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Doing Product Development Activities: The Role of Experience and Ends-in-view

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Abstract

Drawing on Deweyan pragmatism and the Science-Technology-Society approach, this ethnographic research aims at understanding the role of experience and ends-in-view when handling a product development activity. The research focuses on doings conceptualised as engineer-artefact reciprocity and contributes to practice-based learning and product development studies. The analysis demonstrates that past activities embodied in experience and materialised in artefacts and, likewise, future activities embodied in ends-in-view influence the handling of an activity differently, resulting in either a derailment of handling the activity, habitual completion or reflective completion of the activity. Derailment occurs when experienced engineers are incapable of achieving a common end-in-view; habitual completion is when engineers form a vague end-in-view and no one challenges this; and past experience combined with the formation of a common end-in-view paves the way for reflective completion of the activity. Only the last-mentioned facilitates engineers to gain new experience and create usable artefacts.

Keywords: Pragmatism, sociotechnical practice, engineer-artefact reciprocity, experience, end-in-view, practice-based learning, product development

1. Introduction

The handling of every single Product Development (PD) activity is influenced by the engineers' experience and ends-in-view. Schön's (1983) 'reflective practitioner' is a seminal contribution to understanding how engineers handle each PD activity, and indeed his Deweyan pragmatic approach has formed the basis for several studies. For example, the handling of a PD activity draws on discourse and cognitive actions (Khaidzir and Lawson, 2013), situated cognitive processes (Kelly and Gero, 2014), collective cognition (Kleinsmann et al., 2012) and that a team's mental model belongs to the cognitive realm (Dong et al., 2013). The engineers' cognition is central in these studies. On the one hand, Schön's Deweyan foundation forms the backbone of his conceptualisation of how engineers handle a PD activity. For instance, according to Schön, the handling of a PD activity is a social and reflective conversation with materials within situated practices (Schön, 1983), where engineers have different intentions and understandings of the materials (1988), form different design worlds and speak different languages (Schön, 1992), and when handled successfully, it results in changes in configuration of the materials (Schön, 1983). On the other hand, Schön's use of terms such as 'gestalt' [Schön and Wiggins, (1992), p. 156], 'epistemological practice' [Schön, (1983), p. 69] and the

‘Piagetian interweaving of cognitive and affective processes’ [Schön, (1983), p. 320] calls to mind a pure cognitive orientation (see Merriam et al., 2007) which may be the reason why cognition is the focal point of the above researchers. Likewise, the lack of rigorous use of terms could explain why Schön’s work has been subject to some criticism, as for instance that he sticks to introspective human cognition (Bleakley, 1999) and that his understanding of practice and experience is bounded by a certain level of cognitive orientation (Yanow and Tsoukas, 2009).

Nevertheless, a one-sided commitment to cognition is inconsistent with Dewey’s conceptualisation of inquiry (1938) and experience (1933). This research subscribes to his pragmatic understanding of inquiry and experience. The purpose is to empirically study how the reciprocal engineer-artefact interaction influences the handling of every single PD activity and thereby to shed light on how PD and learning unfold within practices. In line with the pragmatic approach that combines practical and theoretical understandings, the research question guiding this research gradually emerges: *‘Which influence do the engineers’ experience and ends-in-view have on handling a development activity?’*

The current paper combines a Deweyan pragmatic approach to gaining experience in transforming an indeterminate situation into a determinate situation successfully as well as engineers’ experience and artefacts evolve reciprocally with Science, Technology, and Society studies’ (e.g. Henderson, 1999) that social and technical matters are co-shaped and fused into sociotechnical practices. The paper subscribes to Schatzki’s (2012) viewpoint that practices and the way of doing things are mutually constitutive.

The research follows the PD and pre-production of control and monitoring applications. It addresses how engineers having different organisational and/or departmental affiliations handle PD activities in open-plan offices, meeting rooms and production areas. A micro-sociological framework is developed and used to analyse every single PD activity as a sequence of doings [Dewey, (1938), p.117] when engineers transform an indeterminate situation into a determinate situation (like Schön’s naming-framing-moving acts). The analyses focus on how doings and the consequences unfold (like Carlile et al., 2013). Following the analyses of the identification, translation and realisation phases of the PD, the findings from the three analyses are juxtaposed.

The contributions are fourfold: First of all, the paper exemplifies ‘development in the making’ as well as demonstrates how the handling of each PD activity is influenced by both past and future activities. Second, the paper suggests a micro-sociological framework as a new method for studying PD within sociotechnical practices. Third, it brings clarity to how embodied experience and ends-in-view influence the handling of every single PD activity differently throughout the PD. Forth, it illustrates the gradual formation of an end-in-view, and how an end-in-view does not always lead to a successful handling of the activity. This paper highlights the necessity of making various ends-in-views noticeable for others and exposing them to criticism.

The rest of the paper is structured as follows: First, the theoretical conceptualisation is elaborated followed by methodological considerations. Then, the paper presents, analyses and discusses the PD project, including the contributions, and, finally, a conclusion is provided.

2. Theory

Following a brief literature review, the analytical framework applied in this paper is elaborated.

2.1. Review

Systems engineering and engineering management researchers of PD highlight the importance of interdisciplinary collaboration in order to obtain a common understanding of the problem to be solved (DeFranco et al., 2011) and to determine the appropriate managerial guidelines for encouraging collective learning within and across development teams (Albors-Garrigos et al., 2016). To facilitate this, the team(s) should strive to reduce the cognitive complexity (Simpson and Simpson, 2011). Yet, the faced complexity and learning processes differ during a systems engineering project (Walworth et al., 2016). In general, however, these studies conceptualise ‘the whole PD as an activity or as a project’ rather than a web of PD activities conducted by employees having different organisational and/or functional affiliations.

Developing a complex product involves the completion of many activities. To examine the handling of every single PD activity, Kelly and Gero (2014) study situated cognitive processes and state that a ‘move’ (here the handling of an activity) is influenced by the engineer’s experience and expectation (here an end-in-view) of the development. They equate the end-in-view with Schön and Wiggins’ (1992) ‘intention’ and suggest that if the end-in-view misfits the observations when handling an activity, the engineer brings experience into the situation to change the end-in-view of the activity. Kleinsmann et al. (2012) study development experience and, in conclusion, they highlight that PD calls for individual development and collaboration experience. Dong et al. (2013) conduct a similar study in which they account for the benefits of establishing congruent collective cognitive processes among engineers.

The reciprocal interaction between cognitive and technical matters is the focus of another group of researchers. For instance, Khaidzir and Lawson (2013) highlight that handling a PD activity entails perceptual activities which transpire between engineers, representations and artefacts. Boujut (2003) studies the role of representations and artefacts; he examines the cognitive dimension of annotations added to artefacts and states that these facilitate the creation of individual and shared understanding among the participants. Wang et al. (2013) study the interaction between engineers and artefacts, and emphasise that artefacts and experience co-evolve throughout the development. Hannah et al., (2012) illustrate that the engineers’ interaction with artefacts of low fidelity representations is useful for clarifying functional specifications, while high-fidelity artefacts can be used to verify compliance between development and specifications.

The above studies are in general conducted as either experiments addressing the student-artefact reciprocal interaction or as computational models, and the handling of each PD activity is considered an isolated event. However, in real PD, a successfully handled activity forms new experience (Dewey, 1938) and change the configuration of the artefact(s) (Schön, 1983), which paves the way for future development (Belt et al., 2009; Paliszkiewicz, 2010). In other words, the handling of each PD activity is not an isolated event, but rather it is influenced by past activities (experience) and the future dimension of the activity (end-in-view). In the following sections, the analytical framework is conceptualised; *reciprocal interaction*, *handling an activity* and *experience and end-in-view*. A summary presents the analytical framework.

2.2. Reciprocal interaction

Dewey (1938, p. 32) reminds us that each '*organic function is an interaction of intra-organic and extra-organic energies*'. The human's biological functions, such as sensing, thinking and feeling, make up the '*intra-organic energy*', while the perceivable artefacts within practices constitute the '*extra-organic energy*'. The '*energies*' are not two separate matters, and thus, engineers handle the activity **within practices** by actively using their experience in a reciprocal interaction with the artefacts.

This bidirectionality between engineers and artefacts conceptualises reciprocity and likewise the embodiment of experience.

Social and technical matters form an enacted practice (Higgins and Mirza, 2010) having no predated boundaries (Barad, 2003). Yet, the social and technical matters are two distinct phenomena that gradually become interlocked (Leonardi, 2013). Accordingly, practices have mutable composition without predated boundaries between social and technical matters; these matters are co-shaped (Bijker, 2010) and fused into a sociotechnical practice which is a '*spatially-temporally dispersed nexus of doings*' [Schatzki 2012, p. 14].

To study matters within these practices, Pentland and Singh (2012) suggest following the principles of pragmatism emphasising a focus on 'doings and the consequences'. Dewey's pragmatic inquiry (1938, p.117) paves the way for conceptualising the handling of a PD activity as a sequence of engineer-artefact reciprocity; to be elaborated below.

2.3. Handling an activity

When an engineer starts the handling of a PD activity, his/her observations of and reflection about influencing matters enter into 'a means-consequence relationship' (Dewey, 1933). For Dewey, means (here matters) acquire meaning when applied to cause consequences. In other words, the handling of a PD activity is a progressive inquiry in which the individual strives to understand what is going on, and gradually handles the activity by conducting a '*controlled transformation of an indeterminate situation into a determinately unified one*' [Dewey, (1938), p. 121]. A controlled transformation entails that the individual's observations of and reflections on matters should be related to each other. If successfully controlled, it becomes possible to activate the reflective experience and thus create experience (like Tsoukas, 2009); the individual and the artefacts, however, evolve reciprocally (Dewey, 1938). An unsuccessfully controlled inquiry will '*cause subsequent inquiry to be irrelevant or to go astray*' [Dewey, (1938), p. 112]. Consequently, the individual fails to activate his/her reflective experience, resulting in an unsuccessful handling of the activity.

2.4. Experience and end-in-view

Drawing on Schatzki (2012, p. 20), past activities and future dimension of the activity are matters that influence the handling of the PD activity.

Past activities chart a trajectory which affects '*the way for the activity that follows*' [Dewey, (1938), p. 33]. Contextual embodied experience is the starting point and the telos for handling every single PD activity. Dewey (1933) operates with habitual experience forming a habitual attitude of mind as well as reflective experience constituting a reflective attitude of mind.

Miettinen (2000, p. 68) considers the habitual attitude of mind as *'the great flywheel of the society'*. For instance, when the skilled prototype worker assembles wind turbine breaker panels, s/he knows the best practice in terms of the wiring of all components (like Schön's *'knowing-in-action'*). Handling an activity without in-depth reflection is a precondition for living in present-day society; for example, driving a car is done without much thought. For Dewey (1938), the first phases of handling an activity draw on habitual experience: If one successfully transcends this habitual attitude of mind, the subsequent phases will gradually become more guided by reflective experience.

Experience enables engineers to recall the consequences of past activities and, likewise, the 'existential' consequences of past activities are materialised in artefacts.

The future dimension of the activity becomes a matter when humans act for an end (Schatzki, 2012), which necessitates an elucidation of this 'forward-looking knowledge' (Souto, 2014).

The ends (Souto's forward-looking knowledge) that employees have in view influence the handling of activities (Mowles, 2012), but this 'end-in-view' is not the end of handling the PD activity as indicated by Schön (1983); rather it is a desired consequence which may never be achieved (Gotesky, 1963). For Dewey (1933), an end-in-view is the desired, and thus, 'ideational' consequence. Dewey (1933, p. 233) illustrates the ideational consequence by referring to the Wright brothers' end-in-view of constructing 'a machine to fly in the air'. Therefore, an engineer's perception of an appropriate technical/business solution influences the handling of a PD activity.

Collaborating engineers cope with other people's ends-in-view via dialogue (Souto, 2014). Dialogue, a mutual interchange of stances between at least two partners (Tsoukas, 2009), can be verbal, non-verbal and vocal. Productive dialogue (Tsoukas 2009; Majchrzak et al., 2012) results in a common end-in-view, activating the reflective experience (as Maier's (1933) productive thinking) and thus also *'changing the way the thought process occurs collectively'* [Bohm, (1996), p. 9]. Reproductive dialogue leaves the end-in-view unchallenged and therefore, the handling of the activity draws on habitual experience (as Maier's (1933) reproductive thinking).

2.5. Summary – analytical framework

The grey area in Figure 1 symbolises the sociotechnical practice which unfolds in meeting rooms, open-plan offices or production areas when handling a PD activity. Present activity is influenced by past activities materialised in artefacts and contextually embodied in the engineers as well as by the future dimension of an activity embodied in the engineers' ends-in-view. Present activity contains a start-up (leftmost black dot) and a completion (rightmost black dot). The engineer-artefact reciprocity, illustrated as two-way arrows attached to the five small dots, enables the handling of the PD activity. Successful completion of an activity requires a sequence of reflective reciprocity which provides the engineer(s) with new experience and materialisation of artefact(s). Unsuccessful completion is either a derailment of the engineer-artefact reciprocity prior to the completion of the activity, or an unreflective completion drawing on habitual reciprocity.

Figure 1. The analytical framework

3. Method

This study subscribes to constructionism (Crotty, 2010) and combines a Deweyan conceptualisation of experience and inquiry with a sociotechnical perspective on practices and artefacts (Bijker, 2010; Henderson, 1999).

The analyses in the current paper are based on ethnographic material gathered by the author (Mathiasen, 2012). The focal point of the ethnographic study is the practice-based learning when doing PD. In this paper, the research on the influential role of experience and ends-in-view when doing PD is based on, and therefore draws on, topical and theoretical issues which have much in common with the ethnographic study. Thus, since this paper subscribes to Dubois and Gadde's (2002) 'systematic combining', the methodological approach should be understood as a further iteration of the abductive approach of the ethnographic study.

The ethnographic data collection was divided into two phases. The first phase was conducted over a period of four months and included observations in open-plan offices/production areas, four meeting observations and 14 unstructured interviews documented by notes. On average, I was present in the company three working days per week. This phase helped to gain an understanding of the development approach, internalise abbreviations as well as technical/social expressions applied by the engineers, and to gain access to the projects to follow during the ethnographic study. The second phase lasted eight months, corresponding to the development time of the products under study. Subscribing to multi-sited ethnography (Marcus, 1995), the phenomenon being studied is 'in the making'; I followed the development of control and monitoring applications through and between different practices (Neyland, 2007). The data collection comprised: 1) Observations in open-plan offices/production areas with an average duration of six hours per day, three working days a week; 2) observations of 31 cross-functional and 25 interorganisational meetings, each with an average duration of 95 minutes; and 3) 16 semi-structured interviews which were taped. The observations encompassed the engineers' dialogue, body language and voice, how artefacts, mobile phones, laptops and blackboards were used, the characteristics of the room, the operation of IT systems, whether or not persons were reachable from mobile phone, etc. Observations during the meetings were recorded directly in MS Word documents.

Given that the intention is to achieve a well-founded understanding of the empirical phenomenon/phenomena, I have selected the 'identification', 'translation' and 'realisation'

development phases. The selection of these phases draws on Stake's (2000, p. 447) variety criterion and his view that the '*opportunity to learn is of primary importance*'. The three phases illustrate rather different engineer-artefact reciprocity and dialogue.

The analysis consists of two steps; due to variation among the three phases, the first analysis focuses on how experience and ends-in-view influence the materialisation of artefacts in each of the three phases. The second analysis is tailored to learn from rather than strictly compare the cases (Stake, 2000) for which reason the analyses are juxtaposed.

As for the analysis, handling a PD activity is considered as a sequence of engineer-artefact reciprocity. The coding process starts with dividing the PD activities into the three phases, after which 'each of the activities' is categorised according to whether it was unsuccessfully or successfully accomplished. The created analytical framework paves the way for analysing every single doing as engineer-artefact reciprocity. By focusing on how this reciprocity unfolds, it becomes possible to grasp how engineers handle a PD activity within sociotechnical practices.

4. Case

'Supplier' is a medium-sized company with nearly three decades of experience in developing and manufacturing control and monitoring applications; pivotal subsystems in wind turbines. The PD department consisted of 40 engineers/draughtsmen. At the outset of the PD studied in this paper, only three hardware/software engineers and a salesman were involved, while 24 engineers/draughtsmen/prototype workers became involved later on. The engineers/-draughtsmen/prototype workers had some seniority and thus had extensive technical experience: Hardware engineers 1 and 3 were regarded as specialists in control-/monitoring applications. Supplier's project manager (PM) had some technical experience, while the salesman and industrial engineers had limited technical experience.

With regard to the control application development, Supplier' PM and involved Supplier engineers sat next to each other in an open-plan office. As to the monitoring application development, the responsible Supplier engineers were located in another office. Pre-production of all applications took place next to the open-plan office (at the same locality). Following a successful running-in production, the mainstream production should be carried out in a low-wage country (country X).

'Customer', a wind turbine division belonging to a conglomerate based in Asia, had posted abroad 50 engineers in a development office in Germany approximately 500 kilometers away from Supplier. Previously, Customer had developed two wind turbines, but none of these worked properly, and thus Customer had limited experience with wind turbines, including the control and monitoring applications.

A group of the 50 engineers was involved in the development of the control and monitoring applications; in average four hardware/software engineers and Customer's PM attended the interorganisational meetings with Supplier. Customer's PM, a senior engineer, had limited technical experience with wind turbines. The involved Customer engineers were junior engineers with limited technical experience.

The PD was divided into an identification, translation and realisation phase, explained below. Following this, Table 1 presents an overview of selected events.

4.1. Identification phase

Supplier's top management requested that the employees should draw on a well-known technical platform when formulating the pre-clarification with Customer's PM; as the CEO highlighted: *'We cannot develop from scratch every time'* (observation, cross-functional meeting).

As the salesman did not possess detailed technical experience of the applications, three engineers drew up two documents to the salesman to guide the pre-clarification with Customer's PM; one for the control application and one for the monitoring application. In addition to these documents, one of the Supplier engineers involved in the development of the control application attended the interorganisational meetings with Customer's PM from time to time. The PD activities were on track. Consequently, after the pre-clarification document had been prepared, the salesman submitted it to Supplier's and Customer's management for approval.

4.2. Translation phase

Following the approval, a number of meetings were held with the purpose of handing over the PD activities to the project group. During the first weeks, the dialogue at the cross-functional and interorganisational meetings was characterised by many to-ing and fro-ing, and consequently, the translation of the pre-clarification did not progress as expected. The Supplier engineers doubted the technical substance of the pre-clarification document, and emphasised that the document was not suitable for drawing up the technical specifications; at a cross-functional meeting, hardware engineer 1 emphatically voiced: *'We all knew that the customer has other needs'*.

The Supplier engineers took charge and made a new translation of the Customer's requirements, implying that the development trajectory of the control application was temporarily derailed. However, the Supplier engineers put the development back on the right track; this was mainly done within the open-plan office though.

The Supplier engineers responsible for the monitoring application were not actively involved in the translation phase. After reading the finished document, hardware engineer 3 doubted the technical specifications which led to a dialogue with other Supplier employees. Gradually, his view gained a hearing, resulting in a derailment of the development trajectory and, consequently, the technical specifications were rewritten without involving Customer; Supplier defrayed all additional expenses.

4.3. Realisation phase

The prototype workers were capable of building both applications without any elements of uncertainty mainly due to the fact that *'all necessary specifications have been available from the beginning [of this realisation phase], and so far they have not been changed'* (electrical engineer 1 one month after the realisation phase started).

While building the applications, the prototype workers drew up working instructions for the subsequent mainstream production of the applications. However, these working instructions were all tailored to Supplier's running-in production facilities and thus not to Supplier's mainstream production plant located in a low-wage country. In other words, the two facilities

had completely different production set-ups which meant that the working instructions were useless for the blue collar workers operating in the mainstream production.

Table 1 highlights some of the events occurring during the PD. The leftmost column refers to the phase of the PD, the midmost describes the theme of the doings, while the rightmost column addresses whether the doings conducted derailed or supported the development trajectory.

Table 1. Overview of events occurring during the PD

PD phase	Theme of doings	Development trajectory
Identification	<ul style="list-style-type: none"> • Three engineers develop guidelines for the salesman • Salesman and Customer's PM jointly develop the pre-clarification • Salesman draws up the pre-clarification document 	<ul style="list-style-type: none"> • On track • On track • On track
Translation	<ul style="list-style-type: none"> • Supplier engineers call into question the pre-clarification of the control application • Supplier engineers develop the technical specifications for both applications • Hardware engineers call into question the technical specifications for the monitoring application 	<ul style="list-style-type: none"> • Derailed • On track • Derailed
Realisation	<ul style="list-style-type: none"> • Supplier engineers draw up detailed specifications • Prototype workers build the breaker panels • Prototype workers draw up working instructions 	<ul style="list-style-type: none"> • On track • On track • Derailed

5. Analysis and discussion

This research sets out to explore how the reciprocal engineer-artefact interaction influences the handling of a PD activity.

The case description including Table 1 forms the basis of the analyses presented in three separated parts below; the three analyses should be considered parallel parts of equal importance. The analyses are followed by a cross-analysis and a discussion appraising the knowledge acquired from the three analyses and highlighting the main findings by comparing the analyses.

5.1. The identification phase

The Supplier engineers were inexperienced in retrieving suitable information from customers: *'It is actually the first time we draw up a miniTS [pre-clarification document]..., where the collected information is used'* (hardware engineer 2). In addition, according to the Supplier engineers, it did not make sense to sell a standard application. Furthermore, the Supplier engineers were very aware of the fact that business is generated by selling products; for more than three decades, Supplier had collaborated with another customer who made up the majority of Supplier's business. This collaboration consisted solely of the hardware part of the applications. Apparently, the Supplier engineers were trapped in a tension field. Nevertheless, after a while, the Supplier engineers' end-in-view of the technical pre-clarification took charge:

'I took a TS document [technical specification document] from the CSIC 2.0 MW [previously developed control/monitoring applications] and abridged it [...]. This document says something

about I/O and about hardware, but we have really focused on keeping software descriptions out of the material' (hardware engineer 2).

To get the reciprocal interaction on track, the Supplier engineers gradually formed an end-in-view, which originated from the collaboration with the above-mentioned customer, focusing solely on hardware. According to hardware engineer 2, no one challenged this vague end-in-view neglecting software when he, in collaboration with software engineer 1, created the guidelines, neither prior to nor during the pre-clarification with Customer. In the same vein, the salesman had some dialogue with the Supplier engineers to grasp these guidelines. For instance, on a Friday afternoon, he spoke with hardware engineer 3, 'the monitoring specialist'. The salesman ascribed credibility to the answers he received. However, later on during a cross-functional meeting, hardware engineer 3 emphatically emphasised that the information from the salesman was insufficient for discussing technical matters, *'thus, when they contacted me that Friday afternoon and asked for the price of the China park server [monitoring application], I just gave them this price'*.

Anyhow, the vague end-in-view combined with the reproductive dialogue kept the reciprocity on track, resulting in a materialisation of an artefact (guideline document), which, however, proved unusable to clarify Customer's functional requirement. I.e. the vague end-in-view facilitated habitual completion of the activities.

Within the interorganisational sociotechnical practice, the artefact (the guideline document) facilitating the engineer-artefact reciprocity was mainly an input/output overview from which all software was removed. It entailed that the artefact was not, as expected by the salesman, a functional description of the applications. Despite this, the interpretations of the artefact and the dialogue between the salesman and Customer's PM kept the reciprocal interaction on track, which resulted in the handling of all PD activities as well as the materialisation of yet another artefact (the pre-clarification document). However, reciprocal interaction between an individual's experience and an unusable artefact (the guidelines) cannot properly transcend the habitual attitude of mind.

Hence, within the interorganisational practices, the dialogue proved to be reproductive and the engineer-artefact reciprocity drew on the habitual attitude of mind. Nevertheless, the salesman and Customer's PM completed the PD activities and prepared the pre-clarification document. It had some consequences, however, which are illustrated in the following section.

5.2. The translation phase

Supplier sent out questionnaires to Customer to retrieve decisive information, but:

'We noticed that Customer did not understand the questions we sent to them [and] why we need this information [...] I do not know why they could not understand it. It might be due to a lack of in-depth knowledge of wind turbines – that we possess' (hardware engineer 2).

The Supplier engineers having extensive experience were recently involved in a successful development with another new customer. Their experience, combined with drawings, electrical diagrams and technical solutions developed during this previous project, influenced the

handling of each of the PD activities which were mainly conducted within the daily sociotechnical practices. This as well as ongoing materialisation of drawings and sketches tailored to Customer resulted in the Supplier engineers gradually forming a common end-in-view. In addition, the engineer-artefact reciprocity and dialogue became increasingly reflective. Another matter making this end-in-view more durable was the combination of a persuasive and confronting dialogue within the cross-functional/interorganisational sociotechnical practices. This common end-in-view among the Supplier engineers enabled the materialisation of the specification document and collective experience within the daily practices. Thus, the PD was back on track.

As for the cross-functional and interorganisational sociotechnical practices, only one artefact (initially the pre-clarification document and, later on, the specification document in preparation) was accessible; yet again, the specification document was drawn up by the Supplier engineers in their daily sociotechnical practice. Voices and body language influenced the handling of each PD activity within the cross-functional/interorganisational practices. For instance, at a cross-functional meeting in which the top management participated, hardware engineer 1 empathetically asked: *'Are we allowed to utilise our 25 years of experience?'* The president replied: *'Keep in mind that Customer has purchased a CSIC WTC [previously developed application] with two or three modifications'*. The salesman emphasised that *'the miniTS [pre-clarification] precisely defines the scope of the project'*, while the vice president of the PD department pointed out later that the drawing up of technical specifications *'has to be guided by the content of the miniTS'*. Similarly, at an interorganisational meeting, Customer's PM raised his hands to his head and emphatically said that he really needed to understand the technical matters, because *'if you just explain the solutions in the technical specification document, I am unable to gain knowledge of the functionalities. And it is crucial for me to understand'*. Supplier's PM, however, raised his voice to emphasise that *'we have promised to deliver a standard application [...]. We are not a supplier of detailed specifications'*.

It was impossible to achieve a common ground for the involved participants' ends-in-view which then caused a derailment in the handling of the activities (reciprocity) and, thereby, an unsuccessful creation of experience in both the cross-functional and interorganisational practices.

As for the monitoring application, when reading the finished specification document, the responsible hardware engineer's reflective experience became activated, and he emphatically said that the application was *'too simple to sell [...]. It is not a park server [...] that it would be stupid, because it is not what they need'*. His end-in-view of a proper monitoring application initiated discussions within different cross-functional practices, and because this end-in-view was rather durable, the other Supplier employees gradually realised that the translation of Customer's requirements was faulty.

At this point, the interorganisational translation phase involving Customer was completed which placed the Supplier engineers in a tension field. First of all, they did not have any artefacts to guide their reflection, as *'I do not know what they need'* (hardware engineer 3) and, second, the Supplier engineers' experience was characterised by the long-term collaboration with the above-mentioned customer, influencing their end-in-view of a proper monitoring application. Third, they were to comply with guidelines put forward by the management indicating that the

monitoring application had to be as cheap as possible without compromising reliability and quality. Especially the end-in-view of a 'proper application' and the guidelines from the management facilitated the engineer-artefact reciprocity, and thus the handling of the PD activity; more, yet affordable, functionalities were added to the application. In any case, the development was back on track, but the collective creation of experience within the cross-functional and interorganisational practices was minimal.

5.3. Analysing the realisation phase

Throughout the realisation phase, the PD seemed to be on track. However, at a cross-functional meeting, a supply chain engineer read the specification document after which he emphatically highlighted various issues such as a lack of manufacturability and a too complex supply chain. Hardware engineer 1 firmly emphasised that these issues were unimportant, as the manufacturing should be in accordance with the technical specifications. Since the other employees supported this view, the handling of this PD activity was deliberately blocked before activating the employees' reflective experience. This indicates that the other Supplier employees had internalised the hardware/software engineers' common end-in-view in terms of the applications to be manufactured.

The materialisation of the operational applications mainly took place within the manufacturing areas. The prototype workers worked closely together with draughtsmen and different engineers (hardware, software, electrical, mechanical), but the collaboration with the mainstream manufacturing facilities in country X was limited: *'I have to admit that we leave out of consideration the production facilities in [country X]'* (Supplier's PM). Prototype worker 1 said: *'We really do our best to achieve an optimal production afterwards [...], but we do not know what is appropriate for them'*.

Although the prototype workers had a great many years of experience and strived to ensure a high level of manufacturability, the mainstream manufacturing in country X was not embodied in their end-in-view. All Supplier employees were aware of the fact that the running-in manufacturing facilities were completely different from the mainstream manufacturing facilities and that it had a huge impact on the manufacturability. Despite this, the dialogue within the cross-functional and daily practices did not make it possible to transcend the habitual attitude of mind, resulting in the engineer-artefact reciprocity with regard to manufacturability not drawing on reflective experience. Thus, an end-in-view neglecting the future mainstream manufacturing obstructed reflective engineer-artefact reciprocity in terms of ensuring manufacturability when handling such development activities.

Findings from the three analyses above are juxtaposed in the below.

5.4. Cross-analysis and discussion

The analyses reveal that both the engineers' experience and the ends-in-view influenced the handling of the development activities differently, resulting in a derailment, habitual completion or reflective completion of the activity.

The middle column of Table 2 illustrates different types of experience and ends-in-view which influence the handling of the development activity depicted in the leftmost column. The rightmost column presents examples from the analyses.

Table 2. Examples of handling the activity – experience and ends-in-view

Handling the activity	Experience and ends-in-view	Examples from the analyses
Derailment	Experienced employees, yet incapable of achieving a common end-in-view.	<p><u>Translation:</u></p> <ul style="list-style-type: none"> • Supplier engineers and management were incapable of achieving a common end-in-view. • Supplier's PM and Customer's PM were incapable of achieving a common end-in-view regarding the form of collaboration. <p><u>Realisation:</u></p> <ul style="list-style-type: none"> • Prototype workers/employees accepted the Supplier engineers' common end-in-view; consequently, the supply chain complexity was not an issue to be discussed.
Habitual completion	Experienced employees, yet inexperience in handling a specific activity, formed a vague end-in-view.	<p><u>Identification:</u></p> <ul style="list-style-type: none"> • Materialisation of the guideline artefact to facilitate the inter-organisational pre-clarification drew on a vague end-end-view; no one confronted this end-in-view. • Unusable artefacts guided the interorganisational pre-clarification and materialisation of the pre-clarification artefact. <p><u>Realisation:</u></p> <ul style="list-style-type: none"> • Manufacturability was not considered, as engineers/prototype workers' common end-in-view neglected the mainstream manufacturing facilities.
Reflective completion	Past experience combined with the formation of a common end-in-view paved the way for aligning the engineers' reflections.	<p><u>Translation:</u></p> <ul style="list-style-type: none"> • Intensive discussions within cross-functional and interorganisational practices and ongoing materialisation of artefacts within daily practice facilitated a common end-in-view among Supplier engineers <p><u>Realisation:</u></p> <ul style="list-style-type: none"> • Supplier engineers and prototype workers were capable of manufacturing workable applications tailored to the running-in manufacturing facilities.

The chronological analyses expose that the consequences of past doings do not predate the handling of an activity, as suggested by Leonardi (2013), but the consequences unfold when handling the activity. Indeed, Kelly and Gero (2014) suggest that designers (here engineers) often change the notions of their doings when handling an activity. Moreover, they emphasise that designers' notions draw on expectations of the situation and past experience. The current research appreciates this view; however, the handling of an activity does not just draw on the 'internal representation' as indicated by Kelly and Gero. For instance, each PD activity handled during the identification phase charted a trajectory materialised in an artefact (pre-clarification document), but the transition to the translation phase resulted in a rejection of, initially, the control application trajectory and, later on, the monitoring application trajectory. The rejection

of both trajectories was the consequences of long-standing discussions among engineers, salesmen, managers and top management and the use of various artefacts; in fact, all activities handled during this period were derailed. Hence, this research suggests that the engineers' notions of what they do when handling an activity draw on the ongoing reciprocity between past materialisation of artefacts and the embodied, yet contextualised experience and ends-in-view. The above empirical findings support Higgins and Mirza's (2010) theoretical conceptualisation of artefacts as being significant means to reflect and reconceptualise the understanding of the matters underpinning the accomplishment of practical activities.

The analyses show that the end-in-view is not the end of handling each single activity, e.g. '*Petra's first architectural drawing of the department*' (Schön, 1983), or fixed '*departmental objectives*' (Carlile, 2002), or just '*expectation to a specific situation*' (Kelly and Gero, 2014) or purely '*tacit forward-looking knowledge*' (Souto, 2014). Rather, an end-in-view is gradually formed and addresses desired consequences. As exemplified in the analyses, the end-in-view either positively or negatively influences the quality of the materialised artefacts. For instance, due to inexperience in retrieving information from customers, the engineers formed an end-in-view which guided the materialisation of an unusable guideline document to facilitate the pre-clarification. Later on, the engineers realised that the pre-clarification was inadequate and, gradually, they formed a common end-in-view which was used to retranslate Customer's functional requirement; indeed, the majority of the retranslation was accomplished without involving Customer or employees from other departments. In the same way – and due to the fact that the majority of the engineers/prototype workers have embodied this common end-in-view – all technical and manufacturing specifications were tailored to the materialisation of a workable application neglecting design for manufacturability.

Beyond doubt, this paper appreciates Dewey's (1933) conceptualisation of '*end-in-view*' and Schön's (1983) conceptualisation of '*intention*'; however, both highlight the positive consequences. As this paper demonstrates both positive and negative consequences in terms of gaining experience and materialisation of artefacts, the findings might contribute to Dewey's (1933) '*end-in-view*' and Schön's (1983) '*intention*'.

What the above examples resulting in inappropriate materialisation of artefacts have in common is that the discussions among the employees were conducted in a friendly atmosphere. According to Majchrzak et al., (2012), this co-creative approach should have facilitated productive dialogue. However, the dialogue appeared reproductive, and, consequently, the engineer-artefact reciprocity drew on the habitual attitude of mind. Hence, to realise a proper materialisation of artefacts and creation of experience, the analyses demonstrate that it is crucial to make the different ends-in-view noticeable for others and thereby expose the end-in-view to criticism. For instance, confrontation of ends-in-view resulted in the trajectory of both the control and monitoring applications being derailed. Especially with regard to the cross-functional practices, the engineers' end-in-view was confronted by other employees (colleagues, managers and top management) during a two-week period. They constantly questioned why it was necessary to use another technical platform than the one specified in the pre-clarification artefact. For more than two weeks, all employees' reflections wandered aimlessly around but, gradually, the engineers formed a common end-in-view, and their views

became more and more durable in the discussions with colleagues and top management. This empirical account of a productive dialogue echoes Souto's (2014) understanding of dialogue: She emphasises that the dialogue should facilitate a deep and insightful understanding and that such a dialogue is noisy and confused face-to-face conversation in which different views (here ends-in-view) coexist.

This research appreciates Schön's (1983) understanding that handling an activity is a reflective conversation with the materials of the situation. Yet, by examining PD 'in the making', the current study acknowledges that PD occurs over a period of time and highlights the roles of past activities embodied in the employees' experience and materialised in artefacts as well as future activities embodied in the engineers' ends-in-view. By doing so, the study moves beyond research which solely measures learning and PD (e.g. Kanchana et al., 2011; Salim and Sulaiman, 2013; Khasmafkan Nezam et al., 2016).

Thus, handling a PD activity is not just 'talk-in-interaction' as suggested by Kleinsmann et al. (2012), and the creation of experience is neither constituted by enacted practice (Higgins and Mirza, 2010) nor discursive practices (Barad, 2003); rather, the creation of experience unfolds when handling an activity within mutable practices and draws on reciprocity involving various artefacts, embodied experience and ends-in-view. Wang et al. (2013) illustrate this as an 'artefact-process experience dependency' throughout PD; a viewpoint this paper supports. However, the analyses expose that the required experience to handle an activity is not always present. Employees' different ends-in-view influence the handling of the activity, and from time to time, artefacts are unusable. This implies that the 'artefact-process experience dependency' is not obvious.

Finally, as the current paper subscribes to pragmatism and adapts Dubois and Gadde's (2002) systematic combining approach, the analytical framework is gradually created after several modifications during the research. The framework is tailored to the study conducted in this paper, i.e. enabling a laser-like focus on the micro processes (doings) to handle a PD activity.

The usability in other research settings requires access to detailed data/information of the phenomenon being studied and tailoring the framework to the research. Accordingly, in multiple case studies, it will be resource demanding and time-consuming to apply such a framework.

3. Conclusion

The purpose of this research was to understand the influential roles of the engineer-artefact reciprocity when handling a PD activity.

By combining the Deweyan pragmatism with Science-Technology-Society studies, a micro-sociological framework to study the handling of a PD activity is constructed. Hopefully, the analytical framework as well as the findings in this paper will contribute to fulfil the call of Kleinsmann et al. (2010) and Dong et al. (2013) as well as Salim and Sulaiman (2013) for new methods and future studies to improve our understanding of how the creation of experience in 'natural design teams' occurs over a period of time, and also to Kelly and Gero (2014), who

suggest future studies to address the interaction between external materials and internal representations produced.

As illustrated in Figure 2, the research proposes that both past and future activities influence the handling of an activity, and that engineers and artefacts evolve reciprocally. A successful completion entails reflective reciprocity which results in the engineer(s) gaining new experience and the creation of usable artefact(s).

Figure 2. Handling a PD activity

<u>Handling a product development activity</u>		
Past & future dimension of the activity	Engineer-artefact reciprocity	Outcome of handling the activity
Experience to handle the activity Forming a common end-in-view		Create usable artefacts and collective experience
Experience to handle the activity Do not form a common end-in-view		No creation of artefacts and do not gain new experience
Inexperience to handle the activity Forming a vague end-in-view		Create unusable artefacts and unsuitable experience

Collective creation of experience occurs (uppermost illustration) when engineers are able to align their ends-in-view and the engineer-artefact reciprocity to follow a convergent track throughout the handling of the activity. If derailing the engineer-artefact reciprocity (middle illustration) when handling the activity, neither individual nor collective creation of experience occurs; derailment happens if engineers are incapable of forming a common end-in-view entailing the engineer-artefact reciprocity to follow different tracks. Habitual completion of the activity takes place (lowermost illustration) when engineers form a vague end-in-view and no one challenges this.

The managerial implications of the research are: 1) Since an end-in-view, often associated with positive consequences, may cause the creation of unusable artefacts and unsuitable experience, managers should encourage the involved engineers to make the different ends-in-view noticeable for others as well as expose the ends-in-view to criticism; 2) As the end-in-view addresses features of the final product being developed rather than the ‘end of handling every single activity’ – and as the end-in-view is gradually formed – managers need to accept a period of time, where the engineers’ dialogue and reflections are aimless.

This research has limitations. First of all, the case is highly condensed; hence, many of the statements from interviews and observations within daily, cross-functional and inter-organisational practices have been omitted in the empirical description of the three phases. This may imply a limitation of the paper’s credibility, because these interviews and observations have contributed to the author’s understanding. Second, this study does only follow PD within one company which may question the generalisability of the findings. Therefore, future

research could challenge the findings in this paper, e.g. by adapting the constructed micro-sociological framework to other contextual settings, or by accomplishing a study that appreciates that ‘time matters’ and that ‘employees are heterogeneous’.

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