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Fostering insights from real-time data

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Abstract. A logical first step for many manufacturers when embarking on a transformation towards digitalization of their production system is to acquire technologies that captures data in real-time to help monitor and improve machines and production performance. Nevertheless, the presence of real-time digital data will not in itself lead to significant improvement in production performance. It also requires manufacturers to enable shop floor workers to generate insights from these real-time captured data to frame and resolve problems. As such, this action research paper presents the outcome of a learning intervention's first action learning cycle at the Danish Roof-top windows manufacturer VELUX. The intervention aimed to institute a lean learning system to enable the further successful digital transformation of the company's production system.

Keywords: Lean, Digitalization, Action Learning, Action research.

1 Introduction

Today, most manufacturers have initiated a digital transformation to enable their organizations to utilize new digital technologies to cope with changing customer demands [1]. Manufacturers who already have integrated lean practices into their existing production system are therefore exploring how lean and digital manufacturing technologies are supplemental or integrated. Several studies examine the affiliation between lean practices and digital manufacturing technologies, e.g., Bittencourt [2]. However, these studies predominantly address issues related to digitization and not digitalization. Digitization is the technical process of transforming from an analog to a digital form. In contrast, digitalization is a socio-technical phenomenon about organizations' capability to utilize digital technology and data to transform [3]. Hence, it is the technocentric focus associated with digitization that can prevent manufacturers from capitalizing on their investment in digital technologies and utilizing the increasing amount of digital data available on the shop floor [4]. Therefore, lean manufacturers pursuing a digital transformation must achieve a higher degree of organizational learning capabilities [5] and insights gained through experimentation and reflection [6].

Develop organizational learning capabilities would require manufacturers to supplement their production system with a learning system, e.g., to develop capabilities for utilizing digital data on the shop floor [7, 8]. Therefore, this study seeks to advance our understanding of how manufacturers can institute a lean learning system that simultaneously engages all organizational hierarchy levels in developing shop-floor workers in gaining insight and acting based on digital data. This paper outlines the first action cycle of designing and deploying an action learning intervention as part of an action research project at VELUX to develop a lean learning system. By investigating this first action cycle, the paper seeks to answer the research question: "*How can manufacturers develop and enable shop-floor workers to utilize real-time captured data, gain insights, and initiate actions - based on the scientific method.*"

2 Literature Review

2.1 Lean as a learning system

There is a growing consensus in extant operation management literature that adopting a lean production system requires manufacturers to understand lean as a learning system [9]. When understanding lean as a learning system, the purpose of lean tools and methods is to foster insights among employees and develop an organization of problem solvers instead of a sole objective of improving efficiency [8]. Hence the manufacturers are obliged to ensure that new tools and methods, either analog or digital, are standardized and formalized into the workers' daily work in an enabling way and not perceived as coercive [10]. When shop-floor workers perceive real-time data capturing systems as enabling, they are more likely to be motivated intrinsically to address problems, which is a prerequisite for generating insights, action, and learning without awaiting permission from management or specialists [10].

An underlying element of a lean learning system is action learning, based on the notion that no learning can occur without action and no (sober or deliberate) action without learning [11]. Revans [12] proposes a theory for action learning consisting of alpha, beta, and gamma systems and equally important. These three systems are not connected linearly or sequentially but are intertwined. System alpha is the task of framing a problem by investigating the external demands and how these correspond with the existing internal capabilities and the problem solvers' values and mental models. System beta is the underlying problem-solving process based on the scientific method [6]. System gamma is the learning process of examining the divergence between expectation and experience by questioning and critically reflecting on the contextual taken-for-granted preconceptions [13]. Moreover, a distinct element of a lean learning system is the presence of a supportive learning environment [4,14]. A supportive learning environment embodies an atmosphere of psychological safety where workers feel safe expressing their and ideas and spaces to explore each other's ideas, experiment, and reflect together [15].

3 Research method

To accommodate this study's interventionistic and action-based design, an action research approach is adopted [15] and follows the 5-step action learning cycle process of diagnosing, action planning, action-taking, and evaluation [16]. The research is part of an ongoing industrial Ph.D. project to advance VELUX's ability to utilize existing and future digital technologies as part of a digital transformation. VELUX has developed its production system on lean tools and methods for the past two decades. This paper reports on the first (pilot) of three action learning cycles facilitated by the first author at a VELUX lead factory in Denmark.

4 Results – the action research process

4.1 Diagnosing

As part of the diagnosis phase, the first author followed the implementation of a new real-time digital capturing system on one of the Cladding department's production lines. Six months after commission, production had not improved, nor had the workers used the data to initiate any problem-solving or improvement activities. To understand why the real-time capturing system's implementation was unsuccessful, the first author conducted a series of observations, interviews, and a survey with managers, project managers, specialists, and shop-floor workers [4]. The diagnosis resulted in the following key findings:

- The predominant approach to problem-solving is firefighting [17]. The scientific method is only applied episodically.
- The shop floor workers believe that it is not their job to initiate problem-solving or improvements themselves, but only to notify the maintenance department or manager and perceived the new real-time data capturing system as coercive [10].
- There is no visible presence of learning structures and processes supporting system alpha, beta, and gamma where shop floor workers, specialists, and managers can collaborate on conducting experiments and reflecting [12, 14].
- Leaders did not perceive their job as fostering a supportive learning environment [14]. Instead, they provided the answers and solutions instead of asking questions and developing the scientific method's usage among their direct reports [18].

As part of the action research process, the diagnosis's findings were examined and validated by the research participants. The respondents and the project steering committee agreed to design and test an action learning intervention [15].

4.2 Action planning

The first author designed an action learning intervention based on Revan's [12] intertwined alpha, beta and gamma systems to resolve the issues identified during the diagnosis phase. The purpose of the action learning intervention is to develop the managers'

ability to enable and empower shop-floor workers to apply the scientific method and utilize (digital) production data when solving problems by fostering a supportive learning environment.

The factory leadership team decided to pilot the intervention in two separate departments. The first case took place at the cladding department and involved the department manager and two groups consisting of 3 shop-floor workers. The second case took place at the flashing department, and besides the department manager, two consisting of 6 participating shop-floor workers. In both cases, the aluminum factory manager, the general manager, and the first author participated.

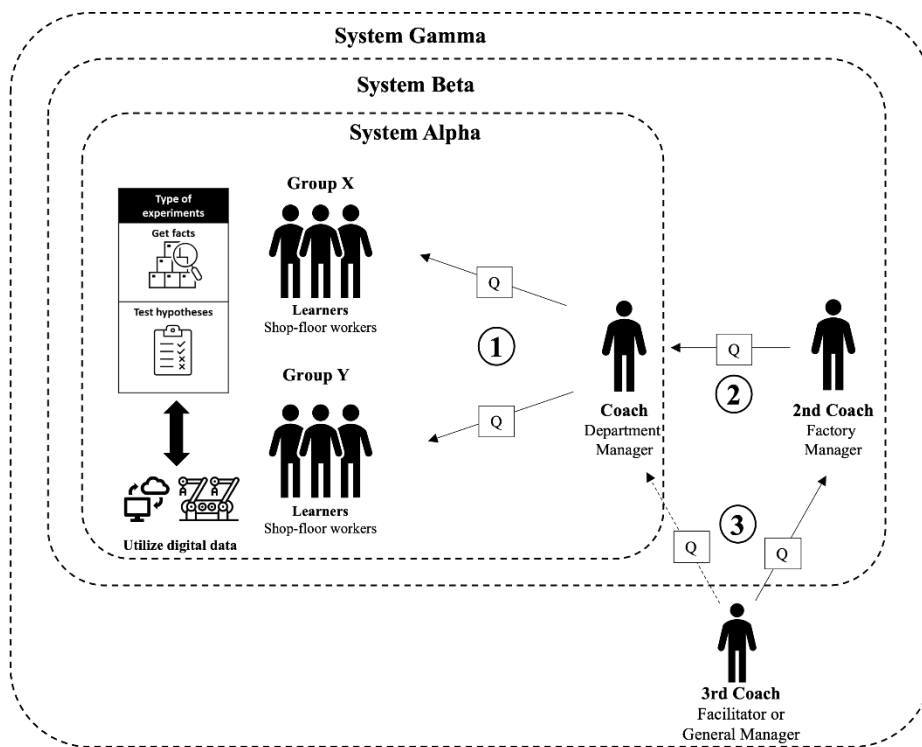


Fig. 1. Action learning intervention for developing a supportive learning environment based on system alpha, beta, and gamma.

System alpha. As illustrated in figure 1, the action learning intervention setup is for the shop-floor workers to find, face and frame a specific operational problem identified with their department manager. To support them in applying the scientific method, the groups meet every morning for 15 min of coaching with the department manager (step 1 in figure 1). Grounded on Rother's [19] coaching kata, the department manager firstly asks the groups to visualize the current situation of the performance gap they are working on closing. To foster insights into the group's problem, the department manager

facilitates a content reflection [20] on their last experiment as knowledge input to define the next small experiment to be conducted until the next day's meeting. The groups are encouraged to decide between two types of experiments. Either gather facts or test specific hypotheses. For both types of experiments, the groups utilize existing digital production data to solve and validate the experiments. Should the groups, e.g., lack the ability to retrieve or analyze data from the data gathering system, the next-day step is then to learn this ability. To capture the gained learning and insight, the groups use a learning board and an experiment log designed with inspiration from Rother's [19] improvement kata.

Preparation and problem identification. In the first case, the department manager decided to invite the shop-floor workers to introduce the learning intervention and discuss the problem the groups should start resolving. In the second case, the department manager decided to start directly with initiated the morning coaching cycles.

Initiating the daily learning cycles. In the first case department, the coaching cycles were conducted as planned, and the groups began to start working on gathering insights for framing the identified performance gap. However, the department manager struggled to help one group frame the problem and identify experiments within their circle of control and not eschewing the problem. Contrary, the other group felt a sense of empowerment and quickly improved their ability to follow the scientific method and utilize data.

Since specific performance gaps for the groups to close were not identified upfront, the second case department struggled with starting their learning process. During the first week, no experiments were defined and initiated by the groups. The department manager realized that just because several performance gaps were apparent to him, it was not apparent for the shop floor workers. He, therefore, invited the groups into a set of meetings where he presented the available performance data and facilitated a process where the groups identified performance gaps to start closing. Afterward, the groups began to identify and execute their first experiments.

4.3 Action taking

System beta. System beta concerns forming solutions through cycles of action by having the groups generate insights for closing the concrete performance gaps. During this process, the department manager, as the coach, must focus on the underlying problem-solving process and develop the group's ability to apply the scientific method. The department manager's task is not to propose solutions but to facilitate a cycle of actions and process reflections with the groups of learning how to solve the problem at hand, how the insights of the problem and countermeasures are evolving, and how to conduct and evaluate experiments [20, 21, 22, 23].

To develop the department managers' ability to facilitate a cycle of actions and reflections with participating groups, the factory managers observe the conversation between the groups and the department manager. Afterward, the factory managers facilitate a cycle of actions and process reflection [20] with the department manager on

developing the groups' scientific method abilities (step 2 in figure 1). These conversations are expected to result in gemba-walks [18] to help the groups conduct their experiments.

Conduction daily learning cycles. In both departments, the daily meetings continued for five weeks until solutions were in place to close the identified performance gaps. In the first department, the department manager decided to drop the group that was eschewing the learning process and only helping the other group. In the second department, both groups exceed the manager's expectations.

4.4 Evaluation

System Gamma. The purpose of system gamma is firstly about reflecting over (and sharing) emergent learning. Secondly, it is about developing the factory managers' ability to learn how to learn and become aware of preconceptions and mental models [13] that hinder the groups from applying the scientific method and for the factory to adopt a lean learning system. The facilitator and the general manager observe both conversations (Steps 1 and 2 in figure 1).

Afterward, the facilitator and the general manager engage in premise reflection [20] with the factory manager on developing the department manager's thinking and practice for developing the group's scientific method abilities (step 3 in figure 1). This conversation can be described as upstream and downstream learning [24]. 'Upstream' learning can be classified as a critical reflection process of examining the managers underlying mental models, assumptions, and values that govern the 'downstream' behaviors.

After-learning cycle evaluation. Derived from observations, performance data, and interviews both during and after the intervention pilot's ending, the participants reported the following learning:

- Both department managers observed that the shop-floor workers took more ownership to improve their work and solve problems. They were proactively experimenting with ideas on improving their production lines. The department managers also observed improved communication among the shop-floor workers where they were helping each other more and openly discuss and distribute tasks in a respectful manner.
- The shop floor workers all agreed that they want to continue working in this new way and worries that it was a one-time activity. They all felt that they obtained a shared understanding of their problems, resulting in more open discussions without co-workers becoming defensive. They also realized that it is much more effective to focus on what they themselves can do to improve performance instead of pointing fingers at other departments and waiting for maintenance.
- The Factory manager evaluation observed that the department managers had started to be more critically reflective of their mental models and behavior [13], leading to a more long-term focus beyond resource efficiency.

Operational outcomes. In the first case, the participating shop floor workers improved OEE (Overall Equipment Efficiency) from 48 to 60. The shop floor workers in the second case improve their daily output by 10%.

5 Discussion

The evaluation of the first action learning cycle indicates:

- Most participating shop-floor workers applied the scientific method by iterating between experimentations and reflections to generate insights from available production data.
- The participating shop-floor workers experienced first-hand how to expand their circle of control by conducting problem-solving or improvement activities themselves without waiting for maintenance or management to take action.
- The participating shop-floor workers experience that data gathering systems can enable them to improve their production lines' performance.
- Instituting a lean learning system with structures and processes build on the intertwined systems of alpha, beta, and gamma and involving the whole organizational hierarchy simultaneously is an effective way to foster a supportive lean learning environment for conducting experiments and reflection [25].

The evaluation also suggests that the department manager identify a potential performance gap with the participating shop-floor workers before initiating the daily morning cycles. The managers must furthermore be patient and expect to set aside time to communicate and coach between the morning coaching cycles in the beginning to avoid groups abandoning the learning process.

6 Conclusion

This paper describes the outcome from the first cycle of an action learning intervention at VELUX. The purpose of the intervention is to build a lean learning system that enables shop-floor workers to gain insight and act based on real-time digital data according to the scientific method. Designing the action learning intervention based on the intertwining systems of alpha, beta, and gamma [12] combined with simultaneously involving all organizational hierarchy levels proved successful. It positively addresses the organizational issues identified in the diagnosis phase and the challenges of developing organizational learning capabilities as part of a digital transformation. However, the study has its limitations. The paper only describes the first learning cycle of the action research project, which only involved 5% of the workforce at the Danish VELUX factory. Moreover, the first learning cycle lasted only five weeks and did not cover the intervention's longitudinal effects. Thirdly, there is a limitation in terms of transferability to other contexts as a single case study.

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