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Globalisation of Concurrent Engineering Activities: Transferring-, Translating- and Transforming Approach

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Abstract. The paper analyses the consequences of using a one-size-fits-all concurrent engineering (CE) approach. Six CE projects are studied; each addresses a company located in a high-wage area and one of two abroad facilities located in low-wage areas. The analysis reveals; the companies neglect the consequences of a higher perceived newness and interdependence than anticipated from the outset; habitually, practitioners' understanding draw on existing solutions; because the sub-stance of the handed-over information differs, the one-size-fits-all approach is inappropriate. Three approaches to gain a convergent understanding are suggested: 1) transferring approach, 2) translating approach, 3) transforming approach.

Keywords. Concurrent engineering, globalisation, one-size-fits-all, learning

Introduction

A geographical dispersion of concurrent engineering (CE) activities makes it difficult to achieve a convergent understanding among the practitioners. To achieve a convergent understanding some researchers advocate knowledge sharing across boundaries [1], while other researchers focus on managerial issues [2] adapted to CE principles [3]. In general, these models advocate a one-size-fits-all best practice approach. Ahmad et al. [4] and Cooper [5] question this one-size-fits-all approach and suggest the use of contextual-based models. These models however, do not address the consequences of a geographical dispersion of the CE activities. Likewise, as CE involves different professional disciplines [6] practitioners operate in various working practices [1]; [7] meaning that knowledge is embedded in practice [8] and is continuously modified [9]. This contextual knowledge implies that the use of a "knowledge-transfer best practice" approach is problematic. Hence, to achieve a convergent understanding within and across working practices calls for either a "transfer, translate or transforming approach" [10].

To the best of the author's knowledge, researchers have paid little attention to handle CE in a global context where part of the activities are located in high-wage areas while other activities are located in low-wage areas. This paper aims at revealing the consequences of applying a "one-size-fits-all" approach and by combining these findings with practice-based theories to suggest a method to manage CE in global set-ups.

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The paper subscribes to a practice-based viewpoint of learning [11], appreciating that more information does not always facilitate a convergent understanding [12] among interdependent practitioners operating in different practices [10]. Hence, the achievement of a convergent understanding depends on the degree of newness in terms of the development and the degree of interdependence among the practitioners.

The empirical material illustrates a company located in a high-wage area (Global-Company) and two captured facilities, one located in Eastern Europe (Facility-Europe) and one in Far East (Facility-Asia). The CE of six products is presented and analysed.

The findings are; degree of newness and interdependence among interacting working practices are not a subject upstream the development; habitually, the practitioners' understanding draws on well-known solutions and they do not question the one-size-fits-all approach; as the substance of handed-over information differs, the one-size-fits-all approach proves to be inappropriate. The paper suggests that practitioners should be proactive in terms of degree of newness and interdependences. Three approaches to gain convergent understanding are suggested: 1) transferring, 2) translating, 3) transforming.

1. Theory

CE has received considerable attention [6]. In relation to this paper, academia suggests a best practice for managing development and a best practice for sharing knowledge.

The best practice for managing development addresses the use of guidelines as for instance stage/gate models [2], product-industrial V-model [13], set-based CE [3] using iterative front loading [14] and guidelines facilitating manufacturability [15]. In this stream of research, a large number of guidelines have seen the light of day; Dombrowski et al. [16] reveal 181 guidelines, while Anderson [15] suggests 142 guidelines.

The best practice highlighting the role of sharing knowledge questions the deterministic effect of guidelines; rather, the enabler for CE is a combination of guidelines and lessons learned from past CE activities [17]. In other words, CE draws on the creation of and utilisation of knowledge embedded in different practices [18]. As a means to handle this embedded and continuously modified knowledge researchers suggest the use of a representational guideline model [19]. Indeed, Dekkers et al. [20] suggest that managerial structures and guidelines can have a negative influence on practitioners' experience, judgement and thereby the creation of useful knowledge. Likewise, front-loading of functionality and manufacturability guidelines might paralyse the practitioners [21] and often these requirements and guidelines are conflicting [22]. Hence, it can be called in question whether the involved practitioners have the ability to handle all these guidelines or they are overloaded with information; overload occurs if the information-processing requirement exceeds the information-processing capacity [12] entailing inappropriate decision-making processes [23]. In addition, as knowledge can have differt semantic [1], a one-size-fits-all approach to share knowledge within and across working practices is inappropriate. This is elaborated below.

"Practice and knowledge creation" unfold when handling a CE activity. Referring to Dewey's [11, p. 32] "*every organic function is an interaction of intra-organic and extra-organic energies*". A practitioner's embodied experience constitutes the former, while artefacts and technical matters make up the latter. The two group of matters

evolves in tandem, which entails that experience is embodied and embedded within practice.

The handling of an activity is a five-phased inquiring process [11] that commences when an individual strives to understand what is going on [24] and gradually handles this indeterminacy by ensuring a "*controlled transformation of an indeterminate situation into a determinately unified one*" [11, p. 121]. A successfully controlled inquiring process paves the way for knowledge creation, while an unsuccessfully controlled process results in the inquiring goes astray and consequently no creation of knowledge.

Before elaborating the approach to facilitate knowledge creation within and across working practice the understanding of newness and interdependence are presented.

Newness means that the practitioner(s) can draw neither on their experience nor on existing solutions to handle a CE activity. At the particular point in time of handling the CE activity, something is unknown within the working practice and to find a solution it is necessary to gain access to new knowledge. Newness arises due to new knowledge is or has been created outside the working practice in question.

Interdependence means whether or not the handling of a specific activity in a situated practice influences or is influenced by the handling of activities in other working practices; it embraces activities handled in the past, present activities and the future dimension of activities. Interdependence emerges because of coordinative issues.

"Knowledge-transfer" is pivotal for achieving a convergent understanding. As knowledge is contextual [11] a generic approach to "transfer knowledge" is questionable. In the following, Hutchins [25] account of landing a commercial airliner is used to clarify the *transferring*, *translating* and *transforming* approaches. Hutchins explicates the pilots' actions and use of manuals and instruments during descent and touchdown. The landing manual and technical instruments are the outcome of past development activities in which specialist engineers have written text into the manual and created the instruments.

Transferring: The pilots have lots of experience with landing the airliner and they are well-versed about the landing manual and technical instruments; the manual and instruments enable the pilots to conclusively determine the descent and landing speed. As the pilots are familiar with the manual/instruments syntax, knowledge is transferable.

Translating: If randomly taking one of the passengers from the airliner this person is most likely incapable of doing the landing. However, if the passenger in question is a pilot trained in another type of airliner, he/she might be capable of doing the landing. Despite this passenger is not familiar with the specific syntax in the manual and instruments he/she might be able to use his/her experience from landing other airplanes to translate the information and thereby calculate the descent and landing speed. Thus, the pilot faces semantic knowledge, see [1]; this calls for a translation approach [10].

Transformation: If, for some reason, the manual for landing has to be updated, the specialist engineers need to understand all the codes, indexes and symbols displayed in the manual. In addition, they have to take into consideration information from pilots, various logbooks from the airliners and information on changes/updates conducted on the airliner in question. Referring to Carlile [10], this kind of knowledge is "localised, embedded and invested in a situated practice"; it is pragmatic. This means that something is at stake when handling this knowledge, which requires a transformation approach.

2. Method

Observations are conducted at Global-Company in a five-month period three days in average per week and a visit at Facility-Asia lasting one month. Planned on-location observation at Facility-Europe is replaced by video-, skype- and phone meetings. 15 meetings are observed; lasting from 30–60 minutes. 8 unstructured and 12 semi-structured interviews are conducted, each lasts on average one hour.

Global-Company, founded in the early eighties, is doing business in the consumer goods industry; The company has 350 employees at Headquarters. In 2005, Global-Company acquired Facility-Asia; Facility-Asia has 500 employees. Global-Company acquired full ownership of Facility-Europe in 2008; Facility-Europe has 320 employees.

A stage/gate approach for managing the development is applied; a "business-as-usual" approach. The first stage focuses on creating a design proposal, followed by the preparation of a "concept-plan". The selected facility receives the approved concept-plan and the practitioners gradually clarify the detailed specifications and create a prototype. Finally, the mainstream manufacturing-/supply chain specifications are created.

Table 1 presents how Global-Company, in collaboration with either Facility-Asia or Facility-Europe, develops the six products. The left column shows the labelled project name and duration of the project. The right column illustrates the number of iterations, the project outcome as well as the anticipated/perceived newness and interdependence.

Table 1. The six development projects.

Project	Newness and interdependence
F-Asia 1 Three months.	1 minor iteration and successful outcome. *Global-Company*: Anticipated and perceived newness are low. Capable of creating functional specifications without involving external actors. *Facility-Asia*: Anticipated and perceived newness are low. Capable of creating detailed specification and workable prototype without involving external actors
F-Asia 2 So far, eight months.	3 costly iteration and still awaiting final approval. *Global-Company*: Anticipated newness and perceived newness are low. Functional specifications created in a rush without involving external actors. *Facility-Asia*: Anticipated newness is low; perceived newness is higher than expected. Received information is an upscaling of existing product; struggles to grasp the information to create detailed specifications and a workable prototype; some knowledge interchanges with Global-Company.
F-Asia 3 Seven months.	2 minor and 3 costly iteration. Successful outcome, yet supply chain is inefficient. *Global-Company*: Anticipated newness is low; perceived newness is higher than expected. Specifications do not address product architecture issues; limited knowledge interchanges with Facility-Asia; involves external designer. *Facility-Asia*: Anticipated newness is low; perceived newness is higher than expected. Struggles to achieve understanding of interface issues; collaborates with Global-Company to handle this. Neither manufacturing nor supply chain influence the development.
F-Euro 1 Three months.	1 minor iteration and successful outcome. *Global-Company*: Anticipated and perceived newness are low. Collaborates with Facility-Europa to gain knowledge about manufacturing/supply chain issues prior to drawing up functional specifications. *Facility-Europa*: Anticipated and perceived newness are low. Capable of utilising functional specifications to create detailed specifications.

Project	Newness and interdependence
F-Euro 2 Three months.	1 minor and 3 costly iteration and successful outcome. *Global-Company*: Anticipated newness is low; perceived newness is much higher than expected. Functional specifications do not address product architecture issues; involves an external designer. *Facility-Europa*: Low anticipated newness; perceived newness is much higher than expected. Received information is insufficient to create specifications and a workable prototype; intense collaboration with Global-Company; an external specialist suggests a redesign of the product architecture.
F-Euro 3 Seven months.	5 costly iteration. Termination of the project after 7 months. *Global-Company*: Anticipated newness is low; perceived newness is much higher than expected. Collaborates with external designer to draw up functional specifications; does not realise that this customisable product requires modularised architecture or issues related to manufacturing/supply chain. *Facility-Europa*: Low anticipated newness; perceived newness much higher than expected. Shortly after starting-up detailed design, Facility-Europa realises that the development differs radical from current knowledge; do not understand specifications despite collaboration with Global-Company.

3. Empirical findings and analysis of the six CE projects

Facility-Europe accomplishes the CE activities more systematically and acts as the preferred collaborator; if the objectives of the development is to break new ground Global-Company goes for a collaboration with Facility-Europa. Due to the relative short distance it is more affordable for the practitioners to regularly visit the European facility to evaluate the development activities. However, despite the different conditions, culture heterogeneity and the facts that the practitioners accomplishing the CE activities in Facility-Asia/Europe have different educational background and experience, the application of the "business-as-usual" approach causes to a remarkable homogeneity among the six projects being studied. The findings reveal that the "business-as-usual" approach has a profound influence on the accomplishment of the CE activity. One could claim that it explicates a deterministic effect of managerial guidelines. On the other hand, it can be argued that the business-as-usual approach is too successfully implemented, which constrains the understanding of potential drawbacks upstream the development; in other words the practitioners' do not question the one-size-fits-all approach. Habitually, all practitioners anticipate low degree of newness and thus it makes sense for them to draw on existing knowledge and solutions. In four of the six projects, the perceived newness is higher than expected, which results in costly iteration and in one situation a termination of the development. Indeed, only when the practitioners conducted the iteration the interdependence for sharing knowledge was realised.

The use of the "one-size-fits-all" approach results in a gap between anticipated and perceived newness; please see table 1. The perceived newness of F-Asia 1 and F-Euro 1 is as anticipated low. This is also the situation for F-Asia 2, but during the preparation of the detailed specifications, Facility-Asia faces higher degree of newness than anticipated. As for F-Asia 3, perceived newness turns out to be higher than anticipated by both companies. Finally, perceived newness of F-Euro 2 and F-Euro 3 is much higher than anticipated. The two projects characterised by low degree of newness are completed successfully and only minor iteration occurs. The analysis of these two project reveals that the involved companies mainly do their part of the development on their own; thus, the degree of interdependence is low. The remaining four project,

having higher degree of newness than anticipated, are characterised by costly iteration. These four project have in common that the practitioners at the abroad facility gradually realise an insufficient understanding. The analysis of F-Asia-2, F-Asia-3 and F-Euro-3 demonstrates an interdependence between Global-Company and the abroad facility, while the F-Euro-2 reveals a triadic interdependence among Global-Company, Facility-Europa and an external specialist in product modularisation. However, this interdependence is not a subject matter during the stages of the development where Global-Company has the lead; the interdependence is gradually acknowledge after the abroad facility has taken the lead entailing that the iteration occurs late in the development.

F-Asia 2 is considered as a straightforward development meaning that the functional clarification is accomplished in a rush without involving Facility-Asia. It appears that Facility-Asia is incapable of achieving a sufficient understanding of the handed over information to handle a smooth transition between the functional clarification and the creation of a workable prototype. Likewise, the F-Asia 3 and F-Euro 2, which strictly follow the standardised approach, reveals a similar problematic transition between the functional clarification and the commencement of specifying a workable prototype.

The problematic transitions result in the abroad facility struggles to comply with the functional requirement. The analysis reveals that the accomplished iteration occurs be-cause the practitioners do not address pros and cons in relation to the chosen product architecture; by habit, an integral architecture is chosen. It seems to be a challenge for the practitioners to gain sufficient understanding of the interfaces among subsystems to create a workable prototype. In the same vein, Global-Company does only gain an under-standing of the existing manufacturing-/supply chain set-up upstream the development in one of the six projects; the F-Euro 1. Nevertheless, costly iteration and the realisation of interdependence enable the practitioners to modify the chosen product architecture to the existing manufacturing-/supply chain set-up and thereby achieving an acceptable manufacturability in F-Asia 2 and F-Euro 2. This is not the case in F-Asia 3; despite the practitioners acknowledge the interdependence, it is too complicated at present time to modify the chosen product architecture to the supply chain set-up.

As for F-Euro 3, Global-Company and Facility-Europe realise a high level of inter-dependence shortly after commencing the creation of detailed specifications. Despite intense collaboration during this stage of the development, the practitioners are incapable of creating a workable prototype. Three contributing factors to the termination are identified. First, upstream the development the practitioners employed at Global-Company determine the functional specifications on their own; they are not aware of F-Euro 3 differs radical from the current understanding and existing solutions; they do neither address issues related to the product architecture nor to the manufacturing and supply chain set-up. Second after handing over the functional specifications, the practitioners employed at Global-Company and Facility-Europe do not achieve a convergent understanding in terms of how the "specified customisation options" influences the choice of product architecture and likewise the consequences in relation to the manufacturing-/supply chain architecture; the manufacturing and supply chain are tailored to fulfil current sales variety/volume and not to customisable products. Third, even though the interdependence becomes acknowledge when creating the prototype the practitioners do neither gain an understanding of the interfaces at subsystem level nor how to manufacturing these subsystems. Contrary to F-Euro 2 development, the

practitioners do not involve an external specialist in an attempt to gain access to the necessary knowledge.

4. Discussion and conclusion

The rightmost part of Figure 1 summarises the analysis of the six projects, while the figure to the left suggests three different approaches to gain access to and utilise practice-embedded knowledge depending on degree of newness and degree of interdependence.

The "time axis" in the rightmost figure illustrates the stage/gate approach; in accor-dance with the business-as-usual approach Global-Company has the lead upstream the "point of transition", while the abroad facility takes the lead downstream this point. Newness and interdependence are depicted at the other two axes.

As it appears from the figure, at the outset of the CE the anticipate newness and interdependence are low in all six projects. The arrows alongside the time axis, starting and ending at the grey squares (F-Asia 1 and F-Euro 1), grey triangles (F-Asia 2 and F-Asia 3), grey circles (F-Euro 2) and grey rhombus (F-Euro 3), illustrate how the perceived newness and interdependence unfold during the six projects. The grey square arrow demonstrates CE where practitioners are familiar with the development and thus the handed over information. The *transferred* information enables the practitioners to accomplish the development on their own. The grey triangle arrow illustrates an example where the transferred information is insufficient meaning that the abroad practitioners are incapable of accomplishing the development on their own. A higher degree of newness and interdependence becomes apparent and it is acknowledged that the abroad practitioners need support to *translate* the handed over information; in other words, costly iterations are necessary to bring the two projects back on track. The grey circle and grey rhombus arrows show that the handed over information is obscure for the abroad facility and despite the acknowledgement of a high interdependence the two interacting companies are incapable of gaining a convergent understanding. The analysis demonstrates that something is a stake in terms of the chosen product architecture as well as in the existing manufacturing/supply set-up. The involvement of an external specialist enables a *transformation* of the information handed over in F-Euro 2 (grey circle arrow), which is not the case in the F-Euro 3 (grey rhombus arrow); the high degree of interdependence is not acknowledge and at the end the project is terminated. Hence, at the point of transition the one-size-fits-all knowledge transfer approach is habitually applied. Likewise, the consequences of the actual degree of newness and interdependence are not acknowledged before the abroad facility throws in the towel. This reactive approach results in the practitioners are incapable of handling the information; in the words of Galbraith [12], the practitioners are overloaded with information, which results in costly iteration and a termination of one of the project.

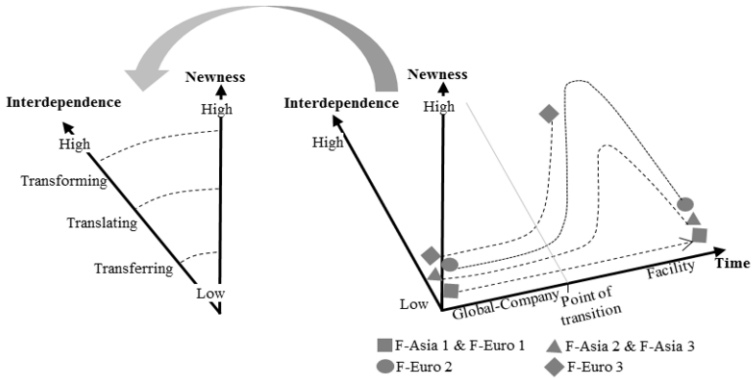

Figure 1. Newness and Interdependence, and three approaches.

This paper suggests a proactive and ongoing reflective assessment of the anticipated degree of newness and degree of interdependence. Obviously, an unambiguous clarification of newness and interdependence is not possible prior to doing the development, but the assessment should be precise enough to understand how difficult it will be for the practitioners to gain access to and utilise the practice-embedded knowledge. The leftmost part of the above figure 1 is a mirror image of the newness and interdependence axes in the rightmost part of figure 1. Based on an assessment of newness and interdependence an approach to handle practice-embedded knowledge is decided. Three approaches are suggested; transfer, translate and transform.

A low degree of newness and interdependence means that the practitioners are on safe ground and thus can draw on well-known solutions (see the analysis of F-Asia 1 and F-Euro 1). As the practitioners are familiar with the development and they know how to understand the handed over knowledge the transferred approach is suitable.

A medium degree of newness and interdependence entails that the practitioners are unfamiliar with and therefore do not offhand understand the handed over knowledge, which is needed to accomplish the CE activities. To gain a convergent understanding the practitioners have to do a translation of the accessible practice-embedded knowledge; in the analysis of F-Asia 2 and F-Asia 3, we witness how practitioners having different organisational affiliation gradually translated the handed over specifications.

A high degree of newness and interdependence means that the received knowledge misfits the current technical solutions and/or manufacturing/supply chain set-ups and thus the prevailing understanding within the specific working practice; as demonstrated in the analysis of F-Euro 2 and F-Euro 3, something is at stake. The achievement of a convergent understanding depends on whether it is possible to transform the practice-embedded knowledge, either within one or among all involved working practices.

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