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Doing Systems Development – A Pragmatist Take on the Learning of Engineers

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Abstract. Systems development of wind turbine control is competitive with respect to innovation, time and cost. So how can learning possibly occur under such circumstances? Dewey’s pragmatist approach to learning is adopted, emphasising reciprocity between the systems developer’s individual experience and the sociotechnical practice. The framework involves the concepts of sociotechnical practice, anchoring of indeterminate situation, and strip of doings towards determinate situation. An ethnographic study was made of four cases of systems development and learning do occur in the cases, enabled by converging anchoring of the indeterminate situation and the systems developers’ different experience. However, an extreme case reveals initiated learning processes and that the interchanges between materiality of the artefacts and systems developers block the learning processes due to a customer with imprecise demands and unclear system specifications. The specific contribution of the paper is the understanding of the individual systems developer’s learning, complemented with the possibility for collective learning and the mechanisms of blocked or derailed learning processes. The practical implications are that managers of systems development should ensure that constitutive means are present, and specifications are sufficiently obdurate. Too ductile means, such as customers with unclear demands, can block or derail learning processes.

1 Introduction

Companies developing control systems combining hardware (HW) and software (SW) elements are exposed to increasingly harsh global competition (Vidgen and Wang, 2009). This includes the Danish-based part of the wind turbine industry, which has undergone a transformation over a long period from relatively lucrative growth conditions to more and more aggressive competition, especially from Asian players. Danish-based sub-suppliers, which offer systems development of wind turbine control systems (WTC) combining HW and SW in a packaged product, are therefore looking for new customers abroad to supplement their present customer base of the two large Danish-based wind turbine manufacturers, Vestas and Siemens. Such new customers represent new challenges and require adaptation. This article’s focus on learning should be seen in this context.

Learning in systems development has been studied both in intraorganisational (Vidgen and Wang, 2008) and interorganisational settings (Finnegan et al., 2003). Most studies and design approaches focus on the internal process, and learning has often been approached in a manner in which either learning as a concept is taken for granted (Vidgen and Wang, 2008) or individual learning has been disregarded – for example, through imprecise notions of organisational learning (Lyytinen and Rose, 2006). Or the opposite occurs – precise understandings of learning as a bridge between working and innovation, yet as a culturally
oriented concept (Brown and Duguid, 1991). Here, the focus is on both intra- and inter-organisational processes and on individual learning (Finnegan et al., 2003) zooming in on the very micro trajectory of learning, and asking:

*What intra- and inter-organisational learning occurs in a systems development project, using the case of wind turbine control systems?*

The systems development and learning are closely intertwined with business processes and occur in a commercial company (Tjornehoj and Mathiasen, 2008). The challenge is to create low-cost yet robust and quality systems where operational systems development interacts with sales and strategic management on a daily basis.

The empirical work is an ethnographic study of a medium-sized WTC systems developer and manufacturer (Mathiasen, 2012). The focus is on the development of the wind park monitoring and control system called A80. The company, “SystemCO” (a pseudonym), supplies physical breaker panels consisting of HW and SW, an operational WTC that is supposed to be cost effective and reliable. This core business involved a series of systems development activities, such as developing specifications, programming, testing, and prototyping as well as manufacturing of the WTC.

In the wind turbine industry, the Original Equipment Manufacturer (OEM) usually sources a range of sub-systems and components, including the WTC systems. As SystemCO has been operating in this industry for a long time, it possesses competences for acting in various more or less comprehensive supplier roles, depending on the OEM’s understanding and delimitations of its supply needs.

The framework of understanding draws on Dewey’s (1933; 1938) work on learning and use elements of science technology and society studies (STS), (Hutchby, 2001; Henderson, 1999; Latour, 1992; Woolgar and Grint, 1997). According to Dewey (1938), experience and the meaning creation process are central for learning. Here this understanding is applied in combination with the understanding of technology and materiality of artefacts as text (Latour, 1992; Woolgar and Grint, 1997) as well as the view of system development processes as forming sociotechnical practices (STP), (Henderson, 1999). Experience facilitating the “reading and writing doings” is central to the understanding of learning (Dewey, 1933: 277). However, Dewey reminds us (1938: 32), that experience is inseparable from the STP implying doings are facilitated by reciprocal interchanges between the system developers’ experience and accessible constitutive means within the STP. “Doings” is a term used by Goffman (1974) to understand what is initiated when an individual is confronted with an indeterminate situation and tries to make sense of “what is going on here” (Goffman, 1974: 8). The gradual transformation of the indeterminate situation into a determinate situation requires a sequence a doings, which is defines as a strip of doings (Goffman, 1974: 10).

Learning is therefore understood as moving through a strip of doings from an indeterminate to a determinate situation within an STP. The notion of STP is adopted to underline the mutual shaping of the social and the material/technical in system development (Henderson, 1999).

The paper is structured as follows. The framework of understanding for learning processes is presented and discussed first, followed by the methodological considerations. Then, the case of the systems development of the wind park monitoring and control system (A80) is
presented and analysed, followed by a cross-case analysis, a discussion and finally the conclusions.

2 Framework of understanding

There has been a wave of contributions to understanding learning and knowledge development (Brown and Duguid, 1992; Carlile, 2004; Nonaka et al., 2000) studying organisational and interorganisational processes and across sectors including IT (Finnegan et al., 2003; Rosencranz et al. 2014). And a series of concepts have been proposed ranging from cognitivist to cultural (Newell et al. 2009). Yet there is a tendency for most contributions to get lost in more general organisational conceptualisation or to miss out the processual element. Therefore this contribution adopts a third position (Elkjær 2004), a Deweyan pragmatist, focusing on the micro processes of individual learning and viewing this as being socially embedded. The central interest of this article is through this lens to better understand how learning occurs when SW and HW engineers interact with materiality of the artefacts during systems development. Systems development activities happen within STP involving a dual heterogeneity; i.e., we understand the STP to be constantly mutable in the interaction between the social and the technical (Henderson 1999) and in addition the system developers are neither passive individuals nor a homogeneous crowd. Rather the HW- and SW engineers are heterogeneous and they demonstrate different levels of commitment and experience when developing HW and SW.

As a process, learning is defined as the transformation of an indeterminate situation into a determinate situation; a successful inquiry (Dewey, 1938: 27). An indeterminate situation arises due to disturbance in system developer’s experience. Given that the system developer’s experience is inseparable from the contextual setting the indeterminacy arises within an STP. Thus, the learning process is enabled by the system developer’s habitual-/reflective experience and the materiality of the accessible artefacts within the STP. A restoration of determinacy creates new experience, i.e., learning, for the system developer. So saying, learning as a product is defined as new experience for the system developer. The system developer and the STP, however, are evolving in reciprocity. Focusing on how doings unfold within the specific STP makes it possible to grasp this reciprocity between materiality and system developers’ experience and thereby analyse the learning process. Doing is an act conducted by the system developer.

The doing is initiated when a system developer is confronted with an indeterminate situation and tries to make sense of “what is going on here” (Goffman, 1974: 8). This indeterminacy incorporates the natural as well as the social world. In addition, Goffman (1974: 24) emphasises that the doings might result in a manipulation of the natural and/or social world. The indeterminate situation occurs as a disturbance of the habitual experience, which Dewey (1938: chapter 6) regards to be a precognitive phase of the learning process. To transcend this precognitive phase and thereby activate reflective experience requires a proper understanding of the indeterminate situation; i.e., anchoring of the indeterminacy is crucial for ensuring a continuation of the micro trajectory learning process. Drawing on Dewey (1938: 112), an indeterminate situation grows out of an empirically real situation and to active reflective experience it is crucial to ensure a proper anchoring of the indeterminacy. Practising doings without a well-defined and empirically anchored problem implies that the system developers merely fumble through the learning process.
Materiality of artefacts is here understood as the physical (HW) and/or digital (SW) materials in a particular form (Leonardi, 2012). The composition of the STP influences and the doings being conducted develop the materiality of an artefact.

Strip of doings forming the micro trajectory consists of a number of sequential doings gradually transforming the indeterminate situation into a determinate situation (see Figure 1). Each single doing can in principle be treated as a topic to be subjected to an analysis (Goffman, 1974: 564). Not all doing leads to learning. Some doings are blocked, or derailed and do not lead to a determinate situation.

The technology-as-text metaphor equates systems development of a WTC with the creation of text and dependant on reading other texts. The use of the technology-as-text metaphor in this research is slightly different than the approaches applied by Latour (1992), Akrich (1992), and Woolgar and Grint (1997), since it is here embedded in a pragmatist understanding of learning (Dewey, 1938).

This research subscribes to the idea that technology-as-text is inseparable from the engineers’ process of meaning creation. Accordingly, just as reading texts in books/articles makes it possible to gain new experience and thereby be able to write new texts in books/articles, the reading (doing) of sketches, drawings and electrical diagrams makes it possible for the engineers to conduct writing (doing) into these artefacts, i.e. shape and design them.

![Figure 1: The framework of understanding. Learning occurs as doings, proceeding from the indeterminate situation (left) to the determinate situation (right) (source: Mathiasen, 2012).](image)

The enabler for the reading and writing doings is the reciprocity between SW and HW engineers’ experience and the materiality of artefacts. And this reciprocity involves interaction between heterogeneous engineers and artefacts with different levels of materiality (Orlikowski and Scott, 2008). Such STPs form over the systems development project process characteristic trajectories of series of STP (Dewey 1938, Elkjaer 2004).

### 3 Method

The method consists of an integrated theoretical, methodological, empirical and analytical part (Dubois and Gadde 2002, 2014), which in particular is open towards empirical findings and their influencing on theorizing. The chosen theoretical approach builds on and extends a
Dewey conceptualisation of learning, and posits this a main theoretical embedding (Dewey 1933, 1938), but also draw on STS concepts for materiality (Grint and Woolgar 1999, Henderson 1998, 1999, Latour 1992, Leonardi 2012). The understanding of the systems development process and learning processes is overall interpretivist (Howcroft and Traut, 2005, Walsham, 1993) and critical (Klein and Myers 1999), but within this broader school of thought we mainly draw on Dewey’s pragmatism. The understanding of materiality of artefacts is to view it as text, which is in close correspondence with Dewey (1938)’s understanding of inquiry allowing the combination.

The empirical material stems from one author’s PhD study (Mathiasen, 2012). This is an ethnographic field study, carried out in 2009 and of the duration of one year which required the researcher’s long term presence at the project organisation involved in the ASIACORP project three days a week to carry out more than 30 interviews, study written material and attend more than 60 meetings, and be present in the open plan offices where the engineers worked participating in small talk and other activities (Mathiasen, 2012).

The first case analysed below was selected from among four cases developed with the company studied in the PhD project (Mathiasen 2012). The case was selected as extreme rather than critical, as it forms an interesting antidote to the expectation that learning will occur in systems development (Flyvbjerg, 2006). Analysing the case involved among other things using inter colloquial review by the other author and the main supervisor of the Ph.D, increasing the thrustworthiness and credibility of the analysis (Klein and Myers, 1999).

The other three cases all encompass both intra- and interorganisational learning. The four cases were originally selected from two settings. One setting where the customer was regular and well known to the systems developers of SystemCO. And another setting where the customer (ASIACORP) was new to Systemco. This selection was carried out in to steps of study where the first selection step originally was done for quite mundane intuitive reasons, i.e. a sense of possible difference in learning between such two case settings. After an initial round of study the separation in four cases (to two times two) was done, this time because of characteristically different learning processes. The three other cases were analysed in a similar manner as the first, but we have chosen not the present this analysis here. The cross-case analysis of all four cases relies on Stake (2000), meaning that each case is viewed as representing important and potentially unique insights about learning. It is assumed, moreover, that the variations in the cases being studied will provide insight into the complexity of learning processes. We therefore compare the cases, even though we do not claim generalizability (re discussion in Flyvbjerg, 2006, see also Klein and Myers 1999 and Dubois and Gadde 2002).

This article was developed through revisiting the empirical material developed in the PhD (Mathiasen, 2012). The original material relies on the same theoretical framework and focuses on product development in order to analyse SW and HW engineers’ learning. Here, the understanding of the process shifts to viewing it as systems development of the HW and SW that was carried out. We understand the shift from product development to systems development as a minor change in emphasis within the same research paradigm and methodological approach. We also choose to not discuss the differences between cases related to one or the other customer here.

The limitations to this contribution are first that revisiting the empirical material in the described manner delimits us from establishing stronger links with information systems literature on learning processes before making the field work, as the original study builds on
product development literature. Second, even if wind turbine control systems (WTC) belong to a larger family of control systems we do not study systems development of such a group of control systems, but go into detail with these four cases in one company with accompanying interorganisational relations to other companies.

4 SystemCo makes control systems

SystemCo develops its systems in an interorganisational setting. In the selected systems development case this consists of a constellation including a customer company, two consulting companies and the specifying and system-producing company. The customer for the system development project is a major corporation with headquarters and departments in Asia (ASIACORP). It is represented in Europe through a department in Germany that focuses on renewable energy. The company developed its first complete wind turbine roughly ten years ago and a second six years ago. Neither were successes and the SystemCO representatives therefore view the customer as having limited experience with wind turbines. Two consulting organisations, Alpha and Bravo, have therefore been involved in the design of the new wind turbine to ensure mechanical stability with respect to vibrations that has huge impact. SystemCO’s product, the WTC, regulates the other components/systems and the function of WTC will influence vibrations in nearly all components/systems in the wind turbine. ASIACORP therefore makes use of SystemCO’s experience regarding development of WTCs (interview, SW engineer 1). SystemCO’s experience is viewed as important for the entire turbine system.

The project organisation for the turbine development project encompasses a (customer) project group of 22 staff in Germany. The two consultancy companies, responsible for the mechanical stability and engineering of the gearbox, are attached to this group together with SystemCO. SystemCO has also established its own project group in Denmark with links to its production unit in Poland. ASIACORP’s interaction with Alpha and Bravo is rather dense and focuses on engineering services. In contrast, SystemCO supplies physical breaker panels to ASIACORP, an operational WTC that integrates HW and SW, the aim being to be cost effective and reliable. These different roles give rise to conflicting perceptions of the task to be handled by SystemCO.

The order commissioned consists of parts of the WTC: HW and SW elements: the pitch control system, the converter, eight so-called breaker panels, one park control and monitoring system (A80), a slipping ring (mechanical piece), cabling and aviation lights for the turbines. The focus here is on the system called A80. At the outset of the development, the elements were all to be built according to a known model from China Shipbuilding Industry Cooperation (CSIC). Yet the A80 represents new systems development for SystemCO, although the widespread opinion amongst the engineers was that the order for ASIACORP involved simple deliveries compared to their existing competences.

The project group is responsible for the development of all SW and HW for the WTC. SW is integral in controlling and regulating the wind turbine; therefore, it is a pivotal means to minimise the above-mentioned vibrations/forces in various components/systems. To optimise the mechanical stability some collaboration between the HW/SW engineers and the two consulting organisations is necessary.

“Alpha conducts lots of simulations concerning load and stress on the components in the wind turbine. In order to carry out these simulations, they need to know how we regulate
the wind turbine. For instance, depending on how we pitch the blades in the wind, you will get different forces and vibrations in the components. And as the gearbox is normally a problem, you have to minimise these forces and vibrations.” SW engineer 3, SystemCO

At SystemCO, the inter-organisational meetings take place in the boardroom. Laptop, blackboard and various artefacts are applied to facilitate the dialogues. But in this room, the physical modular panels are not involved in enabling determinacy.

4.1 The development process of the A80 system

The specification process of the system, was carried out in two steps: first, developing a so-called miniTS (preliminary technical specification), which the parties needed to agree on before entering the detailed specification phase - in SystemCO’s terms, ‘the TS-phase’; and second, proceeding to a full technical specification, where agreement was needed prior to production and delivery. The A80 is not handled by a co-located project group within the boardroom, but by HW and SW engineers also working with other systems development activities. During the miniTS phase, the development of the A80 was the responsibility of the salesman and ASIACORP’s project manager. Central design criteria for a park monitoring and control system to fulfil the customer’s needs/wishes encompass functionality, the number of necessary redundancies, and the number of wind turbines being monitored. In this regard, the salesman considered the technical support for achieving determinacy as an area where there was room for improvement.

“The park server (A80, author) is created by Leo (HW engineer 3, author) and he pieces together the breaker panel, while Frank (SW engineer 2, author) makes the SW. In the sales phase, we need input from HW, SW and from production as well, but they do not talk with each other.” Salesman, SystemCO

Based on a dialogue with HW engineer 3, the salesman completed the technical pre-clarification with ASIACORP’s project manager and made the miniTS dealing with the A80. In accordance with the miniTS, the A80 was a copy and paste from a previous CSIC 2.0MW project. HW engineer 3 acknowledged that he had been asked about the A80 for ASIACORP.

“You see they (the salesman, author) contacted me a Friday afternoon about half past one o’clock. They asked whether the park server (A80red.) being used in the China project could be used in the ASIACORP project; actually, it was my starting point. Of course, it will work, or at least the HW will work, but I do not know where the park server is placed or what they want to put into it. But I gave them a price for the system that we created for the China project.” HW engineer 3, SystemCO.

SystemCO’s project manager considered the cross-organisational pre-clarification of the A80 to be rather exciting; but/and in this regard he clearly doubted the validity of the information gathered about ASIACORP’s needs/wishes.

“I do not think the customer has spent much time on the park system, and honestly, I do not think that we have made enough of an effort to explain to him (ASIACORP’s project manager, author) what he will get. Furthermore, I do not think that we know what is included in a park system and what to offer to our customers. For new business development [department], a park system is just a thing.” Project manager SystemCo

The transition from the miniTS- to the TS-phase became quite problematic for the project as such, revealing tensions between sales people and engineers internally. The tension
revolved around whether the sold system was to be a standard system or a customized solution. At the time the TS document was made, however, the A80 was only the subject of discussion at the intra-organisational meetings on two occasions; additionally, the A80 was not discussed in any inter-organisational meeting when making the TS-document. The A80 was discussed for the first time at the intra-organisational meeting at the beginning of the TS writing phase, where the scope for the systems development project was on the agenda. The miniTS was the focal point of the presentations and the subsequent doings. During a dialogue between HW and SW concerning the question of the interfaces, it was emphasised that the project group should remember the interfaces between the WTC and A80. This comment did not prompt any doings in this regard, and the topic faded away. The second time that the A80 was discussed was in the project group room, where SystemCO’s project manager met with the salesman informally. Their dialogue addressed the TS document, and especially the increased price level in the TS document compared to the miniTS. The A80 SW development costs were missing in the specification.

“It takes 40 hours to create the SW, and it is not included. Actually, it is necessary to include the SW price in the calculations. We have to do that in the future.” Project manager, SystemCO

As the A80 only received little attention during the TS phase, the technical pre-clarifications retrieved in the miniTS were not refined.

Shortly after receiving the signed TS documents from ASIACORP, an intra-organisational start-up meeting was arranged. The two responsible engineers for the A80 – HW and SW – participated. Since all other deliveries were listed in the project plan, the A80 triggered a discussion on whether or not the SW engineers had the necessary time for the SW; apparently, it was not a problem for the SW engineers. However, at the very end of this meeting, SystemCO’s project manager indicated through his body language that he wanted HW engineer 3 to remain seated, and when the other participants had left, a dialogue took place about the faulty sales prices used. They were perceived to be below SystemCO’s own cost prices.

According to HW engineer 3, the A80 development task was verbally handed over by SystemCO’s project manager; the only information he received was that the A80 had to be similar to the China model. Since HW engineer 3 considered this to be an inappropriate technical solution, he made a proposal for the system that both meet minimum functionality requirement and involve low cost. Undoubtedly, he considered it to be a challenging task:

“I designed a very affordable park server (A80 red.). The cabinet was much cheaper than the one normally being used. But when I was finished, they came by and now they wanted to include new functionalities, and that obviously costs. Later on, another came by and he asked whether or not a SQL license had to be included. But I do not know anything about that, because I never bought SW for a park server. That is the way we have been working. It has been backwards and forwards. For instance, which SQL server to install? The price of this server depends on the number of customers to be connected.” HW engineer 3, SystemCO

The manner the process emerges and ends alludes to the business and contract framing of the systems development processes. Responsible managers at SystemCO decided to hold ASIACORP indemnified meaning that SystemCO defrayed all additional expenses with respect to the A80 system. The involved SystemCO employees agreed that the A80 process
had been miserable. The technical employees described the problem to be a blurred understanding of ASIACORP’s needs/wishes. The information retrieved by the salesman was inapplicable for designing the park monitoring and control system. Actually, HW engineer 3 did not consider the sold application to be a system, but rather a ‘tool applied to collect data for fun’. This distinction shows how he disappreciated the involved learning.

5 Analysis

The approach taken here on how to understand learning in systems development is initially to examine the described case, considered as an extreme case. This analysis goes through the steps of the development process, followed by a cross-cutting discussion covering all four cases studied, including the first.

In relation to A80, the drawing up of the miniTS required the gathering of information before the salesman initiates the preliminary technical clarification with ASIACORP’s project manager. The salesman, interacting with the HW engineer 3, did this. As a consequence of the salesman’s limited experience with A80, these strips of doings did not lead to learning. HW engineer 3 considered the information provided by the salesman to be insufficient for him to be able to give precise answers: The price level of an A80 system depends on the functionality needed, the level of necessary redundancies, and the number of wind turbines connected to the A80 system. None of this information was accessible during the strip of doings involving the salesman and HW engineer 3. Furthermore, HW engineer 3 did not consider himself an A80 specialist, because his experience was limited to HW issues. Nevertheless, the information handed over by HW engineer 3 to the salesman ensured a continuation of the strip of doings, resulting in a determinate situation. The salesman interpreted the achieved determinacy as approval of using the CSIC technical platform in the project. However, a proper anchoring of the indeterminate situation did not occur. There was no disturbance in habitual experience, which is necessary in order to transcend this precognitive phase and thereby activate the reflective experience. The continuation of the strip of doings thus drew on habitual experience and the mere handing over of information, thus constraining the learning process. Although the achieved determinacy turned out to have a low level of sustainability just after the TS document was signed, the salesman used the approval of the CSIC technical platform as the constitutive means to guide and thereby ensure a continuation of the strips of doings when drawing up the miniTS.

As mentioned in the above, the salesman’s interpretation of the CSIC platform was the underlying basis for the collaboration when drawing up the mini TS. However, during the miniTS phase an I/O overview diagram became the constitutive means. The salesman from SystemCO and the customer’s project manager regarded this I/O overview as a functional description and drew on this constitutive means to facilitate the strips of doings. Apparently, the strips of doings facilitated anchoring of the indeterminate situations enabling a commencing of learning. However, an I/O diagram is not a functional description implying this constitutive means turned out to be unusable as it represented a product description of the breaker panels, revealing an internal tension in SystemCO between delivering standard and/or customized modules. As neither ASIACORP’s project manager nor the sporadically participating HW/SW systems developers’ pay much attention to the A80, the salesman is alone in deciding technical issues to be discussed within the inter-organisational STP. Consequently, the strips of doings originated from his experience with the HW/SW elements
of the CSIC solution. As a result, HW/SW issues and/or functionalities of the A80 neither prompted any anchoring of indeterminate situations nor any successful strips of doings within the inter-organisational STP. As the indeterminate situations were not properly anchored, the writing doings in the miniTS drew on habitual experience and thus the handing over of information. Merely handing over information constrains the learning process.

Also during the TS phase, there was a lack of focus on the A80. It was not the subject of any strips of doings throughout the TS phase, whether within inter-organisational, intra-organisational or daily working STPs. Thus, the TS phase did not result in any changes/modifications to the pre-clarifications; it remained a CSIC technical platform. At the time when the A80 caused disturbance in the habitual experience and thereby activated reflective experience, the signed miniTS was replaced by a signed TS document. Consequently, the interplay between inter-organisational and daily working STPs was completed without progress. Subsequent to the signing of the TS, however, attention was drawn to A80 as part of an intra-organisational STP. One strip of doings addressed the creation of SW, while another strip of doings occurred between SystemCO’s project manager and HW engineer 3. This addressed the trajectory charted by all strips of doings throughout the miniTS and TS phases, since this caused disturbance in the project manager’s habitual experience. HW engineer 3 acknowledged that he handed over information concerning the CSIC A80 to the sales manager, but based on his experience he questioned whether the specification constituted sellable SW and HW. Anyhow, this strip of doings caused a radical change of the trajectory, by which the TS document became an unusable constitutive means for enabling the strips of doings.

HW engineer 3 never met a representative from ASIACORP. Since neither the miniTS nor the TS document were any longer usable constitutive means, HW engineer 3 needed something to guide and enable a continuation of the strips of doings in his attempt to create an A80 for ASIACORP. In this situation, a statement by SystemCO’s project manager became crucial. He pointed out that the A80 had to be as cheap as possible, without compromising reliability and quality. This had a constitutive effect, which made it possible to achieve a sustainable determinacy. Reading doings in the TS document disturbed the habitual experience, which enabled a proper anchoring of the indeterminate situation. This triggered the reflective experience, dismissing the previous trajectory of strips of doings. HW engineer 3 had a clear understanding of a usable technical platform for an A80 system. This understanding combined with the project manager’s statement guided and enabled the continuation of the strips of doings during the creation of the product/production documentation and the pilot production. As the radical change in the trajectory took place after the TS document had been signed, all strips of doings conducted to create the A80 took place only within the daily working STP. Consequently, no inter-organisational learning occurred.

5.1 Cross-case analysis

The PhD-project that forms the background for this article studied four cases of learning processes. Two cases relate to ASIACORP. Two other cases relate to a large OEM, which in general takes the lead regarding the development of HW and simultaneously develops all SW applications itself. In the setting of delivering to ASIACORP, however, SystemCO had the opportunity to move the boundary between the wind turbine manufacturer, the purchaser, and
SystemCO’s own services and enter an area of combined SW and HW systems development. The customer, ASIACORP, wished to create an environment for mutual learning (Finnegan et al., 2003), yet for various reasons, SystemCO did not play along, and a series of inter-organisational processes (STPs) were hampered or even blocked in the interaction between SystemCO and ASIACORP.

Across the four cases, the composition of STP, the anchoring of the initial indeterminate situation, and the continuation of strips of doings reveal some interesting patterns.

Across inter-organisational STPs, intra-organisational STPs, and daily STPs, the learning enabling elements encompass high accessibility to constitutive means and different levels of experience among the engineers. If the constitutive means, such as a specification, is too ductile, it will create insecurity, whereas if it is too obdurate, the risk exists that any learning will be blocked.

The anchoring of the indeterminate situation is crucial for the learning process. A proper anchoring enables transcending the precognitive phase activating the system developers’ reflective experience. A continuation of the learning process draws on reciprocity between the system developer’s reflective experience and materiality of the constitutive means. Moreover, convergent anchoring in a group enables collective learning, which involves reciprocal interchanges between the constitutive means and the systems developers. The anchoring varies across inter-organisational STPs, intra-organisational STPs, and daily STPs, but four main anchoring types can be identified, coupled to four characteristic micro-trajectories of learning:

- No through road for reciprocal interchanges constrains or blocks learning.
- A one-way road to hand over information constrains learning.
- A way station for reciprocal interchanges constrains learning.
- A mountain road for reciprocal interchanges enables learning.

The four micro trajectories of learning are juxtaposed in table 1 below, which we denote the anchoring matrix. It categorises the learning processes according to orchestration and interpretation of the initial indeterminate situation. As Dewey (1938: 112) remind us “to set up a problem that does not grow out of an actual situation is to start on a course of dead work…”. A problem emerges due to disturbance in habitual experience. To transcend this precognitive phase, the indeterminate situation has to be actual; the indeterminate situation has to emerge within an STP. In contrast, a ready-made indeterminate situation is formulated beyond the boundaries of the STP in which it has to be handled complicating to transcend the precognitive phase, and thus the leaning process. The following interpretation of the indeterminate situation can either diverge or converge.

The case analysed here, A80, is a case of the second type (one way road), where information is merely handed over. However, our cross-case analysis also identifies several other micro-trajectories where the learning process is blocked. The fourth type therefore deserves particular attention here. The “mountain road” learning trajectory is characterised, we find, by high accessibility of diverse and usable constitutive means as well as engineers with different levels of experience.
Orchestration of indeterminate situation: | Interpretation of indeterminate situation | Convergent
---|---|---
Emerging within the STP | No through road: | Mountain road | Reciprocal interchanges | Reciprocal interchanges | Learning occurs
 | Reciprocal interchanges follow divergent tracks |  | draw on reflective experience |
 | No learning |  | |
Ready-made outside the STP | One way road: | Way Station | Reciprocal interchanges |
 | Mere handover of information |  | are put on stand by |
 | No learning |  | Pave the way for learning |

Table 1: Anchoring matrix: Microtrajectories of learning (adapted from Mathiasen 2012)

Also, the STP is relocated from engineering premises to production premises in the mountain road trajectory. This facilitates the reciprocity between the constitutive means and the engineers’ experience. The mountain road trajectory is winding, there are occasions of barriers that need to be overcome implying that this successful trajectory requires more resources than the three other micro-trajectories.

6 Discussion

Our analytical framework has enabled us to apply a laser-like focus on the micro processes that enables or constrains the learning processes and to appreciate how STPs unfolds alongside the strips of doing involving reciprocal interchanges between engineers and systems element. Our findings have something in common with Rosenkranz et al. (2014) findings in terms of different “brokering situations” can be more or less resource demanding to achieve learning. However, due to our focus on the micro trajectories of learning processes, we have been able to show that learning does not automatically occur, neither is it automatically embedded in the participating organisations’ domain specific knowledge.

Other analytical frameworks to understand practice-based learning (among others, Brown and Duguid, 1991; Gherardi and Nicolini, 2000; Nonaka et al., 2000; Carlile, 2004), do normally acknowledge a situated working practice. In general, however, these analytical frameworks to study practice-based learning consider individuals as being homogenous crowd having similar learning mechanisms and motivation for action; being a member of the practice enables learning per se. The analytical framework in our research acknowledges dual heterogeneity as we understand the STP to be constantly mutable and that system developers are heterogeneous and they demonstrate different levels of commitment when developing HW and SW. Consequently, the analytical framework focuses attentions on how an activity – a strip of doings - unfolds within an STP making it possible to grasp that both the engineers and the STP are heterogeneous and that engineers and STP are evolving in a reciprocal interaction. By doing so, the analytical framework makes it possible to identify and analyse the characteristics enabling or constraining the learning process when engineers conduct an activity.

Our particular contribution thus is the emphasis on individual learning in interaction with materiality of artefacts and the social context. The STP found involves building reciprocal relation between man and matters (Dewey, 1938; see also Leonardi, 2012). But secondly and
importantly we find that the heterogeneity of the engineers as a group enables learning processes, and that management can make a difference by providing more or less frozen specifications, and that the business context might dismiss the learning. All elements that transcend a Deweyan man-matter inquiry.

7 Conclusion

This paper sets out to investigate the intra- and inter-organisational learning that occurs in a systems development project through focusing on micro-trajectories of learning processes. The framework of understanding highlights the importance of moving from an indeterminate to a determinate situation through a strip of doings. Through the analysis of an extreme case where inter-organisational learning was blocked, we illustrate the reason why learning did not occur. By including three other cases, we show how learning as accomplished strips of doing can occur for systems developers involved in the intra- and inter-organisational STPs in various parts of systems development.

In the particular case studied – the development of a wind park monitoring system – striving for cost efficiency and swift development lead to some rocky processes that cause learning to be blocked. Neither individual nor organisational learning occur automatically during systems development. But central preconditions for learning are heterogeneity amongst systems developers, successful anchoring of an indeterminate situation, accessibility of usable artefacts, and the composition of the STP.

The implications of the findings are that managers can enable learning processes during systems development in a number of ways. For example, they should ensure that constitutive means (artefacts), such as specifications, are accessible and that they are sufficiently obdurate. Too ductile constitutive means, such as customers with unclear demands, can block learning processes. Learning processes are enabled when engineers with different experience collaborate. Focus on anchoring the indeterminate situation in a convergent manner is enabling for collective learning, as opposed to only individual learning.

On a more business strategic level, systems development companies can focus on the anchoring (orchestration) of the indeterminate situation in order to safeguard their learning and even protect their product knowledge, which at a time is an asset for interorganisational learning even involving the challenge of managing the risk of giving knowledge away.

References


