PARTICIPATORY ENGINEERING: ESSENTIAL BRIDGE IN INNOVATION

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ABSTRACT

Based on a grounded approach this paper introduces the notion of participatory engineering: the participation of downstream stakeholders from operations in upstream innovation activities like engineering. An abstracted description of the overall innovation process, the IDER-model, is used to position the activities of these innovating actors. Participatory engineering occurs at a stage in which the product/service concept and all associated operational processes are developed in a user-centered fashion, where the operational actors are the future users. The downstream actors don't participate as performers of the engineering activities but contribute as informants. At the same time they initiate their own contribution to the innovation process and get prepared for the product that soon will be produced in their operational processes. The grounded approach taken in this study resulted in describing the basic social process of participatory engineering as an interaction process that aims to synchronize the incongruent mental models of the actors from development and operations respectively. Seen through the lens of the IDER-model synchronizing clearly relates to the field of socio technique and related notions as heterogeneous engineering.

INTRODUCTION

User centered design, or UX, places the user of the end product central in its development processes. These users are actors that are positioned outside the innovating organization and form the target group of the innovation process. Bringing these users inside the development process is typically referred to as participatory design. Buur & Matthews (2008) introduced participatory innovation as a combination of some existing user-oriented design approaches and complemented with a market and business (model) orientation. In this perspective initiating business actors work collaboratively with industry partners (i.e. the future users) on the conceptual design of new coherent product/service concepts including possible associated business concepts. The participatory innovation perspective seems to extend the participatory design process to cover the full innovation cycle from idea to market. However, in its readings participatory innovation has a dominant focus on involvement of end-users and on developing conceptual business models and overlooks the stages that sit between design and use. And with that it also overlooks the innovating actors in between the designers and end users.

To bridge the gap between design and realization this paper reports on a research project that investigated the transition from development processes to processes in the operational chain like manufacturing and assembly. These insights come from a large set of empirical data collected in a grounded study (e.g. Glaser & Strauss 1967) that investigated the interface and boundary transition from product development to manufacturing and assembly. This particular study took a social constructivist approach to describe and understand what happens among the participants representing the respective processes of development and manufacturing.

The paper is structured as follows. To be able to position the transition activities between development and the operational chain within the overall innovation process, first an abstracted perspective on innovation is introduced. This IDER-model describes product innovation at an abstracted level from Initiation, via Design, followed by Engineering to reach Realization, hence IDER (Smulders et al. 2014, Smulders 2014). The

IDER-model will also serve as base for presenting the research findings later. The paper continues by presenting the research approach and research process. The results are presented in three stages. It starts by describing the social process among two sets of actors which is followed by describing the new notion of participatory engineering. Finally it uses the IDER-model to position these findings as part of the overall innovation process. The paper ends by elaborating on this new notion and by putting this in perspective of the total innovation process. Some challenging research issues will conclude the paper.

THE IDER MODEL

Innovating is about the realization of something new in an existing environment. The recent hype on design thinking caused us to examine what happens if design thinking is applied outside its conventional domain of new product development (NPD). Based on the generic steps as found in literature on product innovation processes (e.g. Roozenburg & Eekels 1995, Ulrich & Eppinger 2008) an abstracted model was developed that positions the design activity relative to its associated activities. This resulted in the IDER-model in which all four stages of innovating are sequentially dependent and each stage is characterized by a different set of dominant process characteristics (Smulders et al. 2014). The first element 'I' of *initiating* covers the front end of product development by, for instance, market research and/or ethnographic studies. The second element D of *designing* concerns the development of concepts of the new product/service. The third element E covers the *engineering* and embodiment of the artifact and the associated development of the necessary manufacturing processes and tools. Engineering aims to validate and consolidate what comes out of the D element and to prepare that content for implementation in the totality of the R element. The fourth *realizing* element R aims at inserting 'life' in the value chain, that is, ramping up all activities associated with, e.g., purchasing, logistics, production, sales and use of the new product. The R-element is to be seen as a new or adapted socio-technical reality in which actors perform on a routine basis activities that are part of the overall value chain, including the use of the new product or service. This situation marks the end of the innovation-cycle (and possible the beginning of a new one). The R-element therefore stretches far beyond the product only to include all the processes in a performative state that are necessary for realization of the product innovation envisioned.

If, and that is assumed here, the R-element includes all processes, then the three preceding IDER-elements, thus IDE, also need to stretch beyond the product to include all these necessary objects to be innovated. Think of the department of legal affairs that details the contract with a new supplier, which is very similar to what engineers do when they detail components of the product and decide upon tolerances. And like product development, contract development first goes to a similar cycle of 'initiation' to look for suitable suppliers, 'design' to discuss the ins and outs of what will be supplied before the concept contract ends up on the desks of legal. And in this sense, each discipline (or innovating actor) that is affected by the innovation process moves through its own IDER-cycle to prepare the new content and make it fit for use in the existing socio-technical system. Therefore, the IDER-model must be seen as a system of nested sub-IDER-cycles (Figure 1) that are illustrative for its recursive character. Every development activity needs to be initiated, designed, engineered and realized. The total set of realized development activities will form the integrated whole of the operational processes. The IDER activities are sequential dependent! One can't realize any object, if there is no 'engineering' that aims to predict its robustness that again is part of a designed conceptual frame that at some point is initiated because of the need to have such an object for full fledged realization (R). The duration of IDER-cycles can range from seconds to months and years. This depends on the level of aggregation.

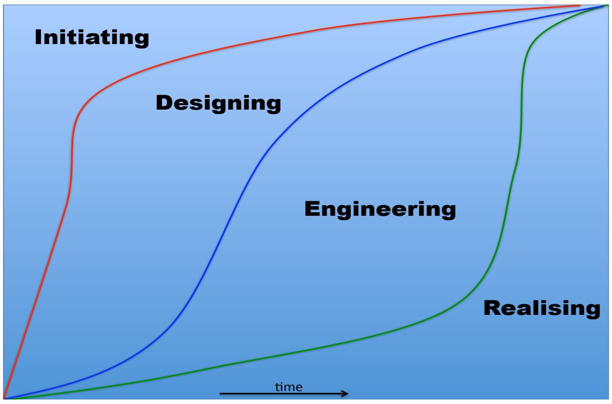

Figure 1: Schematic representation of the nested and recursive IDER-elements over the full innovation cycle. (Smulders 2014).

Over time and towards the end of the overall innovation cycle less and less objects need to be developed and need to go through IDER-cycles as Figure 1 aims to illustrate. At the same time, more and more content (i.e. realized objects) ends up in operational processes that progress towards their final performative state.

If, and that is assumed here, all objects have their own IDER-cycle, then the summation of all these sub-IDER-cycles make up the full organizational product innovation cycle that is also represented by an IDER-cycle, hence where we started from. From this point of view the IDER-model may be regarded as a basic innovation cycle at organizational level that is applied to every object (process or artifact) that is part of the overall object of innovation, that is, the new (or adapted) operational processes that produce this new object (Smulders 2006 & 2014). Based on the observation that the IDER-model is applicable at any level for any object it is suggested to be a 'process-within-similar-process' that follows the metaphor of the nested doll principle, i.e. the matryoshka principle.

RESEARCH APPROACH

The research reported here aimed to uncover the socio-interactive perspective on the boundary transition from NPD to Manufacturing. On the level of the social process concerning the actors there is not much literature on this particular subject. The aim was to identify tentative elements and their relationships to build a conceptual theoretical construct of social interactions. Within the empirical sciences, the inductive approach is directed from empirical data to theoretical conceptualization (Swamidass 1991, Locke 2001) and the rhetoric tends to follow the sequence 'method, data, findings, theory' (Daft 1985). This is opposed to the hypothetico-deductive rhetoric which tends to follow 'theory, method, data, findings'. From the options within the empirical sciences, like action research, ethnography and case studies, a choice was made for grounded theory as the most appropriate method at this juncture in the project. A grounded approach following the work of Barney Glaser (e.g. Glaser & Strauss 1967, Glaser 1978 & 2002, Goulding 2002, Locke 2001) was applied. This approach is believed to be different from the work of Straus (Straus & Corbin 1990 &1998) who parted from the original work by both Glaser and Straus in 1967. It was the rigidity of collecting and analyzing data that were according to Glaser (1992) in contradiction with the aim of the original work, to uncover the basic social process. In fact this rigidity left not enough space for the necessary creativity and inductive leaps that bring the myriad of observations, categories and tentative notions into one theoretical notion. To illustrate how important the proper naming of observed patterns of interaction is for instance Locke writes: "Grounded theories are very much oriented towards micro level processes reflected in action and interaction. The researcher focuses on the study of patterns of behavior and meaning which account for variation in interaction around a substantive problem in order to arrive at conceptually based explanations for the processes operating within the substantive problem area" (Locke 2001, p. 41). The NPD-Manufacturing interface forms the substantive problem area that was explored at the micro level of interactions between the actors. To arrive at a socio-interactive perspective, i.e. a description of the social process among the divers actors, conceptually based explanations are needed that could account for the patterns of behavior that will be observed in our empirical data.

THE RESEARCH PROCESS

The research process of the grounded theory is in fact one integrated process "whereby the analyst jointly collects, codes, and analyses his data" (Glaser & Strauss 1967, p. 45]. During this so-called theoretical sampling the researcher sort of oscillates between the two main activities: the collection of empirical data and the interpretation of that data including deciding for adjustments in the next step of data collection. One of the ideas behind grounded theory is to analyze parts of data immediately after it has been collected and then adjust the plan or viewpoint for another data collecting activity. Even during interviews the remarks of the interviewees could lead to micro adjustments within the interview protocol. "The rationale of theoretical sampling […] is to direct all data gathering efforts towards gathering information that will best support the development of the theoretical framework" (Locke 2001, p55). This dual track research path in which data collection and data analysis frequently overlap is 'a striking feature of research to build theory' (Eisenhardt 1989, p538). The ultimate goal of theoretical sampling is to collect data to the point of theoretical saturation of the emerging new theoretical concepts. The research process within this study had three stages: scanning, focusing and integrating. The goal of the scanning stage was to develop a feeling for the relevant problematic situations regarding the interface. Therefore, a total of 65 people in three companies were interviewed, primarily in-group settings. The interview protocol for this stage, which was based on the nominal group technique (Delbecq and Van de Ven 1971; Claxton et al 1980), resulted in 26 regularly occurring obstructive situations concerning the researched boundary. A first induction stage with these 26 situations resulted in six preliminary theoretical categories that were helpful concepts in the second, focusing stage of the research. During the second stage a total of 14 in-depth interviews were held in two companies (seven per company) concerning two recent product innovation projects per company (a total of 4 projects). Both companies are of average size (1000-2400 employees) and global players in their niche, respectively high-end consumer electronics (Audiocom) and high-end lighting systems for events (pop festivals) and nightclubs (Lightcom). The interviewees, working either in design or manufacturing, were all questioned individually in semi-structured interviews lasting 1.5 hours. During the interviews, the main topic was their collaboration with the other party, with the product innovation project being used as a 'vehicle'. After each interview the tapes were examined and early insights were noted and taken into account during the next interview. Finally all interviews were transcribed (265 pages) and subsequently analyzed and interpreted with an open mind whereby previous categories (from literature and the first research phase) and insights were considered to be possibly relevant. A first exhaustive inductive examination resulted in 1310 text incidents related to the researched interface between development and production, and classified a total of 37 concept categories (including the previous categories). A further analysis resulted in two related central categories, one on learning and learning styles and the other on changes and interventions. Many of the other categories appeared to have relationships with these two. The third and integrating stage of the research aimed to bring together the two central categories and interrelated properties into one core category. Given the abundance of empirical data assembled in the second stage, it was decided to use these for the third stage as well. In order to increase the theoretical sensitivity, use was made here of a number of existing theoretical concepts from the literature about learning and about change management. These existing concepts worked as a source of inspiration for the conceptualization process in this last inductive stage. This stage is the most important one for arriving at a conceptual theoretical framework and it requires creativity from the researcher in order to be able to make the inductive leap, or series of leaps. In this case, the conceptualization process encompassed numerous iterations between conceptual propositions and empirical data to ensures its groundedness.

RESULTS

We will introduce the results of the research in threefold. The first being a nominal description of the social process as uncovered during the analysis. The second perspective discusses the participatory engineering process as such. The third, being an elaboration of the observations seen from the perspective of the IDER-model.

THE SOCIAL PROCESS

For being able to describe the basic social process of the actors representing NPD and operational processes a richer description of a mental model is necessary. According to Kim (1993) the vast majority of an organization's knowledge resides within the mental models of the individual employees. Mental models are built up over many years of education, training, experience and work (e.g. Kim 1993, Cannon-Bowers et al. 1993, Mohammed & Dumville 2001), they become ingrained with a very deep understanding of our specialized line of work and enable us to carry out our work effectively and efficiently. This resembles what Dougherty (1992) mentions about departmental 'thought worlds' that each have their own intrinsically harmonious logics and ways of reasoning. But, mental models not only cover thought activities, but also action patterns. Especially, routine behavior is considered to be part of and integrated with the knowledge structures residing in the mental models (Kim 1993). Therefore it can be assumed that the totally different work situations between explorative NPD and exploitative Manufacturing in terms of activities, goals, time frames, assumptions and orientation, result in dissimilar or even incongruent mental models. The understanding within each model goes deeper than explicit understanding that can be taught because it contains lots of implicit and tacit knowledge and is also referred to as implicit and tacit understanding. For instance, an actor from Manufacturing understands why something is not going to work very well in production, but is unable to articulate that insight and make it explicit enough that the actor from NPD, who has a different mental model, understands the same truth. On the other hand, the actor from NPD has an implicit and thorough understanding of the new product. He knows all about the considerations and rejected alternatives that underpin the design at a certain moment (Dorst 1997). Like the implicit knowledge within Manufacturing, it is impossible to make all that NPD knowledge explicit and ready to convey to other actors until they have the same deep understanding. One cannot transfer understanding, because comprehension is an individual process that is guided by the individual mental model (Kolb 1984, Lynn et al. 2003). The only thing that actors can do is to look for those knowledge components that could link the two dissimilar forms of understanding or mental models. This process of interaction that aims to connect the incongruous mental models is referred to as synchronization and seems to be an important social process among the actors. It is a two-sided process whereby both parties attempt to introduce the other to the understanding that resides in their own mental model. This is actually a difficult and complex process since the participants need to extract the right information from their subconscious tacit knowledge, tacit understanding and tacit to inform the comprehension process of the other actor. Understanding of what is conveyed to them is only possible when the participants are able to connect the new information on the product to their existing mental models by making linkages to, what Postrel (2002) calls, docking points. What Lynn et al. (2003) mention about this process of understanding seems related. They say that for information to become internalized and understood it should be congruent with the mental model of the individual. They mean that there must be a fit between new information and existing mental models which implies that senders as well as receivers must actively seek for this fit to enable the right interpretation that leads to understanding. In order to realize the transfer there seems some sort of explicit ánd implicit absorption of the information (Kim 1993). The actors do not specifically aim, or at least should not aim, at making their mental models coincide during the interactions (specialists stay specialists). However, they do try to share the information stored in the individual mental models with each other while developing their product. The sharing process has a transitional character, meaning that information belonging to an actor with one mental model needs to be transferred to another actor with another mental model. The following quote by an actor from Manufacturing in which he reports about an interaction with NPD illustrates the synchronizing process.

> "…It is very hard for our assembly people to understand why the product is not finished when we receive it from R&D and often it is very hard for R&D to understand, why it is such a big problem for the assembly people. It is a different world, they are coming from…" (Lightcom.Mnfct.7.316)

Transcript 1: Text describing the example.

The large and inherent differences in object worlds (Bucciarelli 1988) cause similarly different thought worlds (Dougherty 1992) that somehow need to be bridged during social interactions, here termed, synchronizing incongruous mental models.

PARTCIPATORY ENGINEERING

The interactive process among the actor representing the development department and those from operations, can be seen as a participatory process. The actors from manufacturing and assembly are in fact the users of the final design with drawings (measures and tolerances), assembly sequences and procedures, etcetera. During the E-element of the innovation process two interrelated engineering processes run in parallel: product engineering and process engineering, a process also referred to as concurrent engineering. The active involvement of actors from downstream operational processes provides an additional perspective that is here termed 'participatory engineering'. The actors from down stream processes bring their knowledge to the engineering process in the hope that the final result of the development activities will fit in their processes without too much adaptions and engineering change orders. The latter are unforeseen engineering activities that iterate between the E-stage and the R-stage of the IDER-model and heavily disturb the ramping up of the operational processes. These kinds of iterations typically concern extensive interactions among the different actors in which synchronizing as social process occurs. Therefore actors from for instance NPD within Audiocom put a lot of effort in preparing these participatory meetings. The following text transcript shows such for a meeting around a prototype.

"…they [NPD] made a good preparation for these meetings, so there were models, and some drawings and something which we could look at and then….during the meeting we all….. I think we were….our [Manufacturing] technology manager was involved and the software person was involved and the mechanical architecture person was involved, and electrical…" (Audiocom.Mnfct.3.55)

Transcript 2: Preparations for participatory engineering meeting

The preparations of these participatory meetings typically concerned the explicit use of boundary objects to facilitate the synchronization process (Carlile 2002, Smulders 2006). But even with the help of such boundary objects the synchronization of these incongruent thought worlds during participatory engineering meetings still require considerable effort (see Transcript 3).

"…it is very … it is difficult if you have […] some development people that are working on the project all the time and have the product in their mind and then you ask [Manufacturing] people to come in to give their opinion…" (Lightcom.NPD.4.34)

Transcript 3: Participatory engineering meetings are not always easy meetings.

The fact that NPD actors work on the product every day provides them with deep knowledge structures that are hard to exchange by superficial conversations. So many decisions and alternatives that have been passing by are not explicitly visible (Dorst 1997) and very hard to recollect during such a meeting. These participatory engineering meetings are not always sufficient to arrive at products that are easy to produce and assemble. Meaning, the development was not enough users-centred for the users in production as the following transcript illustrates.

"…Typical is, that they can't make the assembly in the time set for it. So because it is too complicated, or sometimes it is the wrong person we have put in the assembly line. Sometimes we first find out when we go live, everyone has learned but two people have not learned as fast as the others, some have to make the same process 200 times before they know what to do." (Lightcom.Mnfct.1.362)

Transcript 4: Participatory engineering meetings are not enough.

The observation of the participating downstream actors in engineering processes brought the insight that these actors can be considered as being users too. However, not the users and consumers often referred to in the design literature. These mid-innovation users do participate in upstream processes in a similar fashion as consumers, they inform the actual innovating actors. Here however, they also prepare themselves for what comes their way soon. And similar to participatory design, these interactive processes need to be carefully planned and are also no guarantee for success downstream.

PARTICIPATORY ENGINEERING AND IDER MODEL

We have seen that the participatory engineering process serves two goals: informing the upstream actors and preparing the downstream actors. Companies have obviously learned from the former over-the-wall behaviour that early involvement of downstream actors is in favour of undisrupted implementation of the object of innovation in downstream processes. As we have discussed earlier, the IDER-model is representing a basic innovation cycle (Smulders 2014) that is to be found at many instances during the overall innovation process. All these cycles are aimed at the realization of many (sub-) objects that in total make up for all operational activities that need to be adapted, changed or developed in order to arrive at volume production within the operational chain. If we look through the IDER lens we see that the involvement of actors from the R-element during activities within the E-element in fact can be seen as the initiating activities for these R-actors. At the same time these are the 'robustinizing' activities by the E-actors to prepare for 'their' realization, which is in our case ramp up. What is contented here, is that the E-R activities of one set of actors forms the I-activities of the next set of actors. In other words, in sequential dependent work packages realization for one is initiation for the other. From this perspective, participatory engineering could also be referred to as 'participatory initiation' seen from the perspective of the downstream actors in which the upstream actors participate. During the ramp-up of the operational processes, the participatory perspective is also present. Then the operational actors are in the lead of a process in which the upstream actors play an informative role (Smulders 2006). According to Smulders & Bakker (2012) the social process of synchronizing incongruous thought worlds knows many manifestations ranging from story telling, perspective taking, dialogue mapping, etcetera. All these interactional forms are aimed at bringing the innovative idea into good currency as a whole and as its constituting parts. Almost 30 years ago Andrew van de Ven (1986) already pointed to the central problems in innovation. Two of the four, bringing ideas into good currency and managing part-whole relationships, show similarities of what is being brought in this paper. For bringing ideas into good currency Van de Ven points to social and political dynamics that are essential. Putting the political dynamics on the side, the social dynamics might somehow be covered by the synchronizing process. Especially the absorptive capacity (e.g., Cohen & Levinthal, 1990; Zahra & George, 2002) of these social practices plays a crucial role in the success of the transitions from one actor (group) to another. Absorptive capacity of an organisation (or part thereof) is defined as the ability to acquire, assimilate, transform and exploit new knowledge (Zahra & George, 2002). If the absorptive capacity within innovation step 'n' is too low to internalise and work with new knowledge coming from step 'n-1', then the innovation process comes to a halt. In other words, the socially embedded organisational routines (Feldman & Pentland 2003) of any actor or group of actors must be capable of absorbing and handling whatever comes out of step 'n-1' and add its disciplinary value for handover to actors from step 'n+1'. And as can be read from the transcript below, absorptive capacity at this intra-organizational level is the result of a two-sided social process.

> "…the cooperation, the communication between us is so close, so they [NPD] see the problems we have, they see and hear and feel them, because during the ramp up phase, when we have these problems we need them [NPD] to help us to find what is wrong here. When we have found the reason we have to work together to find some practical and good solution which satisfies both the product quality and the production…[efficiency] …" (Audiocom.Mnfct.4.278)

Transcript 5: Social interactions that increase the absorptive capacity.

It seems that actors from both sides of the boundary have considerable influence on the intra-organizational absorptive capacity by careful developed interventions based on emphatic insights (Smulders 2003). This way, parallel running of e-R activities of upstream actors (with small 'e') and I-d activities of downstream actors (with small 'd') bridges the gap between development and volume production. And during this transition, the value adding activities change from participatory engineering to participatory initiating.

DISCUSSION

We have seen in this paper that actors from downstream processes that participate in upstream activities could facilitate the boundary transitions. Especially if this participation occurs during the so termed 'engineering' activities of the upstream actors, hence participatory engineering. In this paper we have looked at engineering in its purest sense, namely, an activity that is specifically aimed at 'robustinizing' the preceding conceptual work and prepare this for predictable behaviour during use in any of the downstream processes (Smulders 2014). In doing so we go beyond the traditional meaning of the engineering activity as found in the engineering sciences related to artefacts. Engineering as robustinizing any object, be it products, technologies, processes, organizational structures or social systems, can only be done if proper knowledge and heuristics are available. Such perspective on engineering shows similarities with the notion of 'heterogeneous engineering', see for instance the work of John Law (e.g. 1992, 2011). His leading observation is that even a building is part of social, technological and natural heterogeneous system that somehow shows interdependencies with tied and loose couplings. This perspective belongs to the research stream around the actor-network theories (ANT) where "agents, texts, devices, architectures are all generated in, form part of, and are essential to, the networks of the social" (Law 1992, p379). If we combine this with the idea behind the IDER-model as a basic innovation cycle we see that E-activities need to be directed to robustinizing all these objects in order to realize an efficient operational process. Such is according to Law, a heterogeneous system of interconnected flows (1992). The engineering of this large diversity of objects then could fall under the umbrella of heterogeneous engineering. Note that the observation of this large array of engineering activities is just a nominal observation regardless of who performs these engineering activities. For instance, the data of the study reported here, suggests that actors of the operational chain do the 'engineering' of their own social system of interactions to prepare these to become the performative part of the routines (Feldman & Pentland 2003). Whereas the ostensive part might be laid down in assembly procedures created by development actors. This points to a much acceptable perspective on social engineering then the perspective of the 80's that pointed to detached and technocratic social engineers that would be capable of engineering the society. In future research we plan to look through the IDER-lens to investigate how social technical systems are coming into being.

CONCLUDING

Based on the observations and grounded theoretical constructs uncovered in the study a first sketch of participatory engineering was given. First of all, the actors from the operational chain participating during the engineering process are to be seen as users. Meaning that they become users of the information delivered to them by the upstream actors. Such active involvement of any downstream actor in upstream development activities with the objective to facilitate the upstream-downstream transitions could be seen as a participatory act which was found to have two forms, informing and preparing. Informing towards those that do the 'engineering' work, and preparing as initiation of the future activities downstream. Interesting to note that by participation of downstream actors the upstream process becomes 'user-centred' regarding the next stage. If we draw on this, one could reason that users are to be found throughout all stages of the innovation process, and not just at the end in the role of consumers.

Secondly, synchronizing incongruent mental models was found to be the basic social process among actors from development and operations. The habitat of their respective processes is different in many ways, varying from, abstraction levels, time horizons, learning attitudes and other socially relevant dimensions (Smulders 2004 & 2006). Having a daily life in such divers social environments will result in very different and even incongruent mental models (Berger & Luckmann 1966) or thought worlds (Dougherty 1992).

Third observation is that the 'engineering' activity is much wider than just the traditional engineering of an artefact. Apart from the artefact, all operational processes and sub-processes like purchasing, logistics etc. that are affected while innovating need to be engineered. Therefore, and building on the IDER-model we also referred to this as 'robustinizing' the concepts that come out of any design D-activity and prepare these for handover to next set of innovating actors. And the actual handover is the Realization R-activity for the upstream actor group and at the same time the Initiating I-activity for downstream actors. Some support for this wider perspective on engineering was found within actor-network-theory where reference is made to heterogeneous engineering covering social and institutional dimensions (Law 1992 & 2011).

Finally, as we have seen in this paper, it is important to discern the actor of the value adding activity during innovating from the downstream participants. We saw that downstream actors participate as future users and by that have influence on what they will receive later. By doing so both the upstream and downstream actors are able to collaboratively create smooth transitions downstream processes without (too many) engineering change orders or iterations in general. This observation seems to connect the research presented in this paper to the field of innovation implementation. Some future research therefore will be aimed at connecting these two separate research streams, because from the findings presented here we could come to the conclusion that participatory engineering in its widest (heterogeneous) sense forms an essential bridge in any innovation process!

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