PROCEEDINGS OF PRAGMATIC CONSTRUCTIVISM

journal homepage: www.ProPraCon.com

Communicating design knowledge to support technology management in the manufacturing industry: an application of pragmatic constructivism

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Abstract

The aim of this paper is to the advance pragmatic constructivist understanding about communication in the product development context. In particular, the paper provides new understanding about how proactive truth about design knowledge can be constructed and communicated within product development actors. The paper shows how company representatives in the manufacturing environment, e.g., managers and engineers can together understand the customer-value-creation mechanisms of a specific product and integrate their expert knowledge into visual form. Building the collective understanding requires communication between these actors. Ultimately, the actors may be able to construct a useful proactive truth about related business potentials and thereby support technology management in the product development context.

Keywords: communication, fact construction, technology, design knowledge, design reasoning pattern.

1 Introduction

> “Communication is part of every job and every role we play. It carries bits and pieces of reality constructs around between people. It connect actors and merges their reality constructs to create and maintain practices by encompassing construct with which they cooperate, understand and trust each other. […] By means of communication we can cooperate and organise complex processes. Without communication that would be impossible.” (L. Nørreklit, 2017, p. 48)

The aim of this paper is to advance the pragmatic constructivist (PC) approach by increasing understanding about communication in the product development context. The goal is to answer the question: *how can product development* *actors communicate purposefully to construct factual possibilities about new technologies?* This question is highly interesting in terms of both developing practice and theory. Our approach is to bring together and seek synergy from two different field of research to address the research question: PC and engineering design science. Theories and practices from engineering design science support the understanding of technology in technical sense while PC supports the understanding of human behavior in complex environment, such as in the manufacturing industry. In management accounting research, PC has advantages related to other approaches such as taking human values into account (in contrast to, for example to actor network theory, see Jakobsen, 2017). Using PC also contributes to the practical relevance of our research paper (Mitchell, 2017).

First, in practice, technology evaluation is action that evaluates the future possibilities and possible scenarios related to technology in specific environment. Trying to understand and foresee the effects of technology (i.e. constructing the proactive truth) is highly related to expert knowledge, opinions and feelings (Boer et al., 1998; Braun, 2005; Park & Park, 2004; Dissel et al., 2009; Scheiner et al., 2015; Laine et al., 2016a, b; Lingens et al., 2016; Winter and Lasch, 2016). In other words, the current understanding and beliefs of relevant actors guide the evaluation of technology in a certain context of practice. Consequently, human action is not determined by natural laws (Trenca & Nørreklit, 2017) which, however, also might be objects of discussion in technology-related decisions.

Second, in terms of theoretical development: a core idea in PC is an actor's reality construction that is dimensioned by facts, possibilities, communication and values (e.g., Nørreklit et al., 2006; Nørreklit et al., 2010; Jakobsen et al., 2011; Nørreklit, 2017). The recent study by Trenca and Nørreklit (2017) calls for further research on organizational performance management in complex cases, with their particular interest in analysing actors' specific ways of reasoning. Oftentimes, the context of product development is considered complex from the viewpoint of management control (e.g., Jørgensen & Messner, 2010), which makes the study of collective fact construction and communication in the product development context particularly interesting (see also Laine et al., 2016b). Some pragmatic constructivist studies in the product/service development context already exist (e.g., Jönsson & Johansson, 2011); Laine et al., 2013; Mitchell et al., 2013; Rantamaa et al., 2014; Laine et al., 2016b; Korhonen et al., 2016; Laine et al., 2017; Leotta et al., 2018). However, no integrative methodology for understanding communication that underpins the construction of factual possibilities in research and development (R&D) has been proposed. This is the case, although specific communicative tools, such as boundary objects and boundary subjects have been proposed to facilitate knowledge integration (Laine et al., 2016b; see also Huzzard et al., 2010; Azambuja & Islam, 2018).

Moreover, prior research in pragmatic constructivism, and particularly on the communication dimension, makes a call for further research on managerial processes in complex environments. Indeed, more research is needed to understand the "genome" of managerial work and the communicative processes therein (and even on the long-term realization of related impacts, in Jönsson & Johansson, 2011). In all, our focus in this paper is on communication, to further understand the communication that would be necessary in technology management.

This paper addresses this challenge by using a real-life case study of an industrial company in which product design knowledge is integrated using a tool called the *Design Reasoning Pattern* (DRP, Lehtonen et al., 2016). The real-life case study shows how the DRP could facilitate determining factual possibilities and realizing purposeful communication. The DRP is a tool that can be used as a structure for constructing information about factual possibilities of product features through their dispositions in relation to other aspects of the production system, which they are eventually manufactured and put to work in (Mämmelä, et al., 2018b). Here, dispositions are defined as the proactive truth (or predictions) about the link between a product feature and the respective future product life cycle and value capture therein. Consequently, each design decision (concerning technology in this context) may affect a product feature, which in turn might necessitate iterative knowledge integration – studying which pragmatic constructivism could be a useful approach (Korhonen et al., 2016; Laine et al., 2016b; Rantamaa et al., 2014)

The presented technology evaluation method with DRP forms a basis for shared understanding about factual possibilities of technology and commitments the actors which supports the task execution (H. Nørreklit, 2017), which represents our theoretical contribution (to pragmatic constructivist understanding on communication). In this research the PC is mainly used as a method theory (Lukka & Vinnari, 2014) which provide tools to understand factual possibilities related to technology. However, as our paper contributes to PC as well, in particular with regard to communication, we could see PC both as a method theory and as a domain theory. The paper acknowledges that also understanding about the motives (values) of actors in organizations needs to be considered to support technology decisions. We are therefore presenting the particular perception of how to integrate four dimensions of pragmatic constructivist approach i.e. generating new company level topoi concerning technology decisions (H. Nørreklit, 2017).

This paper applies the pragmatic constructivist methodology for analyzing communication in product design work in the manufacturing industry, to understand how actors (by using the DRP) use a thorough evaluation of factual possibilities and how they systematically consider the effects of action or a decision – thus attempting to understand the triggering events of intentional action (L. Nørreklit, 2017). As a managerial implication, we are interested in supporting managerial work related to technology decisions, in the manufacturing industry. The systematic use of design knowledge in constructing causality, as in the DRP, to support technology-related decisions forms the main managerial implication of this paper. By using DRP, actors can construct and integrate knowledge about the facts and possibilities upon which new products or product features are designed. To provide meaningful results, sufficient design knowledge is necessary for using the DRP approach, underlining the need to integrate accounting information (business impact estimates, component costs, etc.) with technical knowledge (structural engineering, manufacturing, etc.). As a practical implication, the paper supports the understanding of the value creation mechanisms of technology in specific business environments.

Altogether, the value of this paper is to show that the pragmatic constructivist approach can support the technology decisions in the manufacturing industry by considering the values of humans in the part of organization and using the best available design knowledge to construct the causality. So far, such understanding, in the area of design research, relies largely on technical facts; thus, this paper contributes to the area of design research as well.

2 Literature review

2.1 Communication in pragmatic constructivism

According to Hall (2010) managers use monetary (accounting) information primarily to develop knowledge of their work environment, secondly it is one part of wider information set to perform their work and thirdly managers use verbal forms of communication rather than written reports. Communication brings the actors together, to understand the common managerial task:

> "With infinite amounts of information available and with very little time for analysing the possibilities of having values fulfilled, human beings need practical and systematic ways of generating opinions. This is why, on the basis of their life experience and learning, people develop specific ways of reasoning in communication." (L. Nørreklit et al., 2006, p. 48)

Indeed, it is essential to create viable forms of communication. But what is *communication* from the pragmatic constructivist viewpoint? L. Nørreklit (2017) refers to earlier work by Arbnor and Bjerke (2009), to present the process of communication as subjective reflection of a construct by an individual actor, analysis of the construct by actors involved, externalisation their perception of the construct to others, and even objectification of the construct to a widely accepted definition (see also Henriksen et al., 2004; Nørreklit et al., 2010). Later, constructs can be materialized into artefacts of purposeful type (Henriksen et al., 2004; L. Nørreklit, 2017). However:

> "Although communication conveys perceptions of facts, possibilities, reasons and values among people, communication does not, by itself, uniquely determine what people actually do." (L. Nørreklit et al., 2006, p. 58)

This is why actors still determine how they act, based on their reality construction. Communication is a way to build a common, valid reality construction, based on which actors then decide to act in the way they do. From the viewpoint of this paper, it is particularly interesting which kinds of tools/methodologies of communication could support managerial work in the product development/design context. In other words, we are interested in which kinds of communicative practices could support building up a common reality construction that is valid, in the product development/design context. Indeed, as Laine et al. (2013) see, there is indeed insufficient knowledge of communication in the product development context, particularly concerning the monetary expressions of value (e.g. accounting information). Fortunately, some earlier studies in pragmatic constructivism actually provide some background understanding about communication in the product development context. Specifically, such recent pragmatic constructivist research includes the work of Jönsson and Johansson (2011), Rantamaa et al. (2014), Korhonen et al. (2016), Laine et al. (2016b), Laine et al. (2017) and Leotta et al. (2018).

Jönsson and Johansson (2011), choose to understand communication in the product development context as probes that mean statements that actors make to focus collective attention to significant dimensions by questioning prior understandings and making assertions. The idea of such collective sensemaking in product development has also been acknowledged outside pragmatic constructivism (Laine et al., 2016a), and therefore **communicative probes** could be a viewpoint that could be useful for a wide academic audience. Rantamaa et al. (2014) link communication to **knowledge integration** in product development (see also Laine et al., 2016b). In the paper by Korhonen et al. (2016), communication is concerned with profitability information that supports new service development. Laine et al. (2016b) suggest the use of **boundary subjects** to bridge function borders and write that:

> "There is a clear need for enhanced theoretical understanding of the social process of choosing, constructing, elaborating and communicating accounting facts in the PD [product development] context because of the limited understanding of current PD accounting and control practice and the contextual requirements of PD for interaction between different actors and actor groups." (p. 308)

Laine et al. (2017) notice different top-down and bottom-up **modes of communication** in product development, and also the central role of product development project managers as **communication hubs**. Furthermore, they highlight important messages such as bringing up uncertainties and surprises to a relevant group of actors, and state that "enhanced communication among NPD [new product development] management actors would mean (or require) **co-authorship** and increased attention to **intentional (joint) construction**" of common topoi (Laine et al., 2017, p. 129, emphasis added), i.e. the "concepts and arguments applied in a specific setting" (L. Nørreklit et al., 2006, p. 43)

Furthermore, Leotta et al. (2018) see communication to take the form of accounting information to **verify** if R&D projects and strategies are aligned. In all, it seems the pragmatic constructivist literature underlines the importance of communication but in many studies, communication itself is not thoroughly examined. Indeed, no integrative methodology for communication that underpins the construction of factual possibilities in R&D has been proposed. Therefore, this paper attempts to increase understanding about communication in the product development context, by proposing a methodology for collective sensemaking (Jönsson & Johansson, 2011; Laine et al., 2016a) and knowledge integration (Rantamaa et al., 2014; Laine et al., 2016b), including:

- Co-authorship (Laine et al., 2017) and knowledge integration (Rantamaa et al., 2014; Laine et al., 2016b)
- Boundary subjects (Laine et al., 2016b) and communication hubs (Laine et al., 2017)
- Communicative probes (Jönsson and Johansson, 2011)
- Modes of communication (Laine et al., 2017)
- Communication as a vehicle for verification (Leotta et al., 2018).

2.2 Technology from a systems perspective

According to Hubka and Eder (1996, p. 73) "The term Design Science is to be understood as a system of logically related knowledge, which should contain and organize the complete knowledge about and for design." TTS (Hubka & Eder, 1988) is a major part of Design Science and describes the nature and purpose of technical systems. Hubka and Eder describe the transformation system (Figure 1) and its elements by transforming the operand from an existing state to a desired state. A technical system is a key element of a transformation system but also human work and information are highlighted in this theory. Definition of technology (Hubka & Eder, 1988, p. 260) is linked to this understanding; "technology is the specific way of delivering an effect to an operand." Effects in this scope are material, energy or information. Formulation of such models could be seen as an attempt to form causal chains between selected items (L. Nørreklit, 2017).

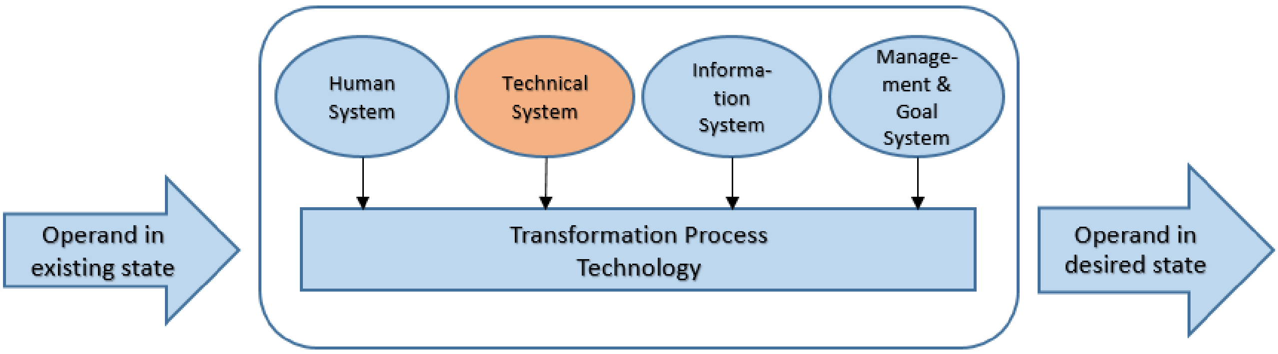

Figure 1. *The Model of the Transformation System in TTS (adapted from Hubka & Eder, 1988).*

In all, TTS provides a theoretical foundation about technical systems. It provides tools for evaluating and understanding the possibilities of technologies that relate to some products examined. TTS presents the idea that **the product** intrinsically has some specific properties, which cause its specific behavior. These properties, and thus behaviors, can be determined by a product designer, which is acknowledged in Property Driven Development (PDD) (see e.g., Weber & Deubel, 2003). The Design Reasoning Pattern (DRP) is a tool that can help actors understand, visualize and communicate the reasoning behind the designing of product. The DRP uses PDD approach (with a distinction between properties and behaviors of a product) as its guiding principle. In order to work, the DRP needs input, guidelines and targets from the business and customer environment – and from product designers to connect the design knowledge to product targets and values that guide work. Building this kind of a shared understanding with a systematic and fact-based approach can be the basis of the evaluation of factual possibilities. In all, from the systems perspective, our approach will focus on the product.

2.3 Technology from an actors' perspective

The main idea behind the pragmatic constructivist approach is to help actors in developing successful, functioning organizational activities in practice. The pragmatic constructivist approach includes assumption that actors always act "under presumption of a specific actor-world relation which they continuously construct, adjust and reconstruct in light of new experiences, context and communication." (H. Nørreklit, 2017, p. 5). This actor-world relation leads to reality construction. To form the reality construction, the four dimensions must be integrated: facts, possibilities, values and communication. Without facts, it is not recommended to make any decisions or actions. Possibilities are based on facts and they have to be known before reasonable actions. Values are needed for motivation and as driving force for actors. Real actions can be done only after communication, e.g., division of labor. (H. Nørreklit, 2017)

But what kind of a context is the product development/design context, from the viewpoint of pragmatic constructivism? One approach is that of technology management, since product development decisions often relate to technology. Generally, technology selection is seen as an important phase of new product development (NPD) activities for future success of firms. Therefore, technology choices are critical but still mandatory (strategic) decisions (Mitchell et al., 2013). Importantly, managers make technology decisions as a part of their managerial work. For related to technology investments, it is essential to try to understand the value of different technological options – also from the monetary viewpoint. What is technically possible is not necessarily economically, socially or politically possible and vice versa (L. Nørreklit, 2017). Some technology valuation methods that prior research recommends cover the **evaluation of the future possibilities of a technology** (Jang & Lee, 2013; Park & Park, 2004). However, we claim that to understand the future possibilities that relate to a technology it is compulsory to understand the **value creation mechanisms** (of that particular technology in manufacturing, in use at the customer, etc.) respectively. In other words, **causal dispositions** concerning technology are needed (L. Nørreklit, 2017). Technology evaluation methods that are based on understanding the product and value creation mechanisms of technology could therefore be beneficial for the product development/design practice (Mämmelä et al., 2018a; 2018b). In this paper, key elements that need to be recognized in a DRP to evaluate the **future possibilities** of technology exploitation are (Mämmelä et al., 2018b):

1. "Technical system intention and business intention";
2. "Product life cycle phases";
3. Desired behavior from life cycle phases;
4. "Product structure";
5. "Technology characteristics";
6. Dispositions between product properties and desired behavior;
7. "Potential effect of technology related to the product"; and
8. "Estimation of financial numbers related to the product".

Indeed, in this paper, information concerning factual possibilities is both **technical and accounting information**, since these naturally intertwine in new product development activities. Moreover, it would be important to look at all the above aspects 1-8 from a **proactive, actor-based viewpoint**, to actually realize the factual possibilities in new product development activities (Laine et al., 2017).

In this paper, our approach comprehends the product in the focus of communication. The reason behind this idea is that a product has specific life cycle phases which interact with departments and actions in the company. In other words, an action done in a company should enable fulfilling the product/business intentions. According to the Theory of Technical Systems (TTS) (Hubka & Eder, 1988), technical systems originate from humans needs; similarly, also valuable product or technology behavior also originate from the work of human actors in a context. That is a reason why the pragmatic constructivist approach can indeed support technology value creation in the manufacturing industry. However, as the selected focal areas for a specific technology valuation exercise are human constructs, natural laws selected for assessment in this exercise are a socio-technical choice (Trenca & Nørreklit, 2017). Such guiding principles can be captured only by constructing a specific understanding of actions and perceptions of actors in an environment. Pragmatic constructivism helps understand the motives of people and evaluate some of the possibilities related to new technologies. In all, our examination of technology management will include evaluating the future possibilities of a technology (Jang & Lee, 2013; Park & Park, 2004; Mämmelä et al., 2018b) by identifying the value creation mechanisms using causal dispositions (L. Nørreklit, 2017).

2.4 The framework of the paper: the application of pragmatic constructivism in product development/design

Based on the reviewed literature above, we can now build our framework. In practice, we will combine the pragmatic constructivist viewpoints to communication and technology management with the DRP. Indeed, the technology evaluation method used in this paper looks at the practical effectiveness by using the best available knowledge and understanding about the product and its design (Mämmelä, Juuti, Julkunen, et al., 2018). This kind of understanding originates from humans actors and it is challenging to study by using mechanist theories or approaches. Understanding also continuously improves during the evaluation process which can be seen a premise of pragmatic constructivism. (H. Nørreklit, 2017)

Proceedings of Pragmatic Constructivism (2019) Vol. 9, No. 1, 4-16

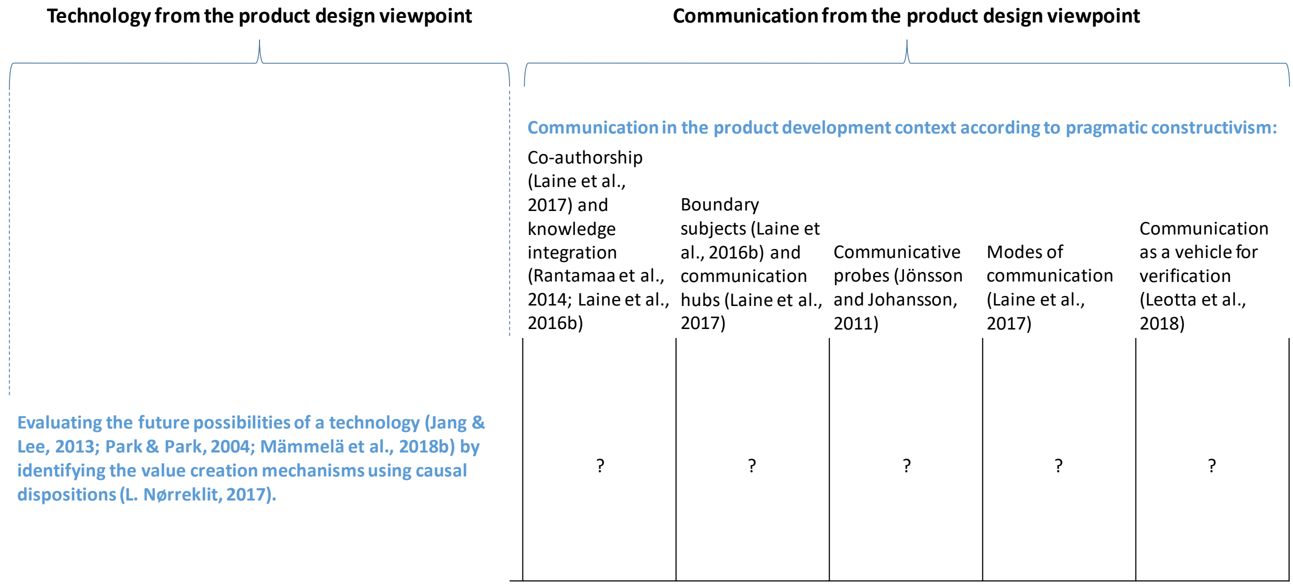

Figure 2. The framework of this paper (the question marks represent lacking knowledge).

In the following, we will show how the use of DRP will add to our understanding of communication in the product development context. Particularly, we will show how DRP contributes fact construction and knowledge dissemination, when, how, and by whom. This way we are able to answer our research question: *how can product development actors communicate purposefully to construct factual possibilities about new technologies?* Naturally, we acknowledge that the tools presented here are only one option, and thereby will describe the use of these tools with potential benefits as well as with possible obstacles.

3 Empirical results and case study

Design principles of used technology evaluation method are shared understanding, modelling tacit knowledge and using participatory methods. All these principles are executed in workshops where the people can communicate and thus form the common reality construction. To help and guide communication, the method focuses on the product and its properties and behaviour as a communication platform.

The main task of product development is to bring products to market through different processes, i.e. product life cycle phases. This means that a product has to behave in specific manner at different stages of product life cycle to be a "good" product. The desired behaviour of this product is related to the values and needs of its owner in each of the product life cycle phases (i.e., an actor that is in charge of the product and it's use in each phase: e.g., a car manufacturer, a car import company, a private car owner, a car wrecker at the scrapyard). Different values need to be converted into technical form (evaluation criteria) for evaluating a technical system. Such conversion represents **co-authorship**. TTS describes that the behaviour of the product is related to the properties of the product and between those properties are links, dispositions. Understanding the dispositions of a product is therefore central to communication in the product development context.

For example, the owner of a car expects that the vehicle is rust-free at least ten years form purchase. To fulfil this value expectation, the designer has to choose certain suitable properties to the product, i.e. here the car. The designer can choose to use, for example, aluminium instead of steel or using anticorrosive treatment. This example represents a simplified description of a real situation. However, there are also multiple different dispositions related to the decision of using aluminium: aluminium is (often) more expensive than steel and can therefore increase the product price.

In this section, the practical results of a case study are explained according to two different levels of communication in the managerial context of making technology decisions: using dispositions to understand the effect of technology (i.e. the evaluation of possibilities) and modelling the dispositions (i.e. fact construction). The presented case study took place in a global original equipment manufacturer (OEM) that operates in the mining business. In 2017, the OEM evaluated metal additive manufacturing (AM) coating technology in their rock drill business. To make decisions about technologies, managers need to have suitable understanding about the possible effects of technology related to business i.e. the value of technology based on technical potential of technology (see Figure 3).

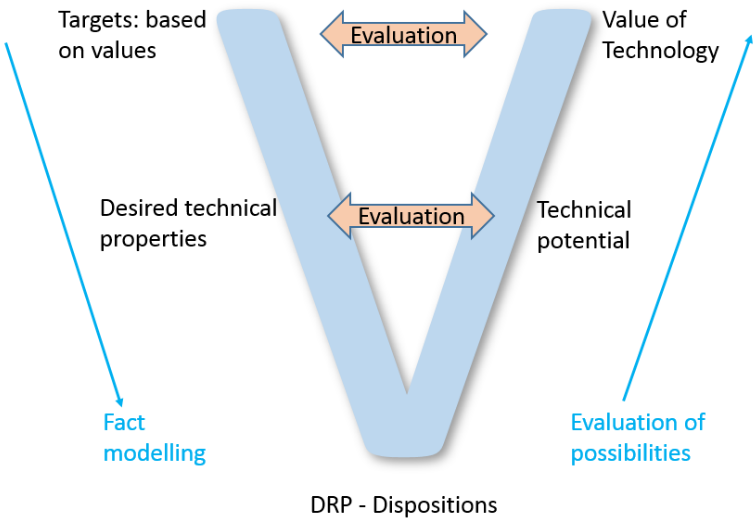

Figure 3. *Technology evaluation at the OEM.*

To manage complexity, the evaluation criteria have to be defined according to decision making principles (Ilori & Irefin, 1997). Again, the criteria are based on actors' values, but values have to be converted into technical properties for technology evaluation, i.e. targets are converted into desired technical behavior. Modelling the dispositions reveals the knowledgeable potential of technology, which actors evaluate against the defined evaluation criteria. Technical and monetary aspects are naturally taken into account in this evaluation method. Also at the OEM, while conducting certain evaluations, some managers preferred technical values and others relied on monetary estimations. Based on the case study, challenges in evaluating monetary values are highly related to sales estimations and market situations: the same product can have significant differences in sales between short periods of time. Moreover, from the viewpoint of the product, a technology incurs transformation through a technical system (Hubka & Eder, 1988). That transformation in the technical system needs to be converted into and communicated in financial terms based on certain business targets.

3.1 Making and communicating the business-oriented technology decisions

3.1.1 Fact construction

The first phase of technology evaluation, at the OEM, was to define the preliminary targets for technology exploitation plans. At the OEM, this target setting was done with the managers who are responsible for the technology decision, in workshops. Target setting is an important phase of starting the **reality construction and integration**; the preliminary targets should be up to date and agreed upon (to a certain degree) by related managers. Actors' values naturally influence the target setting phase: targets include intentions for the product and business and guide triggering events for intentional actions. At the OEM, those events were examined in the coming phases of technology evaluation and the effect of technology is evaluated according to mentioned events. Decisions in this phase concern for example technologies, business goals, products and general values. Usually top managers are involved when making such decisions, representing the **top-down mode of communication**. Values can include, among other things, choices between the best possible performance or environmental friendliness. Importantly, values may be shared (i.e. company value), but in any case, individual actor's possess the values making them subjective.

During the subsequent phases, the chosen values influence the properties of the technical system at the OEM. In the studied case, at the OEM, the focus was to improve the performance of OEM's products by using AM-coating techniques. The manufacturing cost of the product was not the primary target. Other choices done in this phase were the product and business segment selection.

3.1.2 Evaluation of possibilities

After target setting, subsequent technology evaluation phases support the monetary estimation by showing the potential value creation mechanisms and the possible product changes needed. This kind of comprehensive reality construction is rare in practice because of organizational boundaries and conflicting motives. In practice, technology value is evaluated according to change of desired behaviors, for example, 10% improvement of drilling speed can increase the sales or it can support increasing the price of the rock drill. In OEM's case, such estimates originated from their after sales department or other relevant people in a Business Impact Analysis (BIA) workshop. With AM technology, the change of manufacturing processes could also be discussed and evaluated; in OEM's case, manufacturing experts represented the most recommended people for that purpose. Thereby, these workshops represent the bottom-up **mode of communication**. Indeed, the final phase is the communication of technology value, which is done by using monetary estimation based the facts and estimations defined in previous phases. In this communication phase, there is a complete chain from technical properties and business intentions defined by managers to products. Communication makes it possible that the potential of a certain technology is commonly understood, based on the best knowledge available.

Table 1. *The communication focus in the managerial context.*

Communication focus	*Fact construction*	*Evaluation of possibilities*
What	Intentions regarding the product: what product(s) is under analysis? Intention regarding the business: what business is under analysis? Technology in general The main goal for technology exploitation	Monetary estimation of the technology based on recognized dispositions from DRP
Who	Manager(s) responsible for the technology decision and the facilitator of the evaluation (a boundary subject)	Manager(s) responsible for the technology decision and the facilitator of the evaluation (a boundary subject)
Why	To define the preliminary targets for evaluation To limit the scope of evaluation To guide participant selection to next phases	To construct the common reality: - possible technical effects of a technology - possible monetary value of a technology
Where	Target setting workshop	Business Impact Analysis workshop
When	When setting preliminary targets, in the beginning of a technology project (recommended)	When communicating the value of technology Before the final decision concerning technology selection is done (recommended)

In the OEM's case, there were no factual possibilities related to the selected technology. Results were as expected, i.e., the expenses increase by using AM technologies. Therefore, the final outcome of the evaluation exercise was that the technical benefits in this kind of product structure are hard to receive and without increasing manufacturing expenses.

3.2 Using dispositions as a tool for communicating the value of technology

3.2.1 Fact construction

At the OEM, reality construction was continued by describing the targets from the business environment. Facts were identified and the main targets for technology evaluation and input for DRP were given. Knowledge was related to the business environment of the selected product and business. Five key elements were recognized to describe the specific environment of product development in a Company Strategic Landscape (CSL): product structure, strategy, value chain, process and organization (Juuti et al., 2007). A CSL was used in this phase to facilitate the workshop in which related managers were involved. The process and the organization were the most static areas in the CSL; generally they are decided beforehand and cannot be changed easily. Strategy, value chains and product structures, contrastingly, are more dynamic, and based on the choices done by individual managers and guided those individuals' values. The most important outcome of the CSL workshop, in this case, was the attempted common understanding and managers' reality integration. The intentions and targets for technology exploitation were set and finding the triggering events could be started.

In case study, the targets were defined and converted into properties of the technical system. Transforming the values and needs of humans to concrete properties of a technical systems need reflections. This process requires communication between different parties. Because there are no direct links between human values and technical properties, this kind of inference is needed and it is based on the best available knowledge; highlighting the pragmatic approach. In the case, the value of improving the performance of a rock drill was interpreted, among other things, as increasing the drilling speed and operating efficiency. Quality of communication and understanding about the business were key aspects to be kept in mind when organizing a CSL workshop.

The CSL workshop was designed for managers who are responsible for an area of the product's life cycle. The assumption was that these managers would the best people to reflect upon the targets and how to reach the defined targets (see also Laine et al., 2016a; 2016b) – again representing **knowledge integration** and joint reality construction. An experienced designer can have a significant opinion about what is valuable or how things should be done. Therefore, the approach of using product properties and behavior is beneficial if the common understanding is seen valuable as it is in pragmatic constructivism. In the manufacturing industry, the commonly used Cooper's Stage-Gate model (e.g., Cooper, 1990) guides work mainly at the task level, i.e. not as specifically as product properties could. The Stage-Gate model also includes an assumption that managers make big decisions in the beginning of a product development project and more detailed decisions (like product properties) later. However, product development and the communication within are iterative processes in which targets and product properties need to be continuously aligned.

3.2.2 Evaluation of possibilities

In this phase, we have a construct and model our current understanding from human and business values to how the technical system fulfills our need through dispositions. Now it is time to communicate and start the evaluation of the possibilities of a specific technology, in a specific context. In the previous phases, we have set the targets and intentions for technology exploitation and communicated the triggering events related to desired behavior. After those tasks, evaluation of the factual possibilities take place, i.e. we are evaluating the potential effects of technology against targets. To guide this evaluation the best knowledge is collected to a DRP chart and subjected to systematic and logical evaluation. To support the evaluation both technology experts and designers evaluate the possibilities of a technology (**verification**). The main idea is to evaluate the potential change of product properties (caused by a certain technology) and evaluate the change of desired behaviors according to targets defined in the CSL workshop.

In the case study we recognized that the current product structure does not support using the AM coating. That is to say, desired benefits cannot be captured by chancing only the surfaces of the product. The product structure requires also other actions and modifications. Problematically, in OEM's case, there were no factual possibilities according to best knowledge related to AM coating. Table 2 summarizes the findings from this phase of technology evaluation.

Table 2. *Communication focus in with regard to technical aspects.*

Communication focus	*Fact construction*	*Evaluation of possibilities*
What	Converting targets from the business environment to technical properties Business: strategy, value chains, product, process and organization	The technical potentials of a technology related to desired properties and dispositions from DRP
Who	Managers of all related areas (design, manufacturing, supply, …) Facilitator of the method (a boundary subject)	Most experienced designers (verification) Technology expert (verification) Facilitator of the method (a boundary subject)
Why	To set clear targets for technology exploitation (desired properties) Guide the modelling of DRP Provide environment for communication with all related managers	To understand the technical potential of technology
Where	CSL workshop	Workshop
When	In the beginning of a technology project (recommended)	After the dispositions have been modelled in a technology project (recommended)

3.3 *Modelling dispositions by using DRP as a type of communication*

It is central to understand and describe the triggering events for intentional actions. This is done by understanding the properties of the product which the technology has an effect on. Figure 4 shows the simplified DRP-chart from the case study. The desired behavior is in the left and right side of the chart. Triggering events and product properties are in the product structure boxes. Targets and technology guide modelling of a DRP chart. This phase constructs most of the fact base related to technology evaluation. In the AM case we were only looking at the components surfaces because the selected technology has only effects on those components areas.

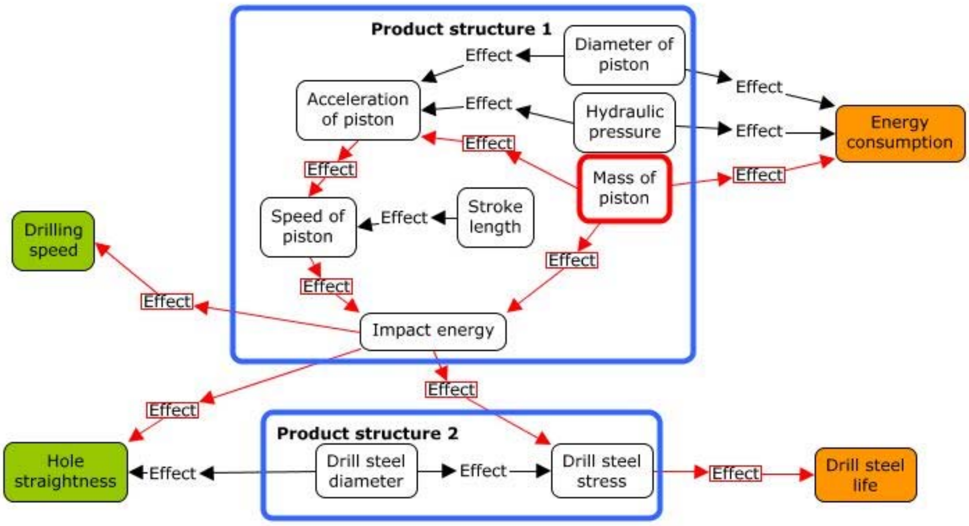

Figure 4. *An example of a simplified DRP-chart (adapted from Mämmelä et al., 2018a).*

A DRP chart is modelled with the most experienced designers and it is based on targets (desired behavior) and product properties. Modelling in reverse order guides the work and ensures that only the most influencing factors are shown in the DRP chart. This kind of modelling and communication between designers is uncommon based on the case study done. However, it could allow new types of **communicative probes**. The reason of the uncommonness of such modelling can be – as the case study shows – that even the most experienced designers have different reality constructs about how the object of design affects desired behaviors. In general, the understanding can be wrong but the disposition act as it is designed. This was the case for example related to the understanding about the shape of the globe; maps based on the flat globe worked fine even if the reality construction was wrong. Modelling and communicating the understanding by using a DRP is seen beneficial to evaluating the future possibilities of technology; and more importantly, to improve the understanding of a current situation. In practice, the DRP is modelled in multiple workshops (Table 3), first with individual designers and after the information seems saturated, the validity of a DRP chart is tested with (all) related designers.

Table 3. *Communication focus in technology evaluation.*

Communication focus	*Fact construction*
What	Dispositions between the product properties and behavior
Who	Most experienced designers available (recommended 2-4 persons) Facilitator of the method (boundary subject)
Why	To understand and model the possibilities of technology
Where	Workshops, with individual designers and validity tested with (all) related designers
When	After the targets are set in a technology project (recommended)

In all, our case study represents an in-depth examination of technology valuation. The empirical results show that communication among relevant actors is of utmost importance when evaluation both technical and monetary values, and presents ideas for facilitating design knowledge communication in the product development context.

4 Discussion and conclusions

In this paper, we have studied technology evaluation in the manufacturing industry based on the pragmatic constructivist approach. Figure 5 summarizes our empirical results from the viewpoint of the framework of the paper, and forms the basis of our contribution to pragmatic constructivism. As the figure shows, we can now supplement earlier studies by elaborating upon some aspects of communication in the product development context, particularly concerning technology decision making.

Technology from the product design viewpoint	Communication from the product design viewpoint				
	Communication in the product development context according to pragmatic constructivism:				
	Co-authorship (Laine et al., 2017) and knowledge integration (Rantamaa et al., 2014; Laine et al., 2016b)	Boundary subjects (Laine et al., 2016b) and communication hubs (Laine et al., 2017)	Communicative probes (Jönsson and Johansson, 2011)	Modes of communication (Laine et al., 2017)	Communication as a vehicle for verification (Leotta et al., 2018)
Evaluating the future possibilities of a technology (Jang & Lee, 2013; Park & Park, 2004; Mämmelä et al., 2018b) by identifying the value creation mechanisms using causal dispositions (L. Nørreklit, 2017).	Different values need to be converted into technical form (evaluation criteria) for evaluating a technical system. Such conversion represents **co-authorship**. Target setting is an important phase of starting the **reality construction and integration**; the preliminary targets should be up to date and agreed upon (to a certain degree) by related managers.	Facilitators of the workshop can be seen as **boundary subjects**.	Modelling and communication between designers is uncommon based on the case study done. It allows new types of **communicative probes**: even the most experienced designers have different reality constructs about how the object of design affects desired properties.	**Top-down mode:** Decisions concern for example technologies, business goals, products and general values. **Bottom-up mode:** There is a complete chain from technical properties and business intentions defined by managers to products. Communication makes it possible that the potential of a certain technology is commonly understood, based on the best knowledge available.	Most experienced designers are used for **verification**. Technology experts are used for **verification**.

Figure 5. *The framework of the paper revisited.*

In this paper, we now propose how actors could communicate when they make decisions regarding technology. We highlight the need to look at the DRP from a proactive, actor-based viewpoint, to actually realize the factual possibilities in new product development activities (Laine et al., 2017). The OEM's fact construction and possibility evaluation method was developed based on pragmatic constructivist ideas. First, target settings was needed. Then, modelling the value creation mechanisms of technology takes place together with constructing facts. After that, factual possibilities are evaluated from the technical perspective and finally, a monetary estimation is made based on collected information.

In all, the contribution of this paper is to form the causality from fact to possibilities of technology using best available knowledge of product and its design. From the pragmatic constructivist perspective, this paper elaborates upon communication in the product development context. Thereby this paper contributes to topical discussions on communication (see Figure 5). Each of the research strands on communication (columns) could benefit from our findings.

- Co-authorship can take the form of conversion of values into technical form, which adds to Laine et al. (2017).
- Target setting is emphasized for reality construction and knowledge integration, adding to Rantamaa et al., (2014) and Laine et al. (2016b).
- Workshop facilitators can serve as boundary subjects (corroborating and supplementing Laine et al., 2016b) and communication hubs (resonating with Laine et al., 2017) in a purposeful manner.
- Modelling of technical dispositions and communication among experienced designers might yield impactful communicative probes (elaborating upon Jönsson and Johansson, 2011).
- Both top-down and bottom-up modes of communication were witnessed (elaborating upon the findings of Laine et al., 2017).
- Communication is an important vehicle of verification, particularly by using design and technology experts opinions (resonating with Leotta et al., 2018).

However, the paper does not study, language games, for example. Such studies represent a relevant future research possibility in the area. How could language games be utilized in the product development context? How could productive practice be advanced by understanding language games better in product/technology management? For example, those are such questions that require further inquiry.

In practice, the paper shows that also understanding the motives (values) of humans in the organizations has to be considered to support technology decisions, which forms a contribution to design research. In other words, the systematic use of design knowledge in constructing causality to support technology decisions forms the main research implication from the engineering point of view. Therefore, sufficient design knowledge is necessary for using the developed approach. Practical implications of this research include supporting the understanding of the value creation mechanisms of technology in a specific business environment. In this paper, the main tool for understanding and capturing the value creation mechanisms of technology is the DRP-chart in which the best available design knowledge is modelled. Targets and intentions are defined by managers and transformed into technical properties. Connections between product properties and behavior is based on designers' understandings and views. Modelled value creation mechanisms are used to evaluate the factual possibilities of a technology and further evaluate the monetary effect of that technology, based on actual technological choices. A reality construction can be developed and focused by using the DRP.

We used pragmatic constructivism to improve and give usable explanations about the complicated environment, which is the case in manufacturing industry and accounting (L. Nørreklit, 2017). The nature of technical systems also originates from the needs of humans and any general value or properties cannot be defined (Hubka & Eder, 1988). The theory base of TTS lead us to model and understand the intentions of the examined company, which originate from the people working in the company. We need understand the value creation mechanisms from technology to intention because technologies have effects on the product and the product has an effect on a business and thereby fulfilling the business intention. There are no any physical or rule-based connections between those elements (people, business, products, technologies), but instead, the connection is formulated based on best available design knowledge and understanding of the operational environment. In the industry, many people and parties have different motives and goals. The method presented in this paper integrates the different viewpoints and communicate the factual possibilities of technology.

Since accounting facts can easily relate to design facts in product development (i.e. a physical product can be a central part of a business model), in this paper we claim that there is importance in examining the product design facts from the viewpoint of pragmatic constructivism. The pragmatic constructivist methodology on communication could even draw inspiration from some of the ideas presented in this paper that stem from the engineering approach to communication in product development. It is essential to determine the factual possibilities that exist in the reality of new product development – and importantly, not by speculation but by systematic and thorough thinking with logical reflection about the causal dispositions of new product development activities and their inputs and outputs (L. Nørreklit, 2017).

Finally, this paper shows that the pragmatic constructivist approach can support technology decisions in the manufacturing industry by considering the values of humans as a part of organization and using the best available design knowledge to construct causality.

References

Arbnor, I., & Bjerke, B. (2008). *Methodology for creating business knowledge*. Sage.

Azambuja, R., & Islam, G. (2018). Working at the boundaries: Middle managerial work as a source of emancipation and alienation. Human Relations, 0018726718785669.

Boer, F. P. (1998). Traps, pitfalls and snares in the valuation of technology. *Research-Technology Management*, *41*(5), 45-54.

Braun, E. (2005). Technology in context: Technology assessment for managers. Routledge.

Cooper, R. G. (1990). Stage-gate systems: a new tool for managing new products. Business Horizons, 33(3), 44-54.

Dissel, M. C., Phaal, R., Farrukh, C. J., & Probert, D. R. (2009). Value roadmapping. *Research-Technology Management*, *52*(6), 45-53.

Hall, M. (2010). Accounting information and managerial work. *Accounting, Organizations and Society*, *35*(3), 301–315.

Henriksen, L. B., Nørreklit, L., Jørgensen, K. M., & O'Donnell, D. (2004). Dimensions of change: conceptualising reality in organisational research. Copenhagen Business School Press DK.

Hubka, V., & Eder, W. E. (1988). *Theory of technical systems: a total concept theory for engineering design*. Berlin: Springer-Verlag.

Hubka, V., & Eder, W. E. (1996). *Design science : introduction to the needs, scope and organization of engineering design knowledge*. New York: Springer.

Huzzard, T., Ahlberg, B. M., & Ekman, M. (2010). Constructing interorganizational collaboration: The action researcher as boundary subject. Action Research, 8(3), 293-314.

Ilori, M. O., & Irefin, I. A. (1997). Technology decision making in organisations. *Technovation*, *17*(3), 153–160.

Jakobsen, M. (2017). A Comparison of Pragmatic Constructivism and Actor Network Theory. In A Philosophy of Management Accounting: A Pragmatic Constructivist Approach (pp. 245–259).

Jakobsen, M., Johansson, I.-L., & Nørreklit, H. (Eds.) (2011). An Actor's Approach to Management: Conceptual Framework and Company Practises. DJøF Publishing.

Jang, W.-J., & Lee, C. (2013). a Technology Valuation Model for the Defense R&D With Income Approach. *International Journal of Innovation and Technology Management*, *10*(04).

Jönsson, S., Johansson, I.-L. (2011). Communication as means for deciding about realistic possibilities. In Jakobsen, M., Johansson, I.-L., & Nørreklit, H. (Eds.) (2011). An Actor's Approach to Management: Conceptual Framework and Company Practises. DJøF Publishing.

Jørgensen, B., & Messner, M. (2010). Accounting and strategising: A case study from new product development. Accounting, Organizations and Society, 35(2), 184-204.

Juuti, T., Lehtonen, T., & Riitahuhta, A. (2007). Managing Re-Use for Agile New Product Development. *ICED07: 16th International Conference of Engineering Design*, (August), 11.

Korhonen, T., Stormi, K., Laine, T., & Liew, A. (2016). Examining technical and behavioural possibilities in developing fleet services in the machinery manufacturing context. Proceedings of Pragmatic Constructivism, 6(1), 3-13.

Laine, T., Korhonen, T., & Martinsuo, M. (2016a). Managing program impacts in new product development: An exploratory case study on overcoming uncertainties. International Journal of Project Management, 34(4), 717-733.

Laine, T., Korhonen, T., Suomala, P., & Rantamaa, A. (2016b). Boundary subjects and boundary objects in accounting fact construction and communication. *Qualitative Research in Accounting & Management*, *13*(3), 303–329.

Laine, T., Korhonen, T., Suomala, P., & Tervala, E. (2017). New Product Development Project Managers as Actors: The Viewpoint of Management Accounting and Control. In H. Norreklit & M. Raffnsoe-Moller (Eds.), *A Philosophy of Management Accounting: A Pragmatic Constructivist Approach*. United Kingdom: Routledge.

Lehtonen, T., Halonen, N., Pakkanen, J., Juuti, T., & Huhtala, P. (2016). Challenges and opportunities in capturing design knowledge. In Koskinen, K. et al. (Eds.) Proceedings of the 10th World Congress on Engineering Asset Management (WCEAM 2015) (pp. 389-395). Springer, Cham.

Leotta, A., Rizza, C., & Ruggeri, D. (2018). Constructing servitization strategies. Accounting information in supporting NPD processes. MANAGEMENT CONTROL.

Lingens, B., Winterhalter, S., Krieg, L., & Gassmann, O. (2016). Archetypes and Basic Strategies of Technology Decisions: Understanding the likely impact of a new technology and the uncertainty associated with it can help managers determine the most efficient, effective approach to decision making. *Research-Technology Management*, *59*(2), 36-46.

Lukka, K., & Vinnari, E. (2014). Domain theory and method theory in management accounting research. Accounting, Auditing and Accountability Journal, 27(8), 1308–1338

Mämmelä, J., Juuti, T., Julkunen, P., Lemmetty, P., & Pakkanen, J. (2018a). Method for Evaluating the Value of Technology in the Manufacturing Industry. *WCEAM 2018, Septemper, Stavanger, Norge*.

Mämmelä, J., Juuti, T., Korhonen, T., Julkunen, P., Lehtonen, T., Pakkanen, J., & Vanhatalo, M. (2018b). Evaluating the value and costs of technology in the manufacturing industry. *NordDesign 2018, August 14-17, 2018, Linköping, Sweden*.

Mitchell, F. (2017). A Pragmatic Constructivist Approach to Studying Difference and Change in Management Accounting Practice. In A Philosophy of Management Accounting: A Pragmatic Constructivist Approach (pp. 272–279).

Mitchell, F., Nielsen, L. B., Nørreklit, H., & Nørreklit, L. (2013). Scoring strategic performance: a pragmatic constructivist approach to strategic performance measurement. Journal of Management & Governance, 17(1), 5-34.

Nørreklit, H. (2017). *A philosophy of management accounting: a pragmatic constructivist approach* (Vol. 21). New York: Routledge.

Nørreklit, L. (2017). Actor-reality construction. In *A Philosophy of Management Accounting: A Pragmatic Constructivist Approach*.

Nørreklit, L., Nørreklit, H., & Israelsen, P. (2006). The validity of management control topoi: towards constructivist pragmatism. Management Accounting Research, 17(1), 42-71.

Park, Y., & Park, G. (2004). A new method for technology valuation in monetary value: Procedure and application. *Technovation*, *24*(5), 387–394.

Rantamaa, A., Laine;, T., & Korhonen, T. (2014). Accounting prototypes supporting product development : integrating different actors ' viewpoints. *Proceedings of Pragmatic Constructivism*, *4*(1), 3–13.

Scheiner, C. W., Baccarella, C. V., Bessant, J., & Voigt, K. I. (2015). Thinking patterns and gut feeling in technology identification and evaluation. *Technological Forecasting and Social Change*, *101*, 112-123.

Weber, C., & Deubel, T. (2003). New Theory-Based Concepts for Pdm and Plm. *Iced 03*, 1–10.

Winter, S., & Lasch, R. (2016). Recommendations for supplier innovation evaluation from literature and practice. International Journal of Operations & Production Management, 36(6), 643-664.