Characteristics of Knowledge and Barriers towards Innovation and Improvement in Collaborative Manufacturing Process Chains

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Abstract. The characteristics of knowledge relevant to initiate innovation projects or improve existing manufacturing processes have been identified against the background of an organisation participating in a collaborative manufacturing process chain. Those innovation or improvement processes rely on differing types of knowledge, which must be combined in order to determine the current state, the desired state, and the methodology to get there. In a collaborative environment, all of these knowledge types can be fragmented and stored within certain partitions resembled by people, or organisational units. Within this paper, two different organisational units, management and employees of a focal organization or those of related partners have been selected to illustrate the problem. By adapting the Johari window to map knowledge exchange, this paper identifies the characteristics of intra- and inter-organisational barriers.

Keywords: Knowledge Management, partitioned knowledge, Johari Window, operations improvement, collaborative innovation, manufacturing process chain, collaborative manufacturing.

1 Introduction

A manufacturing process chain can be defined as specific manifestation of a series of manufacturing processes that focuses on the physical transformation of tangible goods [1]. In industry, these processes are usually distributed between multiple people, highlighting information and knowledge exchange as important research areas [2]. The significance of such communication can be estimated according to a study conducted by [3], which calculated costs of $611bn per year caused by poorly targeted mailings and staff overheads in the US,. [3] also stated that organizations typically overestimate the quality of their data and at the same time underestimate the cost of potential errors. The impact of communication amplifies with rising product complexity: while a complex product requires knowledge and skills from different fields, the product development and the resulting manufacturing process chain are often designed by teams, composed of experts from collaborating organisations [4]. To maintain and improve such collaboration, a successful exchange of knowledge is mandatory.

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This paper aims to shed light on the characteristics of knowledge that is exchanged within manufacturing process chains, and the barriers involved as a problem description. To elaborate on a systematic problem analysis, this paper builds upon an adaptation of the Johari window for intra- and inter-organizational knowledge exchange that has been conducted by previous research in the manufacturing domain.

2 Characteristics of Relevant Knowledge to Improve Collaborative Manufacturing Process Chains

Knowledge Management is the systematic and explicit control of knowledge based activities, programs and governance within the enterprise with the goal to make effective and profitable use of the intellectual capital [5]. The Knowledge Management research field is a very broad one and there are various research areas involved, from social science over psychology and business to engineering and many more [6]. [7] emphasize that Knowledge Management does not only imply successful utilization of knowledge but also creation, identification, allocation, development, usage, conservation and sharing [8]. Knowledge is a key resource for enterprises [9] [10] and sharing knowledge is crucial for every modern manufacturing company especially when working in a collaborative environment [11]. Sharing knowledge is always a challenge as it contains a context dimension in comparison to e.g. information [11]. Knowledge can be available implicitly (e.g. in the head of employees) or in explicit form (e.g. documentation) [12], with some researchers arguing that even explicit knowledge is partly implicit as the person acquiring the knowledge automatically interprets it [13].

The pioneers in the field of Knowledge Management, [14] created the well-known model of the “knowledge spiral”, an illustration of the knowledge creating process focusing on transforming implicit to explicit knowledge. The complexity of such externalization is however dependant on the characteristics of the intended knowledge transfers. While some knowledge can be easily externalized, e.g. creating a technical documentation of a simple product; more advanced knowledge may require complex training mechanisms, e.g. how to operate a milling machine. Such difficulties in externalizing complex knowledge lead, in combination with non-ideal communication, to the fact that each person possesses an individual set of knowledge [15]. Therefore, whenever multiple persons collaborate by sharing knowledge, they face the problem of partitioned knowledge. Such knowledge partitioning is the theoretical notion that independent non-overlapping parcels contain individual sets of knowledge, which may result in people making contradictory decisions for identical problems under different circumstances [16].

The New Product Development (NPD) process can be described as a knowledge-intense activity [17], [18]. Each participant of the NPD process can rely on an individual set of relevant knowledge. Such knowledge can be considered relevant, if it has a positive impact on the collaborative endeavour. Approaches to characterize knowledge relevant for NPD have been made by [19] in distinguishing between two types of memory systems: declarative knowledge (what?), which contains all knowledge

about facts and events; and procedural knowledge (how?), which contains methodologies and provides the ability to act and realize even complex tasks, such as NPD.

The declarative element comprises a broad field that has been narrowed down by consecutive research. [20], [21], [22] identify three critical types of knowledge: *domain-specific* knowledge, *general* knowledge, and *procedural* knowledge. Although, these three types partly influence each other, they are characterized as independent categories [23]:

- **Domain-specific knowledge** is a type of knowledge about the form or function of an individual object or class of objects [23] and has been gained through previous results, in similar or related activities [19], [20]. Either stored tacit or explicitly, it can be used in future NPD projects.
- **General knowledge** is made through everyday experiences and general education [20]. It comprises knowledge that connects domain-specific knowledge about what is happening outside of the organisation
- **Procedural knowledge** is the knowledge about the development process itself [24], and is therefore closely linked to methodological competence. It can be defined as "the knowledge of what to do next" [22]. Many organisations store procedural knowledge in formal routines or process instructions [25].

Contrary to the declarative/procedural knowledge approach, these three types do not cover all types of knowledge that NPD could possibly benefit from. [21] states that other types, such as knowledge about production processes should be considered against this background as well.

The above characteristics apply as well to knowledge that is relevant to the task of improving a collaborative manufacturing process. These types however, need to be extended to cover knowledge about the current as-is state, which is crucial for any improvement activity.

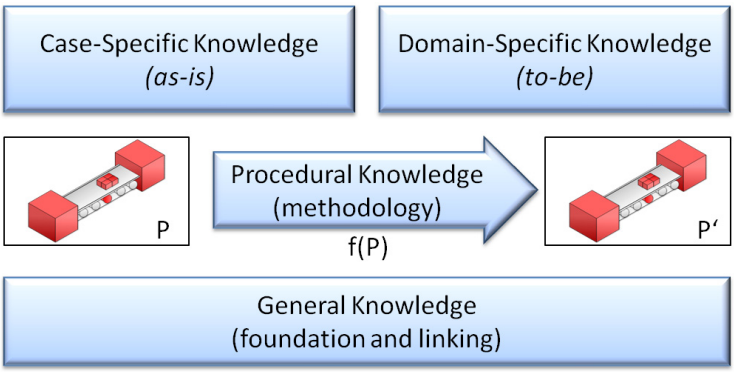

Fig. 1. Knowledge characteristics for improvement of manufacturing process chains

The results, as shown in **Fig. 1**, are four types relevant for improvement or innovation projects based on collaborative manufacturing chains:

- **Case-specific-knowledge** about the current as-is state of the targeted process chain must be collected to successfully derive or implement any improvement measures.
- **Domain-specific knowledge** is crucial to determine opportunities for improvement and to check the feasibility of options.
- **Procedural knowledge** comprises the methodological knowledge and describes how other types of knowledge need to be applied.
- **General knowledge** is the overall foundation of the improvement activities. It is accessed to select the methodology and domain-specific knowledge depending on the current improvement activity.

These types of knowledge apply to process chain improvement in single organisations as well as to organisations in a collaborative environment. The latter however, faces the problem of knowledge fragmentation and resulting boundaries, which are described in more detail in the following section.

3 Barriers between Knowledge Partitions in Collaborative Manufacturing Process Chains

From a knowledge management perspective, a network or even a single organization cannot be considered a collective. Instead they consist of individuals with individual partitions of knowledge. Whenever such individuals collaborate by sharing their knowledge, they communicate to connect their knowledge partitions and to overcome barriers between them. This section builds upon a knowledge management concept of knowledge being fragmented and stored in several partitions throughout a collaborative manufacturing chain. The concept has been previously developed by [26] and features an adoption of the Johari window for inter-organisational use.

3.1 The Johari Window for Inter-organisational Knowledge Management

The Johari window itself is an analytic tool that has been developed in 1955 by Joseph Luft and Harry Ingham [27]. As shown in Fig. 1, the Johari window is a 2x2 matrix that consists of four panels, which contain personal attributes. These personal attributes are sorted by their awareness to the referred person and to the group, thus resulting in four categorizing areas:

- **The Arena**, contains overall attributes that are known to the person, as well as to the group
- **The Blind Spot**, is comprised of knowledge that is available to the group, but not to the referred person
- **The Façade**, which holds attributes that are only known to the referred person and unknown to the group
- **The Unknown**, which contains attributes not known to anyone

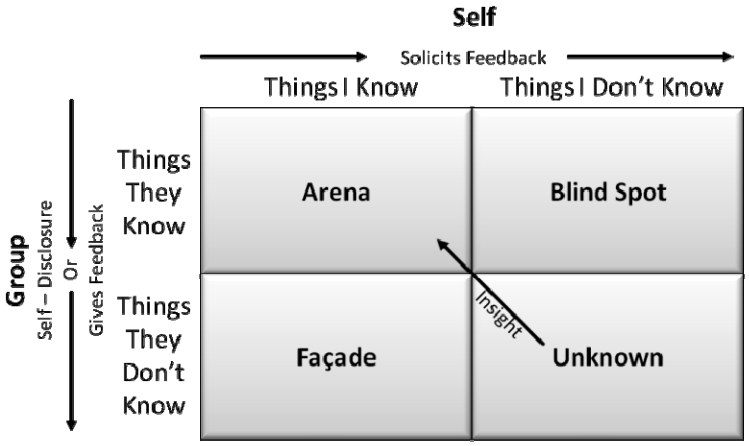

Fig. 2. The Johari Window

Regardless of its age, the Johari Window is still a popular tool to study feedback and exposure processes in various sectors [28], [29], [30], [31]. Its success is based upon its simplicity and extensibility. By adjusting the size of its panels according to their content, the Johari Window can be used to simulate and visualize dynamic feedback [32], [33].

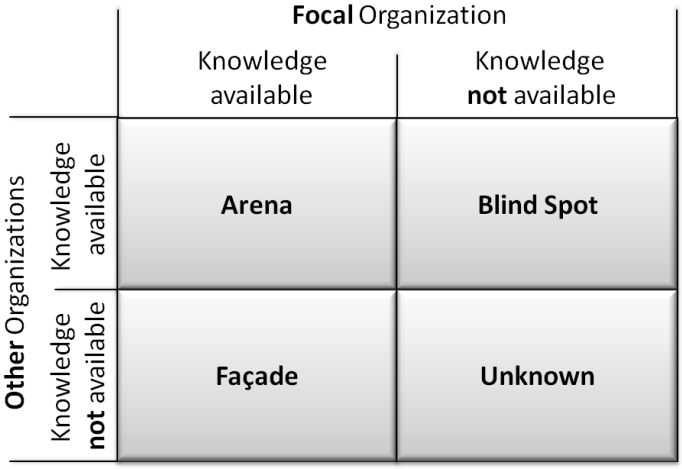

Fig. 3. The Johari-Window for inter-organizational Knowledge Management

The Johari window has been adopted by [26] to map the knowledge of a focal organisation. This results in a 2x2 matrix to sort knowledge that is known/not known to this focal organisation or others, as shown in **Fig. 3**.

3.2 Characteristics of Intra- and Inter-organisational Barriers for Knowledge Exchange

This section elaborates on the characteristics of barriers for knowledge about improvement potential within an organisation that acts in a collaborative manufacturing process chain.

Based on the assumption that measures to improve an organisation's manufacturing are taken by its management, but practical knowledge is gathered by its employees, an exchange of such knowledge leads to the best use of the organisation's potential. If employees and managers are defined as partitions that store certain fragments of knowledge, those partitions are separated by intra-organisational barriers, which are crossed by communication.

With the aim of process improvement in mind, an organisation that participates in a collaborative manufacturing process chain connects with other organisations and exchanges case-specific knowledge. From their differing knowledge base and point of view, those connected organisations might identify potential improvements for the focal organisation's manufacturing processes. To gather such beneficial knowledge about improvement potential, the focal organisation needs to overcome an inter-organisational barrier.

Both barriers are visualized in **Fig. 4**. Organisations should generally consider to access the knowledge of their employees with the highest priority, followed by the management of other organisations. Reaching for knowledge of employees affiliated to other organisations should be conducted with highest precaution, as reactions on such activities depend on the level of trust and type of the collaboration.

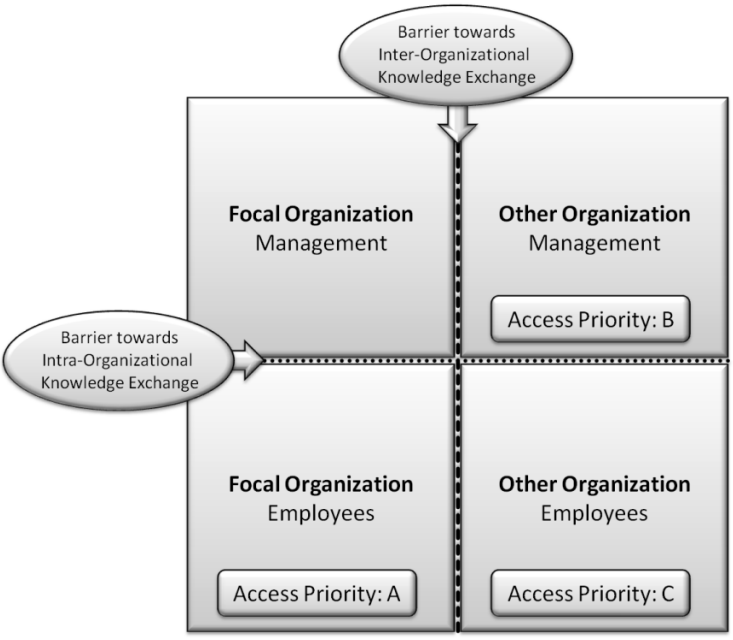

Fig. 4. Barriers for Intra- and Inter-Organizational Knowledge Exchange [26]

The characteristics of barriers towards communication in general are a diffuse, but strongly researched area. According to [34] and [35], significant barriers arise from personal differences in various manifestations, such as different culture, age, language, or personal disposition and character.

Other categories can be identified through encouragement, the organizational support, and the committed resources [36]. Along with the most relevant personal differences, the barriers can be characterized, as shown in **Fig. 5**.

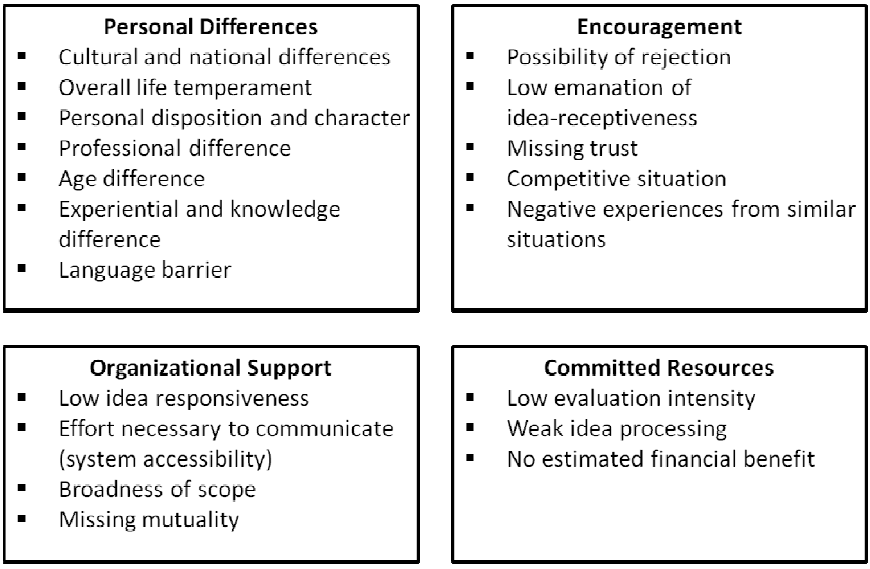

Fig. 5. Barriers for intra- and inter-organisational knowledge exchange (excerpt)

The barrier of personal differences not necessarily requires knowledge about the corresponding person; instead it can be based on assumptions or prejudices, but is always based on at least estimated differences in the characteristics of the respective persons. The four described categories are not independent from each other, but instead impact on the encouragement of a person, which can be considered the precondition for any successful attempt of knowledge transfer between organizations, organization units, or individuals.

4 Limitation and Outlook

The characteristics of knowledge relevant to initiate innovation projects or improve existing manufacturing have been identified against the background of an organisation participating in a collaborative manufacturing process chain. Those innovation or improvement processes rely on a general knowledge to identify the procedural knowledge that must be combined with case-specific knowledge to achieve a targeted state, which is determined by domain-specific knowledge.

In a collaborative environment, knowledge can be fragmented and stored within certain partitions resembled by people, or organisational units. The organisational units identified within this paper are management and employees of a focal organisation, or those of related partners. With adoption of the Johari window to map knowledge exchange, this paper identifies the characteristics of intra- and inter-organisational barriers.

The research is limited in the form that management and employees have been looked at as solid entities, in fact knowledge could be available to people within the management of an organisation, but not to the responsible process owner. This results in an additional intra-fractional barrier that has not been described to this point.

Subsequent research will focus on analysing those previously described barriers more thoroughly, concepts to overcome those barriers and cover the relation of Open Innovation approaches and knowledge diffusion in collaborative environments. Additional potential arises from an impact analysis of material flows on knowledge exchange, possibly conducted by intelligent products, while they flow through such process chains; the potential of intelligent cargo systems; or an innovative logistics concept focussing on transferring not only the product, but also knowledge within a collaborative environment.

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