen 1992], however the vast majority of tools and approaches bearing the label of 'ecodesign' are insufficient in the early product development stages and in most cases can be classified as assessment tools, not design tools.
Following the argumentation that a product's environmental impacts occur throughout its life cycle, it is reasonable to look to the whole value chain when designing the product. Olesen supports this argument by highlighting the inevitable interactions that occur between the product, the product's life phase systems (the context of the product in particular life cycle stages) and the various stakeholders from the value chain [Olesen 1992]. There have been various attempts to chart these interactions, in order to understand the nature and origin of the arising environmental impacts. McAloone describes the *product life gallery* approach [McAloone 2001], which creates a life cycle sequence picture of the product's life cycle stages, tied together with the relevant stakeholders. Matzen & McAloone have introduced an approach – the *activity modelling cycle* [Matzen and McAloone 2006] – towards the modelling of the user and related stakeholders around a particular activity, which is takes its point of departure in Vandermerwe's *customer activity cycle* theory [Vandermerwe 1999]. Studying the role of the design process from a supply chain management perspective, Sarkis identifies a series of influential organisational practices that all stakeholders in the value chain ought to contribute with under the design and development of products – namely the ingraining of reduction, reuse, remanufacture, recycle and disposal alternatives into design [Sarkis 2003].
Traditional literature on value chain processes describes a sequential configuration of adding value, from the input to the producer until the customer is finally reached by the output [Porter 1985], showing the contributions from different functions of one or more organisations in the value-adding process. The value chain model has been used to understand and guide many different types of activity, from the corporate strategic level to the individual, managing a product development project. However, observations of modern business activities by Normann [Normann 2001] have led to the suggestion, that companies should be seen increasingly as *organisers of value creation* within a *value creating system*, which does not necessarily follow the traditional sequential value chain, as described by Porter. In contrast to the value chain, Normann concludes to suggest that the more fitting picture to understand the modern business innovation process is a *value star*. This new image of the value creating process has the significant differences, that the organiser of value creation need not be the largest customer (often the OEM) – as is the case with value chains, that a value star constellation allows for constant reconfigurations of the value creating network, and that the value creation process becomes more of a co-makership, between the value star's key actors – including maybe the end-user. This final difference (co-makership) is of particular interest to this paper, as it points towards a new way of accessing key stakeholders in the value chain, early in the process of product development.

Both Vandermerwe and Normann point towards new frameworks for innovation; Vandermerwe presents the concept of *market spaces*, which ought to be systematically identified and subsequently filled, and Normann presents the concept of *reconfiguring value creating systems* within the process of product/business development. Normann handles the configuration of the value system and thereby the network, by introducing the principle of *density* [Normann 2001]. Density refers here to the best combination of resources, which means that it expresses to what degree mobilisation of resources (reconfiguring) can take place. By reconfiguring, companies use the opportunity to fill value spaces.
Van der Horst et al. provide further thoughts on the appropriate object of design when creating eco-innovative solutions, suggesting that the innovation possibilities that lie within sustainable product or system development depart from the existing product, out towards function and needs [Van der Horst et al. 1999]. Figure 1 shows an example of their thinking, expanding on the notion of a sustainable office chair. Van der Horst et al. call this expansion of the design object the *innovation space*, which should be sought enlarged, in order to arrive at new radically innovative solutions, not bound by the limitations of the physical artefact. Similarly, Sherwin & Bhamra discuss the need to expand the design object in order to move away from incremental environmental improvements [Sherwin and Bhamra 1999]. Their key message with this discussion is to include cultural considerations (i.e. understanding the values of stakeholders) and not purely technology into the design arena (see Figure 2).

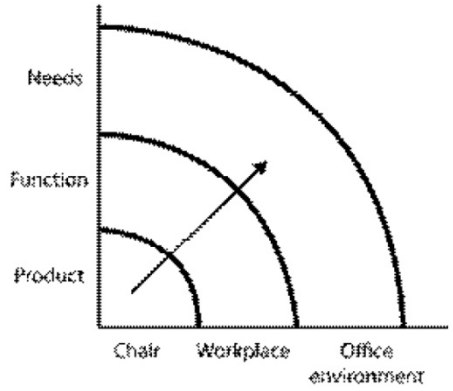

Figure 1. Innovation space [Van Der Horst et al 1999]

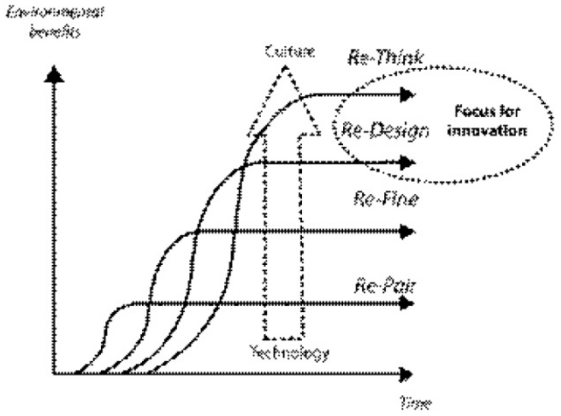

Figure 2. Revised 4-step approach to ecodesign [Sherwin & Bhamra 1999]

Designing from the point of departure of *need* (as opposed to artefact) and enlarging the innovation space to include *cultural insight* (in addition to technology), creates even greater demands on the early stages of innovation, not least due to the levels of knowledge and competency required to create innovative solutions. Lenox & Ehrenfeld focus on the competencies required to ensure that environmental concerns are incorporated into the product development process and identify three key factors that must exist in the organisation: (i) *knowledge resources* on environmental impacts and demands (both external and internal to the firm), (ii) *communication linkages* between product development teams members and their resources, and (iii) *interpretive structures* through which environmental information is understood and valued by product development team members [Lenox and Ehrenfeld 1997].
Lenox & Ehrenfeld's factor (i) above points, therefore, to the understanding, that product innovation is increasingly dependent on the integration of competencies from outside the product developing company and that companies should become increasingly skilled in defining own core competencies and sourcing other areas of innovation competency carefully and in a timely manner in the product development activity. Normann's notion of *value stars* provides an interesting mental model of how to effectively integrate key stakeholders early in the process of innovation, in order to exploit the most optimal set of competencies, with the aim of creating innovative, sustainable concepts.
To summarise we can state that there is a need for a new focus on early decisions and inputs to the innovation process in order to create radically improved environmental solutions. As the design object expands from artefact to function and/or need, so does the solution space and the need for new

competencies. The potential solution to this challenge chosen with our research enquiry described in this paper is to look towards the notion of value-star constellations in the innovation process, to assess whether the related activities of co-design, open innovation and dynamic competency sourcing can be organised to create new eco-innovation opportunities for organisations.

3. Method and cases

An experiment was designed to test the hypotheses highlighted for this study and to inform our enquiry, which aimed at identifying the mechanisms, opportunities and barriers for the realisation of eco-innovation across the value chain – in all its complexity.

On the basis of the aforementioned literature study an empirical study was carried out, including two case studies, where the authors applied an action research approach, acting as facilitators of a series of workshops.

The first case study involved two Danish companies in the furniture branch, which were selected due to their supplier-customer relationship to each other. The supplier company was manufacturer of high quality, eco-designed textiles and the customer company was manufacturer of high-end designer furniture. The case took its point of departure on the two companies' existing relationship, with a view to identifying key areas for eco-innovation, if the existing relationship were to change from value chain to value star. Workshops were held with the two companies together and were explorative in nature, as the object of enquiry here was to identify a match between each of the companies' environmental challenges and competencies.

The first workshop was initiated as a parallel activity, where both companies worked on each their ecodesign challenge that they had identified in their own respective companies. The companies were introduced to a tightly controlled, normative process towards ecodesign and experienced a series of techniques and mental models for framing the ecodesign activity. As this workshop proceeded, it became apparent that there were a number of common issues between the two companies, regarding ecodesign considerations. On numerous occasions, it was found that the supplier company had important answers and insights for the customer company and vice versa. This led to all subsequent dialogue and exercises (from around midday on the first day of the first workshop) being carried out in plenum, between the two organisations.

The second case study was carried out with the same textile supplier as in the first case, but this time together with one of their international customers, a multi-national office furniture manufacturer. The interesting point of departure for this case was, that the textile supplier had the intention of 'moving up the value chain' in order to begin to create revenue based on knowledge and not purely metres of sold textile, and the office manufacturer was already in the full throes of expanding their business activities, both vertically and horizontally in the value chain. There was therefore a great willingness from the two companies to learn from each other. Empirical data had been collected and analysed about both companies in case 2, prior to the actual case study described here, through two separate ethnographic studies of each seven months [Mougaard and Knudsen 2009]. The companies had an existing, traditional customer-supplier relationship, but were also aware of each others' business development intentions and environmental awareness/activities.

A workshop was therefore planned and executed, where the two companies spent the duration of the workshop (1½ days) co-developing a product. In order to avoid problems due to confidentiality, competitiveness or perceived prior-ownership of the solutions to be generated at the workshop, a neutral product and application area was chosen for the workshop, which nevertheless was related to the two companies' core fields of competencies. The case for the workshop was the eco-design of the interior of an aeroplane fuselage (the part that the passenger experiences). Under this workshop, the companies experienced a series of exercises and techniques towards creating eco-innovative solutions, whilst the researchers both facilitated the workshop and observed the activities of the participants.

For both studies the methods of observational study, physical artefact study, documentation analysis, interviews and design-workshops were employed.

4. Empirical data

Many interesting findings were gathered from the two cases described above, much of which is documented in supplementary publications ([Mougaard and Knudsen 2009] plus forthcoming papers). The following empirical data was chosen for this paper to address our research enquiry, namely to assess the potential of a new organisation in the value chain for eco-innovation. The data focuses on the organisation of the eco-innovation task, and for the sake of space, we have chosen to present an aggregated and abridged set of empirical data for both cases, rather than two single presentations of the data.

Absence in Front End of Innovation/product development

Based on the observations of especially case 1, it was quite apparent that the classical value chain relationship between the two companies led to a hindering of early innovation during the environmental improvement task. It was observed, and later confirmed through dialogue, that vital competencies and knowledge about the environmental impacts of processes, materials and certain activities, which could have been activated, were not. As the supplier company was not present in the early phases of its customer's product development process, nor informed of the overall goal of the product, the classical relationship between the companies was defined as a traditional supplier-customer relationship and limited to confines of the task specified by the customer company. Interviews with both companies uncovered that this resulted in reactive approaches towards environmental improvement. Furthermore, the supplier's environmental competencies were reported to be insufficiently transparent – despite their relatively highly profiled corporate position on environmental issues – thus the customer company was not aware of the potential for integrating the supplier's knowhow in the early phases of conceptualisation.

At the customer companies in both case 1 and case 2, sets of eco-design guidelines were implemented, but the majority of guidelines were found to exist in the design embodiment- and later stages of the product development process.

Environmental competencies in product development

All of the companies observed under the case studies had firm environmental policies in place, backed up by environmental specialists in their organisations. The environmental specialists typically carried out remedial and precautionary tasks in the EH&S department of the company, according to laws and directives relevant for the company. All saw a great challenge in influencing the product developers to think in terms of environmental aspects, beyond the precautionary measures dictated by laws, directives and customers. Furthermore it was observed at various stages of the workshops held, that potential environmental impacts in the products under consideration for ecodesign, were perceived to be beyond the reach of the product developers themselves, as they were designed-in during other stages in the value chain.

Object-oriented collaboration

In the light of the previous two aspects, regarding the lack of front-end consideration and the difficulty integrating environmental competencies into product development, it was the intention of the companies in case 2, to experiment with establishing a closer relationship, early in the innovation process, via a common design object. Case 2 was particularly interesting for the participating companies as they had not embarked on this experiment previous to the case, due to an uncertainty as to how to design the right constellation, even though both companies were approaching each other through their own organisational developments. On the one side, the customer company (furniture manufacturer) was in the process of changing their business strategy from simply developing products (artefacts) towards producing more holistic solutions (systems, services and workspaces). On the other side, the supplier company (textile manufacturer) had recently undergone a major reshape of the organisation, in order to realise the potential of their in-house competencies, free themselves of their traditional manufacturing-based activities and become more flexible in terms of new business opportunities. The common design object chosen for this case (the aeroplane fuselage) created the opportunity for the participating companies to realise their intentions of approaching each other and creating a level playing field for a collaborative innovation process.

Co-development workshop

A workshop was created (in case 2), in order to observe how the companies could benefit from co-developing a series of ecodesign concepts. During the workshop, the companies worked in small groups, with an even mix of participants from the two companies and a good representation of product developers, logistics, purchase, management and environmental experts in each group. The environmental experts present were a resource for the whole team, giving advice on a whole host of issues, such as legislation, materials, processes and environmental loads. Through a chain of exercises during the workshop, a positive collaboration was observed, creating a number of feasible ecodesign concepts, which were later categorised and prioritised. Although the main aim of the workshop was to experiment with the co-development activity and less so on the actual solutions arising being realistic and achievable, a number of potential solution concepts were found.

Creating value constellations changes roles

Comparing the two cases it was possible to observe that the supplier company (kept constant for both cases) had a more active role in the case inspired by the value star approach to the organisation of the early innovation process (case 2), as opposed to in case 1, where a traditional, sequential model was followed, with the supplier supplying a locally optimised component to the next stage of a sequential value chain.

5. Key outcomes

Through this study we experienced that it was possible to compare the effects of two different value chain scenarios on the ecodesign process of the involved companies in the value chain – albeit in a very limited fashion. We observed mechanisms to create inclusive problem solving and co-design activities across two organisations, rather than an over-the-wall blaming up and down the value chain.

Value chains and value stars

On analysing the cases it has become apparent, that key stakeholders – seen in terms of environmental knowledge – were classically integrated into the product development process first *after* conceptualisation and embodiment design was finished, thus limiting the potential for important insights into the product's life cycle. Based on Normann's suggestion that companies should be seen as *organisers of value creation* within a value creating system, which he calls a *value star* (see Figure 4), it was possible to compose the value star for the second case study described in this paper, using Normann's approach (see Figure 5). The value star visualises how the customer is placed within a value system and how the customer is a resource of value inputs, instead of merely being the receiver of the output, as it is in the sequential value chain (see Figure 3). Research suggests that companies in need of original, customised ideas for future products should involve their users in the creative phase of their innovation process [Chesbrough 2006]. This is in line with the view of the value creating system by Normann and underlines the importance of viewing customers as co-developers.

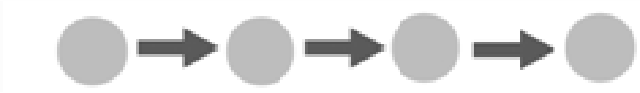

Figure 3. Sequential value chain [Porter 1985]

The dots in the Figure 5 represent the actors in the system. The two companies described in case 2 are marked with the ellipses. The value-creating system is marked as the core of the model by the large central circle, and is the system of the end-user. The value star creates a mental model of the network necessary for the value-creating system in the case and provides a useful visualisation of the complexity of the value star constellations. With this insight it is possible to strategically identify and invite some of the value-adding actors into a co-development by, for example, carrying out a pre-screening of interesting potential actors. In our case study the supplier is the prime mover as they are aware of possibilities in their relationship, that the customer (or others in the network) is/are not aware of. The supplier therefore plays an important role together with the manufacturer, orchestrating the network.

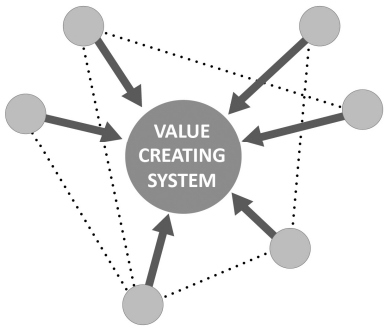

Figure 4. Modified illustration of value star, showing the different actors contributing to the value creating process of the customer [Normann 2001]

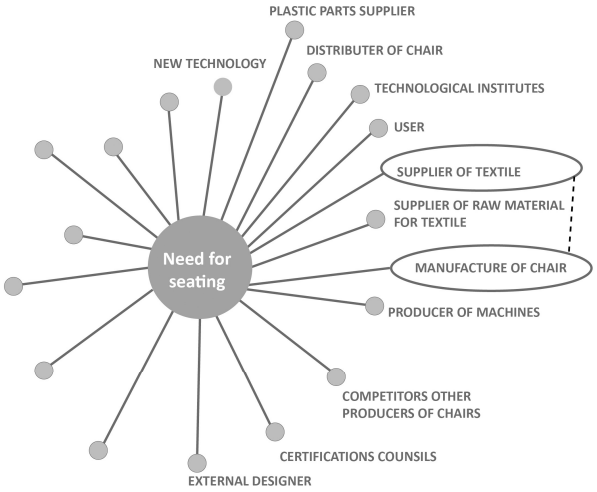

Figure 5. Depiction of the value star described in the case study. Value adds from different stakeholders within the value creating system (two studied in this paper)

The *innovation space* [Van der Horst et al. 1999] is enlarged in case 2, as the point of departure is based upon a need, and not an artefact (refer to Figure 5). As orchestrator of the value star it is possible to reconfigure the value creating system and deliver more than just a product.

We can conclude from our study that many potential environmental benefits lay hidden in the classical value chain, which could be uncovered and activated in a value star constellation. The eco-innovation competencies are, as explained earlier, dependent on the environmental capabilities of the network [Lenox and Ehrenfeld 1997]. These competencies can only perform when activated through connection to the network. Depicting the value star in this way, the different competencies can be seen as assets that can be re-configured and thereby create possibilities for creating new partnerships, or strengthening already existing ones.

In Figure 6 we present a model to describe the mechanisms by which the value star can uncover environmental competencies and reconfigurations (restructuring of the competencies in the network [Normann 2001]). The figure illustrates two actors in the network, detailed by their competency structure. An actor adds value through (1) an activity, (2) a set of competencies, and (3) knowledge resources. Considering Lenox & Ehrenfeld's view on capabilities in relation to this model, we can explain that the *knowledge resources* are expressed as the requirements for environmental design and the knowledge of environmental impacts and demands. Knowledge resources hold more than just individual expertise; they can also include knowledge within technical systems and procedures. The *communicating linkages* are the second factor within environmental capabilities, expressed through the coordination of resources with the product development team and also with respect to external relations to the product development activity. The external and internal knowledge resources and how they are interpreted and utilised affects the overall "group intelligence" of the product development team. The *interpretative structure* can be seen as the frame for the whole activity as it is the final element of superior environmental design capability, namely that the product development team understands and values the environmental information they receive, even more vital for the interpretative structure is that it is supported at management level.

With this in mind, as the eco-innovation competencies change within the value star, it is possible to create a configuration. The outer connecting line in Figure 6 visualises how reconfiguration can result in a new value into the value creating system of the customer, by pooling and coordinating the activities, competencies and knowledge resources of the two actors.

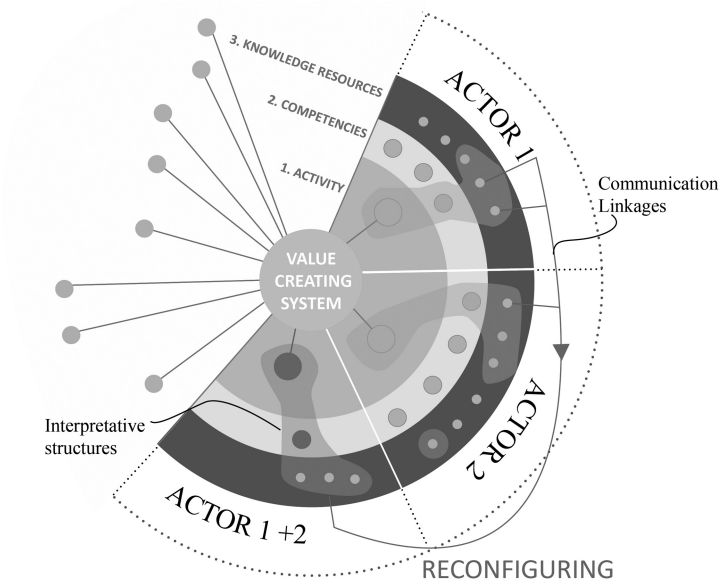

Figure 6. The mechanism of the value star transferred to the design research field

6. Discussion and implications

Based on our hypotheses and research enquiry (the testing of the value star approach) and the results from the empirical work recorded in this paper, there are a number of important issues that merit a discussion, in order to balance the findings from the research.

Firstly, one could ask, whether the value star approach actually delivers, or at least shows any promising signs of pre-empting environmental impacts in the product that can occur due to lacking communication, low motivation, lack of awareness, or misinformation, among stakeholders. Although our study did not set out to investigate these issues regarding the value star approach, it could be seen that the very presence of two complementary stakeholders in a common workshop setting, as was seen in case 1, was motivating and informative for both participating companies. Furthermore, in case 2, where the workshop was designed to create co-design between the two participating companies from the very start, it could be seen that the level of communication and information exchange was high.

The experiment was controlled in this study and confined to two participating companies, who had a prior knowledge to each other beforehand. A question could also be posed, as to whether the value star approach would at all be possible or productive, if more organisations were involved, as Figure 5 suggests could be the case. It was clear under the discussions with the participating companies, that the value star approach must have its limitations and complications in reality, due to perceived ownership of ideas, secrecy, competition factors, and sheer organisational challenges. It is important to remember, that the aim of creating value stars is not to include each and every stakeholder from e.g. Figure 5 in the innovation process, but to make pre-selections of key potential partners, who each offer value to the process and the other companies in the value star, by joining in the collaboration. We have not discussed this pre-selection process in this paper, but are aware that this is an important activity to include.

Does the value star approach provide opportunities and negate some of the barriers for collaboration, creative synthesis and knowledge sharing, early in the innovation process? We firmly believe that by taking a new look at value creation, by broadening the design object and by identifying and utilising knowledge resources and communication linkages between stakeholder companies, strong interpretative structures can be configured. The whole essence of the interpretative structure is to create a temporary space for innovation, based on a set of specifically configured competencies for the task at hand. This activity is not confined to the early phases of the innovation process, but was only observed in this context for the study described here.

Regarding the opportunities for value chain based eco-innovation, we believe that this study has demonstrated clear potential to involve competencies, knowledge and experience in the product development process that a traditional sequential approach to product development would not allow for. Although not discussed in this article, a set of tools have also been identified and tried out for this process [Mougaard and Knudsen 2009]. As regards barriers, the main limiting factors would most likely occur in terms of confidentiality, competition, intellectual property and scale issues, as discussed earlier. One further barrier, identified during our study was that of transparency. Even though the supplier company had a highly profiled environmental image and strategy, plus a flexible and agile organisation, these properties were not easily translated for the customer companies, into candidate competencies for a close collaboration. A potential barrier, therefore, could be the lack of sufficient description of/insight into the partner organisation's competencies.

The mechanism of the value star: a sledgehammer to crack a nut..? We are fully aware that the model proposed in Figure 6 is not applicable as a model to aid value star based eco-innovation in an industrial setting, as it is presented here. This was not our intention with the model. Our idea of presenting the mechanism in this manner was to facilitate the synthesis of a number of existing theoretical views on competence-based approaches to ecodesign, and to begin to understand the contents of the pre-phases to a co-development activity between two or more companies. This model can be developed further, in a theoretical dimension and/or towards a normative description of the process of value star based design.

Are companies really moving towards becoming *organisers of value creation* and away from a traditional sequential value chain approach to business? The simple answer to this is "not all". However there is certainly a tendency towards the inclusion of users and other stakeholders in the early innovation process and the necessity for product developing companies to collaborate more closely up and down value chains, due to increasing complexity of products and also to the global dispersion of technology, production and markets. Both [Chesbrough 2006] and [Normann 2001] have key examples and observations of this shift.

The findings from both case studies were to a high degree a validation of our hypotheses; we found that there was a dominant company in case 2, which drove the process of eco-innovation, based on the value star (hypothesis 1). Furthermore we observed that both cases embarked on the charting of the product's life cycle and also the connected stakeholders and the user's activity cycle, in order to be able to broaden the design object and to create sufficient space for innovation (hypothesis 2). However, the experiments were limited in this study, and in order to achieve certainty in the results of this experiment, a broader execution of the whole workshop setup should be carried out and repeated on a number of cases. For example, the fact that both companies in case 2 were already interested in creating a closer relationship to each has surely influenced the collaboration in the experiment, and the motivation for the supplier company to become more dominant (and therefore more interesting for its customer). Only a larger scale study would overcome issues such as these.

In our study and this paper, we have focused particularly on the use of the value star approach to create advances in eco-innovation and to pull together theory contributions regarding competencies in the field of ecodesign. However, the resulting mechanism presented in Figure 6 looks like it is generic enough to be applied simply to focus on innovation, without necessarily having the 'eco'.

7. Conclusion

We have attempted in our paper to describe the mechanisms, opportunities and barriers for eco-innovation when using a value star approach. We have arrived at an interesting theoretical model, showing the mechanisms for co-developed eco-innovation, based upon a set of useful insights. We intend to continue this research by growing and repeating the experiment to a number of additional cases. Our study has shown us that the field of eco-innovation within the value chain is indeed an important but neglected area of attention, which we believe holds many more interesting findings.

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