INTERACTIVE RESEARCH IN PRODUCTION START-UP

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ABSTRACT

Research regarding production start-ups has increased in interest during the last decades. However, there is still a need to learn more about suitable research approaches in production start-ups as the research need to be carried out in a challenging environment, where industrial practitioners often have time-pressure, handling events and uncertainties related to both the product and the production system. This paper is based on a meta-analysis of four research projects addressing production start-ups including activities before, during and after the start-ups. Focus of the paper is on how an interactive research approach can be implemented to achieve learning and change among individual practitioners, at group level and at organizational level. The findings of the paper may contribute to increased understanding of interactive research in dynamic processes and contribute to the development of research on production start-ups.

INTRODUCTION

For a long time, research has included development of knowledge, dissemination and later application in reality. To increase the contribution of knowledge of practical relevance, Anderson et al (2001) describe how academic research to an increasing extent is conducted in collaboration with industrial practitioners and with problems that are relevant to industry. In examples of collaborative approaches, researchers and practitioners interact throughout the research process, from formulation of the initial problem to dissemination of results (Svensson et al, 2007, Pasmore et al, 2008), and thereby creating mutual learning (Maurer and Githes, 2010).

One challenging area within operations management that has gained a great deal of attention from both practitioners and researchers is production start-ups. Efficient production start-ups are important to reach set targets on cost, quality, and volume in time. Production start-ups involve innovations regarding design of the product, the production system, and/or the organizations where several groups of employees from different departments and organizations need to participate.

To meet fast moving markets, global competition etc, the frequency of production start-ups is increasing (Eisenhart and Brown, 1998; Schuch et al, 2005). Also there is an increasing complexity in the manufacturing context where integration of the production start-up in existing processes need to be managed as well as that levels of newness of the product and the production system need to be regarded (Almgren, 1999).

Within new product development, the production start-up includes pre-series production and production ramp-up, see Figure 1.

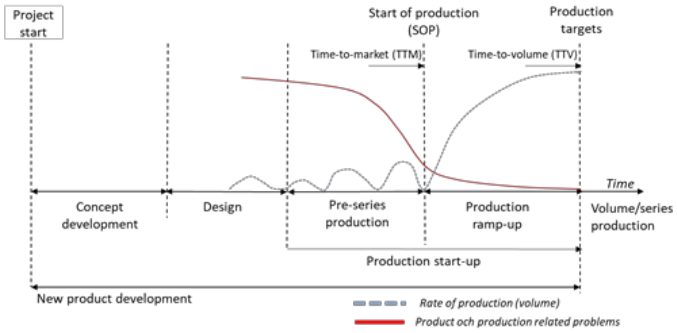

Figure 1: Production start-up phase within new product development (adapted from Bellgran and Säfsten (2010))

During production start-ups, it is common that there is a high degree of uncertainty, which results in an unstable behaviour in the production system (Basse et al, 2014). A number of more or less unexpected events need to be handled and several disturbances may occur (Almgren, 2000). Although there is a body of literature on production start-up from different perspectives, this paper seeks to contribute to earlier research by highlighting the potential of a participatory research process in fast changing environments. During production start-ups, collaboration between researchers and industrial practitioners is challenging due to the time-pressure for e.g. handling critical events and uncertainties related to both the product and the production system (Fjällström et al, 2009). In this paper a meta-analysis of the use of an interactive research approach in four industrial cases with focus on production start-up is presented. The aim of the paper is to investigate if and how an interactive research approach can support learning and change at an individual level, group level, and an organizational level, in the context of production start-ups

LITERATURE AND THEORY

By interacting, research can contribute to practice and practitioners can stimulate the development of new research topics (Anderson et al, 2001). This implies a shift from conducting research *on* operations in practice to conducting research *together with* practitioners who represent the operations in focus (Ellström, 2007). There are different collaborative research approaches, for example collaborative management research, action research, and interactive research (Aagard Nielsen and Svensson, 2006; Adler et al, 2004).

The interactive research approach was developed to meet some of the criticism of action research (Ellström, 2007). Some of the criticism relates to the risk of being too close to practice, and that the researcher acquire too strong role in the development work (Svensson et al., 2007). The proximity might lead to a less critical analysis by the researcher. Furthermore, focus might be on local understanding rather than general analysis, with strong emphasis on the practical work, and less on the scientific productivity (Svensson et al, 2007). One reason might be that the action researcher is more interested in working with their development projects rather than writing about them (Herr and Andersson, 2015). In the interactive model, there are two separate systems for problem solving, the research system and the practice system (Ellström, 2007), see Figure 2, were focus is shifted from the researchers role to a joint learning process (Svensson et al, 2007).

It is an action-oriented approach (Coghlan and Coughlan, 2010; Börjesson, 2012), in which researchers and practitioner interact throughout the whole research process and they are expected to produce a common conceptualization and interpretation of the research

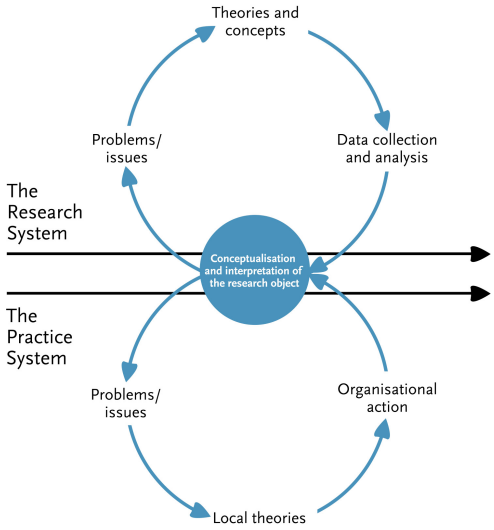

Figure 2: Knowledge creation in interactive research (Ellström, 2007)

object. Focusing on learning, Pasmore et al (2008) describe collaborative management research as a process in which a researcher and a practitioner learn together about how organizational arrangements affect the outcome of a system. In interactive research (Ellström, 2007; Svensson et al, 2007), there is a similar idea of knowledge creation. Similarly, the interactive research approach is presented as a model for knowledge creation through co-operation between researchers and practitioners (Aagard Nielsen and Svensson, 2006; Ellström, 2007; Svensson et al, 2007).

However, as mentioned before, researchers and practitioners have different roles, interests and abilities, why these differences needs to be discussed in the beginning of the research process (Svensson et al, 2007; Börjesson, 2012). In collaborative research, researchers and practitioner participants have different interests, roles and expectations on the outcome of research, see Figure 3.

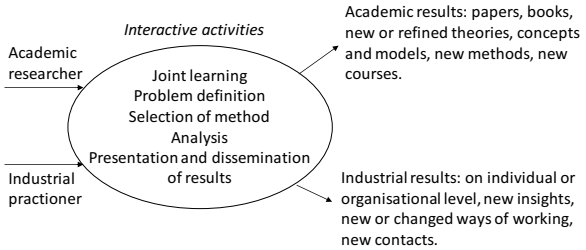

Figure 3: Roles and interests of researchers and practitioners in collaborative research processes (further developed with inspiration from Svensson et al, 2007)

Academic results, for example papers, theories and methods are important for researchers. For practitioners, on the other hand, the usefulness in the organization, new insights and contacts are perceived more valuable.

DATA AND METHODS

The paper was based on experiences from four research projects, all conducted with an interactive research approach (Svensson et al, 2002; Aagard Nielsen and Svensson, 2006). Each research project is here presented as a case, selected so that they represented a variety in production start-ups regarding sectors and contexts, phases in the production start-up, degree of newness in the product and production system, and with different types of interactions between the industrial practitioners and the researchers, see Table 1 for an overview.

Case	Industry and products	Practitioner involvement
Project A	Automotive	Individuals and project teams
Project B	Bearing and seal manufacturing	
Project C	Engines and power solutions	Individuals, project teams, and production management
Project D	Forest and gardening outdoor power tools	

Table 1: Case overview

In Project A and B, specific production start-ups were in focus, whereas in Project C and D the production start-ups were described in the context of the entire research projects. In each case, data were collected through semi-structured interviews before (preparation phase), during and after each production start-up as well as during feedback sessions and discussions.

The interviews in the preparation phase included questions of planned activities, potential challenges, work procedures etc. During the start-up the interviews focused actual critical events needed to be handled, actions taken, information needed and obtained. Towards the end and after the production start-up the interviews also included reflections of the events during the entire process, learnings and improvement opportunities. The interviews were both data collection as well as an interactive reflection of the on-going process on an individual level. The workshops and feed-back sessions had interactivity on a group level where areas of interest to further study where identified as well as development activities in the company.

By following the production start-ups over time it was possible to identify events, challenges and changes throughout the innovation processes (Van de Ven and Poole, 2000) and gain a deeper understanding of decisions taken, actions, etc. Using an interactive research approach created a frame for a research project, and within the project several different ways of working could be included, together with different data collection techniques. See table 2 for an overview of the data collected in each case.

Case	Observations and companies documentation	Semi-structured interviews	Open interviews	Feedback sessions, workshops	Discussions - reference group
	General	Individuals		Project team	Manage-ment and key persons
A	X	X		X	
B	X	X		X	
C	X	X	X	X	X
D	X	X	X	X	X

Table 2: Data collected in the studied cases

DATA AND METHODS – PROJECT A

In Project A, data was collected through observations and company documentation, semi-structured individual interviews with different professional functions before, during and after the production start-up phase, as well as through group interviews and feedback sessions/ workshops. The interviews included topics such as preparations and activities related to the production start-up, encountered difficulties and critical events, work methods and routines, and learning from the product introduction. The respondents were project and production managers, operators, and support function employees (e.g. logistics, production engineering, maintenance, and training). In total, 59 interviews were conducted; 21 before start-up, 18 during start-up and 20 after start-up. Additionally ten interviews were conducted with focus on contextual conditions. The interviews and workshop discussions were audio-recorded and transcribed.

DATA AND METHODS – PROJECT B

Data in Project B were collected from 16 employees with different roles related to the production start-up. They were identified by the company as strongly influencing or being strongly influenced by the sharp increase in production volume. These included four managers with responsibility to plan and realize the change and/or implement the change in the production plant, six operators representing different shifts and competence areas, and six key actors who had an influence on or were affected by the change (production technicians and process developers). The methodology was based on the described framework focusing on before, during and after the start-up. In all phases, semi-structured interviews were conducted. In the pre-phase, interview topics included important resources, main actors, and gain of knowledge. During the change, a number of topics were highlighted, such as critical events and their consequences, knowledge needs, etc. In the post-change phase, finally, the respondents reflected on facilitating and hindering factors for knowledge creation, knowledge sharing and re-use of knowledge. Further, data were collected in a feedback seminar at the company.

DATA AND METHODS – PROJECT C

The project started during the fourth quarter of 2007 and ran until the end of 2011. The research team involved four senior researchers, with complementary competences and background. In total, three companies participated, of which two were original equipment manufacturers (OEM). The third company focused on innovation, technology development and business development for a corporate group, supporting amongst other companies one of the participating companies. In this research project, the interactive research approach was operationalised through four phases: 1) Survey and diagnosis, 2) Feedback of results, 3) Implementation of development initiatives, and 4) Follow-up/evaluation. During the project, various interactive elements were included, such as joint problem formulation, workshops, and development initiatives. The initial phase, survey and diagnosis, was carried out by means of 93 semi-structured interviews with employees with different roles related to the production start-up. Based on the feedback of results and interactive workshops, 15 development initiatives started, out of which four were managed by the research team and the rest by the participating companies. During the final follow-up and evaluation in total 36 persons participated in individual or group interviews. The project was concluded with a joint workshop.

DATA AND METHODS – PROJECT D

The project started in 2013 and was finished in October 2017. The main part of the project was carried out 2013-2015. During the main phase, the focal company and the three initially selected suppliers were engaged. The final phase of the research project, from 2016 until 2017, involves the focal company, one real time product development project, and a set of suppliers connected to the product development project under study. In this research project, the interactive research approach was operationalised in a similar way as in Project C, and included the following steps: 1) Problem-finding and diagnosis, 2) Feedback of results and identification of development activities, 3) Implementation of development activities, and 4) Follow-up/evaluation. During the first step, two rounds of interviews were carried out. During the first round, in total 24 interviews were carried out. Subsequently, specific product development projects were selected for in-depth analysis. Each product development project was treated as case study, and in total nine case studies were carried out. During these case studies the main technique for data collection was semi-structured interviews, combined with analysis of documents from the companies. In total 28 interviews were carried out. All interviews were transcribed verbatim, and traditional qualitative data analysis according to Miles and Huberman (1994) was carried out, and the results was fed back to the companies during a workshop, resulting in 14 development activities. Some of these were implemented in a newly started product development project at the focal company and an opportunity to follow the changes in real time was obtained. This was formulated as a development activity for the researchers. The activity was carried out as a case study. During this case study the main data collection techniques was observations at more than 70 project meetings and 15 semi-structured interviews with project team members and selected suppliers. The interactivity took place through the follow-up meetings where the ongoing development activities were discussed.

EVALUATION OF DATA

Different means were used to collect data, primarily interviews, but also during discussions and feedback seminars with e.g. project teams. In all cases, data were collected before, during and after the production start-ups. This ensures that the studied start-ups were followed during the same phases, which also facilitated a comparative analysis of the cases. The same applies for the choice of industry participants in the studied projects, as perspectives from several influencing groups of personnel participated as well as those strongly influenced by the studied production start-ups. This resulted in a broad view on the production start-up and its consequences.

RESULTS

PROJECT A

Case study A was carried out in an automotive company in Sweden. The production start-up studied during a period of 23 months, specifically involved production ramp-up during a production introduction of a new product within the final assembly plant. The product was assembled in a new platform in a completely rebuilt production area and there where high focus on fulfilling the requirements and characteristics of the final product**.** The production part concerned installation of equipment and systems needed to manufacture the new product. The production start-up was organized by a **'**product project' that had several established work methods and routines to reach planned targets and to handle various types of critical events. The product project team used for example a stage-gate model, a build plan, developed work instructions, virtual training, and scorecards, performed test series, simulations, and risk analysis such as FMEA.

Main phases in the interactive research process

The research process in Project A included interactions between researchers and practitioners during different phases of the production start-up. During the pre-phase, during and post-phase*,* there were mainly interactions between researchers and individual practitioners in the company. During the post-phase the individuals reflected upon lessons learned gained in handling the critical events and how to facilitate future preparedness in relation to some identified critical event areas, i.e. suppliers, product, equipment, production (layout), personnel/education, and work organization. Interactions with individuals were thus carried out

during the three phases. The interactions enabling reflections of improvement opportunities were addressed in particular in the last interview, in the post-phase. Additionally, there were interactions between researchers and the product project team in the company in the post-phase with dialogue of the sub-results.

Outcome
The main outcomes of the interaction on an individual level were identification of 'lessons learned' focusing on critical events, handling the critical events and how to facilitate future preparedness. Some examples included how to:

- Improve process of selection of suppliers and define clear demands in specifications to suppliers to avoid problems related to the material and the equipment.
- Follow routines and rules in a better way, such as the stage-gate model and FMEA to enhance product quality.
- Verify the product design before start of production.
- Improve communication between and within each group of product designers and process engineers and by performing a pre-study where product designers and process engineers are building the product on their own in a pilot plan.
- Facilitate early involvement of production and the usage of assembly knowledge in the projects
- Improve management and planning of personnel resources in the project to reach better continuity.

PROJECT B
Project B included a real-time investigation of production requirements during a planned change, a sharp increase in production volume. The studied company had experienced a rapid increase in production volume. Maximum working hours were reached at the same time as market signals showed even higher order stock. As a result, several measures were taken to handle the specific situation. First, a project implementing a new technical process in production was launched. Second, the company decided to invest in new machines. Third, production managers and human resource managers re-planned work procedures and re-organized the operators' working hours in production. Production requirements were related to individuals and their different roles in the specific change. This multi-voiced perspective included individuals with responsibility to plan and realize the change and/or implement the change in the production plant, operators, and key actors who had an influence on or were affected by the change.

Main phases in the interactive research process
The research process included interaction between the researchers and the participants in the interviews before, during and after the studied production start-up. This also included reflections on critical events, learning and how to make use of the individuals' experiences. Since learning and knowledge sharing was in focus for the study, these topics were highlighted in all phases with all participants. A final workshop was also held at the company, in which 11 employees participated. These were mainly employees that had not been involved in the earlier phases with the idea of transferring the results of the research projects to other personnel groups.

Outcome
The outcome of the interactive research process was the identification of critical events during the production start-up, which were categorized and related to market issues, technology, material supply, or work organization and personnel. Furthermore, improvement suggestions regarding how the company could re-use experiences in the future were identified in interactivity, for example through documentation, personal relations and 'one-issue-lessons'. These suggestions included what measures could be taken by operators, support functions as well as management.

PROJECT C
Case C involves a research project focused on product introductions, and specifically how workplaces close to production may develop competences and competence carrying relations that support efficient product introductions. The aim of the research project was to identify and develop learning methods, work methods, forms for co-operation and collaboration, and management/control practices that strengthen innovation capability and collective competence development related to product introduction.

Main phases in the interactive research process
An interactive research approach was used where research activities were carried out in close co-operation between the research team and representatives from the participating companies (see also e.g. Berglund et al, 2012). The research project involved four main phases: 1). Survey and diagnosis, 2). Feedback of results, 3). Implementation of development initiatives, and 4). Follow-up/evaluation. The initial phase of the interactive research process was carried out as case studies in the two participating OEM-companies. Results from the initial phase was, as the second phase, fed back to the companies during workshops. During the workshop the initial analysis of the data was presented and discussed. The workshops resulted in different development initiatives, identified by representatives from the participating companies. In phase three, the companies started to work with the development initiatives with highest priority. The research team had regular follow-up meetings with the companies during this phase, were the activities were interactively discussed. In the fourth phase, follow-up interviews were made, with similar content as the initial interviews. Based on these interviews the results from the project could partly be evaluated in a dialogue between the research team and each of the participating companies. Apart from the company specific activities

and workshops, there were also three workshops involving all companies. During these workshops, experiences were shared, and joint learning took place through discussions, most often in small groups.

Outcome
Representatives at the participating companies experienced a more structured way of working with product introduction at the end of the project. Preconditions for a changed way of working with product introduction was identified and implemented through several different development initiatives. As some examples of development initiatives, the establishment of a cross-functional meeting forum and a coordinating role could be mentioned, as well as stronger emphasis on arenas were different functions jointly discuss issues related to product introduction, etc. Identified preconditions was, before the final work shop with representatives from all participating companies, categorised by the research team as being related to operational and organizational support/support systems, formal education, and work place learning. The perceived outcome was described on individual level, group level and organizational level. On individual and group level a higher awareness concerning how to handle product introduction was mentioned, as was new work tasks, better use of the competence, increased dialogue, etc. On organizational level, there were both organizational changes and changes in the work process with checklists, a steering group, clearly organised collaboration between product development and production, and a new system for education of operator was introduced.

PROJECT D

Case D involved four participating companies. Focus of the research was on efficient industrialization supporting successful production ramp-up across a supply chain. The research questions raised was: a) What factors, related to actors with different positions and links in a supply chain, in the context of industrialization, are critical for successful production ramp-up? b) How can different interfaces associated with industrialization be handled in a supply chain to successfully support production ramp-up? c) How can suppliers' collaboration, in the context of industrialization, be handled in a supply chain to successfully support production ramp-up? One focal company was selected and together with them three relevant suppliers were chosen to participate in the project. The entire project was guided by an interactive research approach (Aagard Nielsen and Svensson, 2006; Svensson et al, 2007), emphasizing knowledge creation through co-operation between researchers and practitioners (Ellström, 2007).

Main phases in the interactive research process
The main phase of the project included the following steps: 1. Problem-finding and diagnosis, 2. Feedback of results and identification of development activities, 3. Implementation of development activities, and 4. Follow-up/evaluation. The different steps provided the opportunity for joint identification of the current problem. It also provided support to solve problems and explore new avenues for the long-term development of the ability to successfully industrialize and ramp up a supply chain.

During the first step, two rounds of interviews were carried out. Initially a general overview of the current situation concerning industrialisation, production ramp-up and supplier collaboration, in each company (the focal company and each of the three suppliers) was investigated. Subsequently, specific product development projects were selected for in-depth analysis. The selection was made jointly by the researchers and the company representatives, and a theoretical sampling logic was applied, including both good examples but also product development projects that were perceived as less successful. The result from both the initial interviews and the subsequent case studies were fed back to all companies during a joint workshop. Based on the results and discussions in small groups, development activities were interactively identified. This was followed by individual workshops at each company. During these workshops each company selected, prioritized and assigned someone responsible for the selected activities. There were also activities assigned to the researchers. The third and fourth step included implementation of the development activities and continuous follow-up of the progress.

Each company selected three to four development activities. Some of these were carried out in a newly started product development project at the focal company and an opportunity to follow the changes in real time was obtained. This was formulated as a development activity for the researchers. The activity was carried out as a case study, and constituted the final phase of the project.

Outcome
The ambition with the research project was to achieve results that contributed to more efficient industrialisation of a supply chain. The initial steps of the project, with semi-structured interviews and interactive feedback workshops, contributed to reflections among the participants and initiated several development activities aiming at improved industrialisation and supplier involvement were implemented. Many of the development activities were carried out in group, including different departments within the company, and sometimes someone from another company. Among the inter-organizational (supplier-OEM) activities, communication of work processes, education in project management, and regular and more reliable information, can be mentioned. There were also activities carried out solely by one of the participating companies, aiming at improving their own way of working. Among these the implementation of lean-tools such summary sign-off and plan for every part can be mentioned. Follow-up of the development activities in each company was done regularly by the

research team, either with individuals or with groups from the participating company. The progress was also reported and discussed at two workshops including all participants.

DISCUSSION

In this paper we have elaborated on whether an interactive research approach can support learning and change at an individual level, group level, and an organizational level, in the context of production start-ups. In all cases, the production start-ups included activities before, during and after the production start-up. There were different degrees of interactivity between the researchers and the industrial practitioners in all cases individual and group reflections among the practitioners during interviews and feedback sessions were included. More interactivity was achieved in the latter two cases (C and D), in which the interactive research process also encompassed joint identification among the researchers and the practitioners of the problems to focus on, e.g. development activities. This resulted in more improvement activities in the companies, different events were interpreted together, and the companies took greater responsibility for their own learning processes. It thereby generated effects in practice, for example in different professional groups starting to meet in person, organizational changes, and important learning to improve future production start-ups.

A question that can be raised is how the interactive research approach may contribute to practitioners' learning related to production start-up, with a broad definition of learning as being new understandings, identity development, change of practices, and institutional development (Akkerman and Bakker, 2011). In the first two cases, Project A and B, the studies showed that the individuals learned during the research process, and there were also issues raised to a group level. The impact of the research process was increased in Project C. Before the final work shop, the outcome with immediate relevance for the companies from their participation in the research project can be described on an individual level, group level and organizational level. On an individual level, a higher awareness concerning how to handle product introduction was perceived, as new work tasks for some functions had been introduced. On a group level in Project C, competence was also perceived to be used better. Furthermore, in both Project C and D we found an increased dialogue between different functions involved in the product production start-ups. On an organizational level in Project C, the practitioners described that there were organizational changes and changes in the work process with checklists, steering groups, etc. Project C also led to a new system for education of operators. Similarly, Project D resulted in changes in the project model used in the company and in the work processes related to supplier involvement. The studies showed that a precondition to achieve changes on an organizational level was that people on the right level was involved in the research process.

Findings from the four cases show that different approaches of interactive research have different outcomes regarding opportunities for practitioners' learning. These different approaches rely on both the practitioners and the researchers. Regarding the practitioners, the company's preparedness and maturity may influence as well as the timing of the interactive research process. Participating in a full interactive research project requires time and engagement from the companies as well as ambition, drivers and management participation to start development activities. The potential for learning and changes on different levels are set through the development activities. As for the researchers, an interactive research process requires knowledge and skill to collaborate, but not guide the outcome of the process. Another factor that may influence the degree of interactive research is that development activities may not be predicted or controlled in advance, why the researchers' own process may not be able to plan in detail. As the researcher is 'invited' to the practice system (Ellström, 2007), the researchers' action latitude may be limited.

CONCLUSIONS

This paper shows that close participation and higher degree of interactivity during real-time studies of production startups have positive impact on learning and further improvement activities in the studied companies. A challenge for researchers is to balance their role as researchers with increased expectations from the companies to contribute to 'coaching' and improvement work. However, the structured approaches used in the four case studies have the potential for improving development of interactive research methodology, thereby contributing to both practitioners' needs and developing generic scientific knowledge.

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