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Extended Editorial

Thomas Lager * and Koteshwar Chirumalla **

Innovation and production management in the process industries— An extended editorial viewpoint and a way forward for future research

1 Introduction

The third International Workshop on Innovation and Production Management in the Process Industries (IPM2019) was convened at Mälardalen University in Sweden in October 2019. The overall theme is related to bridging academy–industry interfaces, innovation–production management interfaces, and the interactions among different industrial sectors of the process industries. The workshop aimed to explore the possibility of developing a platform for a research agenda for the cluster of process industries as well as develop special issues (SI) in the journal Technovation and the Journal of Business Chemistry. This article, as an extended editorial viewpoint, serves three purposes:

- Contextualizing the significance of the workshop in the area of innovation and production management in the process industries
- Presenting the results from the workshop inquiry and round-table discussions as a platform and directions for future research
- Introducing the articles in this special issue and their contributions to the area of innovation and production management in the process industries

1.1 Process industries as one part of all manufacturing industries

The family of industries generally called "the process industries" spans multiple industrial sectors, constitutes a substantial part of the entire manufacturing industry, and is generally considered to include petrochemicals and chemicals, food and beverages, mining and metals, mineral and materials, pharmaceuticals, pulp and paper, steel, and utilities. In this context, the following definition is used (Lager, 2017a, p. 203):

The process industries are a part of all manufacturing industries, using raw materials (ingredients) to manufacture non-assembled products in an indirect transformational production process often dependent on time. The material flow in production plants is often of a divergent v-type, and the unit processes are connected in a more or less continuous flow pattern.

One of the principal differences between companies in the process industries and those in other manufacturing industries is that the products supplied to and often delivered from the process industries are materials or ingredients rather than components or assembled products (Flapper et al., 2002, Frishammar et al., 2012). Furthermore, whilst product innovation in assembly-based industries begins in the design office, the development of non-assembled products in the process industries generally starts with experimental work in the laboratory or pilot plant (Frishammar et al., 2014). This inherent condition for product and process innovation among sectors within the process industries thus requires unique experimental facilities and development approaches different from those that are common in other manufacturing industries. Moreover, the importance of an integrative perspective on raw materials, process technology, and products in innovation is another significant contextual condition of the process industries (Lager, 2017), a fact that most likely favors a more amalgamated process

* Mälardalen University, School of Innovation, Design and Engineering, P.O. Box 325, SE-63105 Eskilstuna, Sweden, thomas.lager@mdh.se
**Mälardalen University, School of Innovation, Design and Engineering, P.O. Box 325, SE-63105 Eskilstuna, Sweden, koteshwar.chirumalla@mdh.se

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and product innovation approach (Hullova et al., 2016).

1.2 Innovation and production management research in the process industries—A road less travelled

In a special issue of the journal R&D Management on the topical area of management of research and development (R&D) and innovation in the process industries (Lager et al., 2013, p. 194), the lack of innovation management research in a process-industrial context was described as follows: "It could be that the industry environment in the process industries is not as 'glamorous' compared to other industries like IT, design, and service. Additionally, the production process of process firms could appear complicated and hard to understand for scholars lacking an appropriate technical background".

In a special issue on operations management research in the process industries, Van Donk and Fransoo (2006, p. 211) remarked that: "Much of the work proposing models lacks specific knowledge of the process industry domain, enforcing that many of the characteristics are either assumed too general or not addressed specifically". This lack of process-industrial operations management research was also confirmed in a recent literature review (Samuelsson et al., 2016).

An early study found that about 30% of the top 2,000 worldwide investors in R&D belonged to the process-industrial cluster (Lager, 2010). However, despite the importance of this cluster of industries within the disciplines of innovation management and production management, as well as for industrial production and innovation in general and for the world economy at large, the family of process industries is surprisingly under-researched.

This article is organized as follows: Section 2 sets the stage for the third international workshop and provides summaries of three round-table discussions. Section 3 introduces the five articles in this special issue and provides a preliminary synthesis. Section 4 presents the results from the workshop inquiry as well as the top 10 listed topical areas for future research in the process industries. Finally, Section 5 gives concluding remarks and details a way forward.

2 IPM2019: The third International Workshop on Innovation & Production Management in the Process Industries at Mälardalen University (MDH)

The Product and Production Development research group within the Innovation and Product Realization (IPR) research environment at MDH hosted the workshop, whose objectives were to bridge the industry–academy interface and stimulate cross-sectorial and cross-disciplinary research for the future on innovation and production management in the process industries. IPM2019 was the third edition of an international workshop focusing on the process industry, and previously the workshop had been hosted in France and Australia. At this time, it included 40 representatives from various universities and companies in the pharmaceutical, steel, mineral, food and drink, and forest industries from the UK, Scotland, Denmark, Germany, the Netherlands, Switzerland, and Brazil. The organizational and scientific committee included Professor Thomas Lager (chair), Professor Glenn Johansson, Professor Jessica Bruch, and Dr. Koteshwar Chirumalla (program coordinator) from Mälardalen University as well as Professor Jens Leker from the University of Muenster and Mr. Jeff Butler (Technovation).

The workshop offered 6 plenary and key-note academic and industry-related presentations, covering different sectors of process industries, including those by Dr. Thomas Friedli (professor at the University of St. Gallen), Dr. Stephan von Delft (Glasgow University), Dr. Paulo Figueiredo (professor at the Brazilian School of Public and Business Administration), Dr. Rachid Gamal (Nestlé), Magnus Edin (SunPine AB), and Dr. Peter Wallin (Process Industrial IT and Automation, PiiA). Day 1 of the workshop included 14 academic and industrial presentations and a visit to Bolinder Munktell Museum. Day 2 included five round-table discussions on selected topics for identifying a platform for future research directions for the innovation and production management in the process industries. Day 3 included a visit to Outokumpu Stainless AB, Nyby mill in Torshälla.

The following sections present the topical areas and summaries from three selected round tables.

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2.1 Bridging the Industry—Academy interface

The state of affairs was rather provocatively described by Rynes et al. (2001, p. 346) as "academic research [falling] behind, rather than [jumping] ahead of organizational practice". A number of studies support the view that the problem with the "growing gulf between managers and research" ought to be addressed (Ghobadian, 2010). Academic scholars should thus seek industrial input regarding the industrial need for improved management tools and methodologies and to promote the reverse flow of ideas in the form of improved mechanisms for the transfer of research results from academia to industry (Barrett and Osborn, 2018). Because of the important idiosyncrasies of the contextual and inherent conditions for innovation in the process industries, particularly in the unique experimental environment, one can presume that close contact and strong collaboration between academics and industry professionals is of interest to those seeking to stimulate and bridge the gap between industry and academia (Lager, 2017a). In Figure 1 summary notes are presented from the round-table discussion on bridging the industry – academy interface.

2.2 Cross-disciplinary innovation and production management—In search of facilitating mechanisms for a conjoint approach

Brown et al. (2005, p. 15) stated that "there is a need to view operations management as part of a fluid, interactive, mutually beneficial series of relationships between raw materials and the end customer". Although the early integrative development of product and production technology is desirable in other manufacturing industries (Bruch and Bellgran, 2014), the integrative perspective on raw materials, process technology, and products needs to be given much stronger consideration in process-industrial product and process innovation (Hullova et al., 2019, Hullova et al., 2016). A company's ability to respond to change is often limited in the short term, and Hill (1994, p. 128) articulated this state of affairs distinctively for all manufacturing industries:

In all instances, the mismatch results from the fact that while manufacturing investments are inherently large and fixed (once a company has purchased them, it will have to live with them for better or for worse for many years), markets are inherently dynamic […] The inherently changing

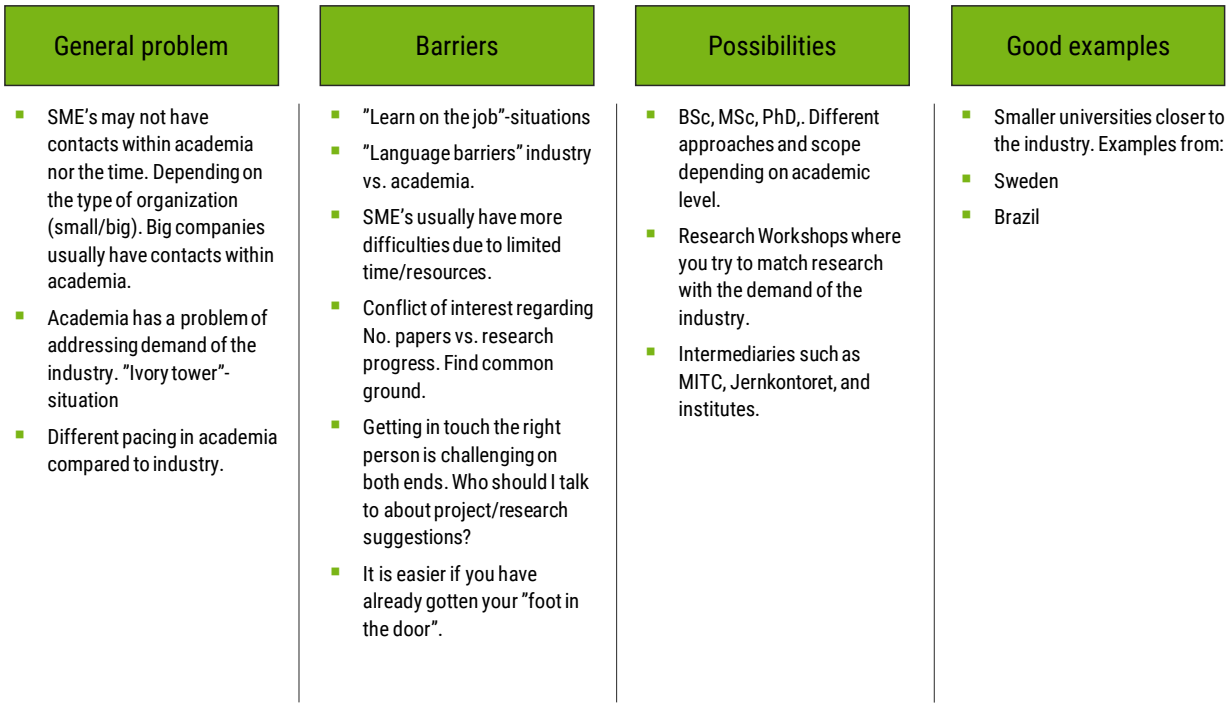

Figure 1 Summary notes from the round-table discussion (own representation).

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nature of markets and companies' ability to alter marketing perspectives to allow for changes and repositioning are in opposition to manufacturing decisions that bind business for years ahead.

However, despite the overwhelming scientific evidence that product innovation and production innovation must go hand in hand, especially in a process-industrial context, this fact is unfortunately often still disregarded in both academia and industrial practice.

Indeed, scholars from the disciplines of innovation management and production (operations) management rarely interact during international conferences, seldom publish in the same journals, and infrequently share ideas in "coffee table" conversations. Likewise, and notwithstanding a desire to bridge the manufacturing–R&D interface (Lager and Rennard, 2014), similar barriers are often found in many manufacturing companies. Thus, one objective for this round-table discussion was to address this unfortunate condition, discuss how to stimulate company cross-functional attitudes and behavior, and search for a cross-disciplinary research agenda for innovation and production management in the process industries. In Figure 2 summary notes are presented from the round-table discussion on cross disciplinary innovation and production management.

2.3 Cross-sectoral learning in innovation and production management in the process industries—In search of common denominators and sectoral idiosyncrasies

Pavitt (1984, p. 343) argued that it is important to study sectoral patterns of technology change because it has implications for our "understanding of the sources and directions of technical change, firms' diversification behavior, the dynamic relationship between technology and industry structure, and the formation of technological skills and advantages at the level of the firm, the region and the country".

However, Hirsch-Kreinsen's (2008, Hirsch-Kreinsen et al., 2005, p. 39) findings also suggest that the concept of sectoral boundaries has to be conceived more broadly as well as more systematically in order to make it possible to understand the relevant aspects of the courses of technological innovation:

[A] comparison between high and medium tech industries shows that recurring principles and similarities with respect to innovation patterns can have a cross-sectoral character. These contexts are only insufficiently grasped by well-established approaches of the systems of innovation.

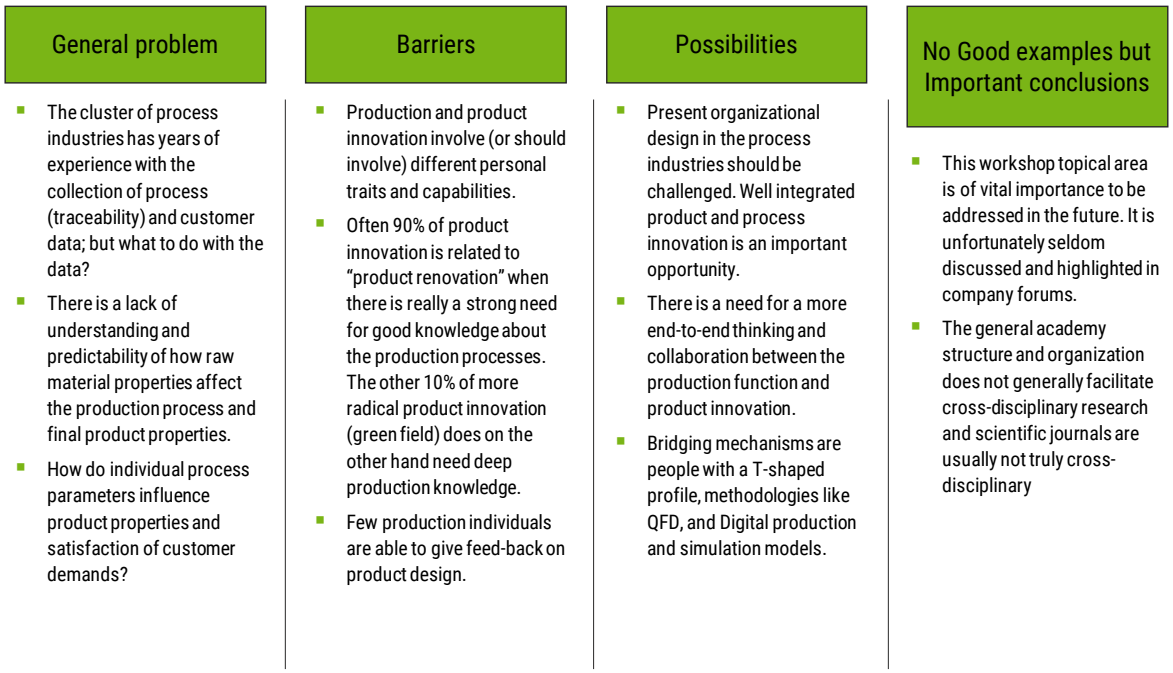

Figure 2 Summary notes from the round-table discussion (own representation).

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Although different sectors of the process industries share a large number of characteristics related to their production systems, those characteristics significantly differ from the production system characteristics in other manufacturing industries (Lager, 2017a). Consequently, sectoral experiences from process-industrial innovation and production management can be shared within the process-industrial cluster but are of less interest for other manufacturing industries. The "family" of process industries is thus similar within itself, but dissimilar to other manufacturing industries. In Figure 3 summary notes are presented from the round-table discussion on cross-sectoral learning in innovation and production management in the process industries.

3 Innovation and technology management in the process industries - In search of common denominators and sectoral idiosyncrasies

Out of the 14 academic and industrial presentations at the workshop, six were selected for potential publication in a special issue of the Journal of Business Chemistry. Two additional articles were submitted in late spring. After the workshop, all potential articles got early feedback from the guest editors and, after resubmission, five articles were ultimately selected and sent out for the double-blind review process.

The following introduction of the individual articles is to be regarded as a collection of "extended abstracts", however, composed by the Guest Editors, and in use of the original text from each article; an aspiration to capture and advertise the most important messages within each article to academics and industry professionals. Because of that, they contain an unusual large number of citations and parts from the authors' original articles; well formulated sentences and arguments which the Guest Editors did not wanted to reduce or even impair.

3.1 Contents of this special issue

The first article, entitled "Digital Transformation in the Swedish Process Industries: Trends, Challenges, Actions" (2020) by Örjan Larsson and Peter Wallin from Process Industrial IT and Automation (PiiA) Sweden, addresses a pressing topical area for all manufacturing industries and, in particular, the process industries. In the context of the fourth industrial revolution and digitalization as a driving force, the current approach in the Swedish industrial innovation system is the public–private partnership Strategic Innovation Programs (SIPs), (Larsson and Wallin, 2020). The program portfolio is funded and administrated jointly by the Swedish governmental agency for innovation systems, VINNOVA, and the Swedish Energy Agency and Formas, a government research council for sustainable

General problem	Barriers	Possibilities	Good examples
▪ Differences between industry sectors also between process industry sub-sectors ▪ Different challenges and drivers between sectors ▪ Cross-sectorial experience sharing is seldom done ▪ Differences drives between functions in companies ▪ Internal budget processes and standard KPIs limits innovations	▪ Different communities ▪ Management does not encourage cross-sectorial learning ▪ Cultural changes ▪ Common believe that their operation is unique limits interests for exchange ▪ Productivity and efficiency drive	▪ Consultants and other suppliers with cross-sectorial business are important in this aspect ▪ Local cross-sectorial exchange to learn ▪ People changing jobs bring in new experiences ▪ Networking	▪ Experience transfer of water treatment from pulp & paper to mining and pharma ▪ Cross-sectorial team visits (pulp & paper to mining) ▪ Change terminology from "project" to "experiment/initiative" for radical developments to change expectation and demands

Figure 3 Summary notes from the round-table discussion (own representation).

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development. "Within the SIPs, and founded in 2013, PiiA was an answer to the process industries' ambitions for increased competitiveness through digitalization". By the beginning of 2020, PiiA had launched nearly 200 research and innovation projects and feasibility studies with 275 participating partners. This article presents seven years of empirical observations, analyses, and conclusions from the execution of the PiiA program.

Experience from previous technological shifts has shown the power of good role models and, using the knowledge gained through the PiiA's project base, three types of companies in different stages of the S-curve were identified in the PiiA model presented in Figure 4.

The majority of companies—an estimated 70 percent (2019)—belong in the aspiring for insights category, meaning they realize that change is coming, but still lack readiness and ability, which must be developed. Such companies may need to assess their technological base and analyze their data management, their organizational data strategy, and the value of their data (Larsson and Wallin, 2020). They need to think about their roadmap for digitalization. They are called aspirants. The rise of the next category has been identified as the pilots, to which an estimated 20 percent of businesses belong. They are engaged in and have dared to take the first steps down the path toward a systematic digitalization approach. The accelerators include a small group of pioneers, estimated to be less than 10 percent of companies, who have found their own best practice solutions and are ready to scale up and transform their businesses using digital technology. It is advocated that: "The accelerator group now needs to shift the responsibility for transformation to their line organizations, along with appropriate expert support, as well as improve their ability to manage job transformation, data as a strategic asset, and the security and ethical issues related to data usage", (Larsson and Wallin, 2020).

The second article by Richard Tuin (2020), entitled "Flawless Start-up of Production Plants in Process Industries: The Link between Successful Project Performance and Optimal

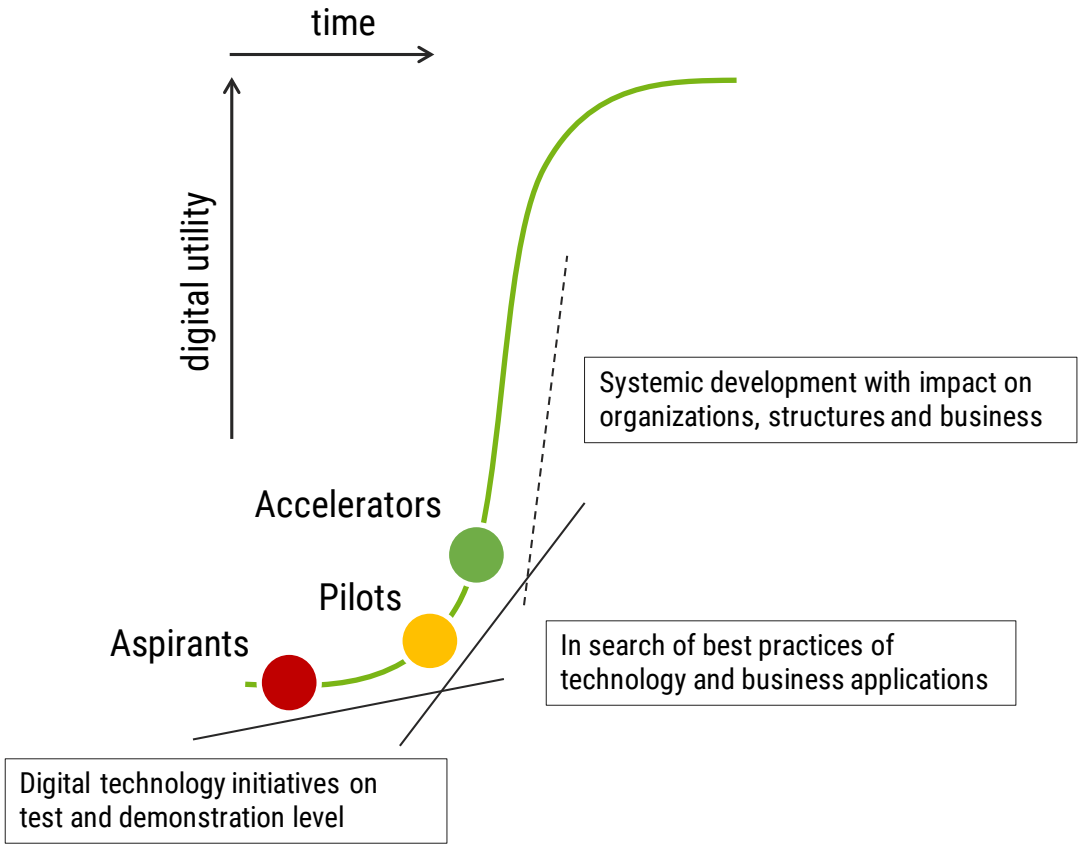

Figure 4 The PiiA model for digital transformation in the process industries (Larsson and Wallin, 2020).

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Future Operations", discusses the last phase in technology transfer—namely, the start-up phase. The article illustrates that projects in the process industries often lack intentional goals for process plant start-up and initial operations, which frequently result in prolonged periods of underperformance. "Apart from underperformance - namely, the failure to reach on-specification (nameplate) operations—there is also the increased risk of harm to both humans and the environment when projects are not executed and delivered properly", (Tuin, 2020). This study describes and analyzes why commissioning and start-up are often underestimated and undervalued, and fundamental measures and approaches are identified that can facilitate the success of commissioning and start-up in process-industrial projects. An improved plant start-up work process is presented, including the following areas (Tuin, 2020):

- Acknowledgments and insights among stakeholders and management on the importance of proper start-up and commissioning
- Determination of start-up strategies and selection of a start-up management team
- Definition of contractual terms with a strong attention to start-up
- Project cohesion and intra- and inter-organizational integration
- Proper planning, budgeting, and organization

Although the scope of start-up activities and resources depends on project size and business organization, this article argues that one of the core issues for success at start-up is the commencement of the front-end phase. Thus, of vital importance is the early involvement of a commissioning and start-up representative; in addition, in the conceptual phase of a project, there must be plans for transforming the project flawlessly into an on-specification operating plant (Tuin, 2020). Ultimately, the authors conclude that cross-sectoral cooperation and knowledge sharing within the process industries are rare, possibly because of an attitude that whatever a particular company is processing is unique rather than viewing the commonalities of technical and business processes for improvement, innovation, and learning opportunities.

Similar to the previous article, the contribution by Haitem Hassan-Beck and Thomas Lager (2020), entitled "Success factors for intra-firm process technology transfer, and a petrochemical outlook", noted that the introduction of existing, improved, or radically new process technology in the process industries is not finished until the technology is implemented and operating well within the company's organization and premises. Moreover, as the company's digital transformation also depends on the successful inter- and intra-firm transfer of technology, excellence in technology transfer is of increased industrial importance. However, the necessary reciprocal information sharing (organizational transmitting and receiving capabilities) highlights the misleading nature of the technology transfer concept, as it seems to indicate a one-way communication process (Hassan-Beck and Lager, 2020).

Based on the authors' previous industrial experiences and their literature review, they developed and operationalized 25 candidate success factors for intra-firm technology transfer. Using the success factors in an exploratory survey of professionals in the petrochemical industry, an illustrative case was further developed. The general high importance ratings of nearly all candidate success factors suggest that they could be deployed in a checklist format for a company's intra-firm process technology transfer (Hassan-Beck and Lager, 2020). The findings further indicate that process companies would benefit from the use of an internal guide for carrying out process technology transfer projects. The success factors from this study could be useful components in the development of such a manual. Moreover, the authors argued that the results can serve as guidelines for both new company technology transfer projects and a company improvement program for technology transfer.

The subsequent article, entitled "Supporting start-ups in the process industries with accelerator programs: types, design elements and success measurement", was written by Thorsten Bergmann and Timo Rothausen (2020) and discusses a different kind of start-up. A wide range of support forms for nascent ventures like start-ups exists, such as incubators, venture studios, start-up competitions, and business angel investors, and one such support form is an accelerator program, which is a novel phenomenon to foster entrepreneurship (Bergmann and Rothausen, 2020). The authors initially conclude that most research on accelerators has previously focused on start-ups dealing with digital media and that little is known about accelerator types, which support start-ups in areas like advanced materials and biotechnology. Currently, no research exists on accelerator types and their design in the context of process industries. To get an in-depth understanding of accelerator types and

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their design in the context of the process industries, semi-structured interviews were conducted with ten accelerator managers using the topical areas of strategic focus, selection process, alumni relations, program package, and success measurement.

The results from this study show that starting an accelerator requires clear strategic goals and focuses, deciding whether to take a horizontal (i.e., including a variety of industries) or vertical (i.e., focusing on a specific industry) approach. Moreover, accelerators must establish a strong network to scout and identify suitable start-ups, and they must provide tangible benefits for start-ups (Bergmann and Rothausen, 2020). It is further recommended that accelerators provide tailored trainings according to the start-up's development stage, needs, and industry background. In the context of process industries, technical expertise and industry experience are very important. Bergmann and Rothausen (2020) further conclude that success stories from alumni start-ups can leverage the accelerator's reputation, improving its visibility, network, and access to high-profile mentors and investors. Furthermore, that accelerators must continuously assess their offers and services with carefully chosen success metrics (such as KPIs). In the context of the process industries, start-ups that offer digital solutions may be particularly interesting for participation in an accelerator, as they require fewer financial resources and are less asset-intensive (Bergmann and Rothausen, 2020).

The fifth article, "Start-ups as an Indicator of Early Market Convergence" by Magdalena Kohut, Jens Leker, Stefanie Bröring, and Nathalie Sick (2020), also discusses start-ups, but from a rather different angle. As the call for this special issue indicated a "search of common denominators and sectoral idiosyncrasies," this topical area is of particular interest. During industry convergence, defined as "the blurring of boundaries between formerly distinct industries," dominant industry logic is subject to significant changes, and established firms need to position themselves adequately in the market and acquire new competences (Kohut et al., 2020). When industries converge, previously vertically integrated value chains begin to disintegrate competition increases, and a new ecosystem starts to emerge, where established firms have to position themselves in new roles. To investigate the role of start-ups in convergence processes, this study examines the field of probiotics, a product family present in several cross-industry sectors that have emerged at the intersections of the chemicals, food and beverages, and pharmaceuticals industries and includes hybrid products like nutraceuticals, cosmeceuticals, and nutricosmetics.

In a new framework, a stepwise convergence process is presented as science convergence, technology convergence, early market convergence, and market convergence, together with the related indicators scientific publications, patents, start-up companies, and reported product launches. The study asked the following research questions: Is start-up formation present when two or more sectors converge, and can start-up formation act as an indicator of early market convergence? In this study, the data sources were scientific publications, patents, and press releases. The empirical results positively answered both research questions, and the authors concluded that (Kohut et al., 2020): "the start-up indicator offered insights into the critical transition from technology convergence to market convergence, where product launches may not yet be observable, thereby allowing the identification of early transfer opportunities along the convergence process". The authors explain that practitioners in the field of industry forecasting can benefit from having the formation of start-ups as an additional data source for the analysis of industry lifecycles. Moreover, further managerial implications arise from the strategic importance of converging industries for innovation, enabling firms to identify these processes early and prepare for changes in demand, technology, and competition (Kohut et al., 2020). As a result, they further concluded that firms can better analyze the competitive environment as well as depict newly forming, cross-industry relationships.

3.2 A preliminary synthesis of the articles in the JoBC special issue

The circles in the matrix in Figure 5 indicate the industry sectors covered in each article. Although some sectors are missing and other sectors are only represented in a single study, the impression is that the empirical evidence covers the family of process industries fairly well. Another impression is that most articles, even when a single sector is used to collect empirical data, have clear relevance for other sectors of the process industries and could be applied elsewhere in a cross-sectoral approach. The experiences from digital transformation in the Swedish process industries (Larsson and Wallin, 2020) certainly further validate such a cross-sectoral approach. The emerging sectoral convergences presented by Kohut et al. (2020) also

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emphasize the importance of crossing sectoral borders in the future.

A noteworthy finding is that three articles take a cross-disciplinary innovation and production management perspective in digital transformation, technology transfer, and flawless start-up of production plants. Part of the content in some articles gives particular insights into a specific industry sector, but may nevertheless contribute to advancing the general understanding of innovation and production management in the process industries.

4 In search of a coherent research agenda for innovation and production management in the process industries—A workshop inquiry

4.1 The inquiry

The workshop delegates were a mixture of academic scholars, industry professionals, and representatives from related organizational bodies, all with a profound knowledge of different aspects related to innovation and production management in the process industries. Thus, the following presentation of the results from workshop delegates can be regarded as "top-of-the-mind" viewpoints from a number of "informants" (Barrett and Oborn, 2018; Kumar et al., 1993). Workshop delegates were introduced to the questionnaire on the morning of the second day, and they received ample time to respond to the questionnaire before participating in the subsequent round-table discussions.

The workshop inquiry presented in the Appendix includes 33 questions covering different aspects of innovation and production management in the process industries. The questions are categorized into the following areas: strategy, digital transformation, product and process innovation, manufacturing, and general. The participants were asked to rate the importance of all areas using a Likert scale, where 1 equals "not important" and 5 equals "very important." In total, 23 workshop delegates responded to the questionnaire.

4.2 Results from the workshop inquiry

The Appendix presents all areas included in the questionnaire together with the mean and standard deviation figures of the delegates' importance ratings. The ten highest rated topical areas are presented in order as a top-ten list:

Industry sector / *Topical area*	Petro-chemical	Chemical	Food and Drink	Steel	Forest	Mineral and metal	Pharma - ceutical
Digital Transformation in the Swedish Process Industries: Trends, Challenges, Actions				●	●	●	
Flawless Start-up of Production Plants in Process Industries	●			●			
Success factors for intra-firm process technology transfer and a petrochemical outlook	●	●					
Supporting start-ups in the process industries with accelerator programs		●					
Start-ups as an Indicator of Early Market Convergence		●	●				●

Figure 5 Abbreviated titles of the five papers included in this special issue are listed in the left column (the practitioner's section uses a green shaded background). The industry sectors from which their empirical information is derived are indicated with the green circles. The upper green shaded part of the industry sector area shows the sectors to which workshop industry delegates belonged.

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1. Managing company digital transformation in the process-industries (industry 4.0)
2. Product and production innovation work processes in a process-industrial end-to-end perspective—from raw materials to end-user applications
3. Production capabilities and product lifecycle management in the perspective of a circular economy
4. Developing and fostering sustainable innovation cultures in production-oriented industrial operational environments
5. Cross-sectoral process-industrial innovation and technology management learning—in search of and fostering adapted and improved management best practices
6. Strategies for fossil-free production technologies
7. Digitalization as a supportive instrument for improved supplier and customer interaction—new innovation and production management tools and best practices
8. Process automation and digitalization for improved product quality and production flexibility
9. Innovative new perspectives on business model development adapted to process-industrial concepts
10. New process-industrial project management perspectives and best practices (e.g., managing long-term innovation projects in times of changing organizational company environments)

A detailed list of the top three rated topical areas in each category in ranking order as well as their respective rank in the top ten list is presented in Table 1.

4.3 Preliminary analysis and discussion

The results reflect some ongoing major shifts in the process-industrial sectors. Digital transformation, circular economy, value chains, and business models are a few of the shifts covered by the top ten ranked topical areas. The following subsections briefly present the top ten areas with respect to their categories.

4.3.1 Digital Transformation

The highest ranked topical area is from the digital transformation category, which is about managing company digital transformation in the process industries, including industry 4.0 technologies. In fact, of the ten topical areas, three belong to digital transformation, which shows the criticality of this area for the companies in the process industries. More specifically, experts acknowledged the importance of studying the role of digitalization and its technologies in improving customer–supplier relations (ranked seventh in the list), product quality, production flexibility, and process automation (ranked eighth).

4.3.2 Product and process innovation

The second highest ranked topical area, product and production innovation work processes in a process-industrial end-to-end perspective—from raw materials to end-user applications, is from the product and process innovation category. Previous research has stressed that more detailed investigations on process-industrial work processes are needed when it comes to product and process innovations. The workshop enquiry extends this view, pinpointing the need for further investigations of work processes from the value chain and ecosystems perspective (i.e., from raw materials to end-user applications). Process industries can benefit by having a broader understanding of work processes, which means enabling value chain collaboration and value co-creation. Moreover, delineating and extending the work processes in detail while especially considering all value-chain actors in the ecosystem (i.e., work process configurations and design) could enhance the process of digitalization and digital transformation in process industries. Thus, a detailed understanding of work processes is a prerequisite for the highest ranked topical area: managing company digital transformation in the process industries.

4.3.3 Strategy

The third topical area from the top ten list is from the category of strategy: production capabilities and product lifecycle management in the perspective of circular economy. This topical area reflects the ongoing initiatives and efforts by the European Union, which announced that a circular economy (CE) is top in its agenda. Indeed, the EU and many European countries announced a CE action plan for a cleaner and more competitive Europe. Of course, there are more issues to be resolved in this context. The experts in our workshop inquiry emphasized that both practitioners and academic scholars need to rethink the existing production capabilities and the product lifecycle management to make a successful transformation toward CE. Moreover, from the category

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Table 1 Top three rated topical areas in each category (own representation).

Category	Description of the category	Rank in the category	Rank in the top ten list
Strategy	Production capabilities and product lifecycle management in the perspective of a circular economy	1	3
	Strategies for fossil-free production technologies	2	6
	Innovative new perspectives on business model development adapted to process-industrial concepts	3	9
Digital transformation	Managing company digital transformation in the process-industries (industry 4.0)	1	1
	Digitalization as a supportive instrument for improved supplier and customer interaction—new innovation and production management tools and best practices	2	7
	Process automation and digitalization for improved product quality and production flexibility	3	8
Product and process innovation	Product and production innovation work processes in a process-industrial end-to-end perspective—from raw materials to end-user applications	1	2
	Customer-centric product innovation frameworks, methodologies, and best practice	2	-
	Managing the "fuzzy front end" in both product and process innovation	3	-
Manufacturing	Developing and fostering sustainable innovation cultures in production-oriented industrial operational environments.	1	4
	Managing process equipment and plant start-up in the perspective of product and process innovation	2	-
	Product introduction work processes in the perspective of management of industrialization	3	-
Organisation	Cross-sectoral process-industrial innovation and technology management learning—in search of and fostering adapted and improved management best practices	1	5
	New process-industrial project management perspectives and best practices (e.g., managing long-term innovation projects in times of changing organizational company environments)	2	10
	Effective orchestration, coordination mechanisms, and collaborative models for supplier, customer, and end-user interactions in complex process-industrial supply/value chains	3	-

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of strategy, two additional topical areas ranked in the top ten list: strategies for fossil-free production technologies (ranked sixth) and innovative new perspectives on business model development adapted to process-industrial concepts (ranked ninth). In addition, also from the strategy category, platform-based production and design of non-assembled products is considered a key topical area (ranked 11th), where the configuration modelling and integration of company raw materials, production technology, and products are anticipated to be significant.

4.3.4 Manufacturing

The fourth topical area in the top ten list is from the manufacturing category: developing and fostering sustainable innovation cultures in production-oriented industrial operational environments. This topical area acknowledges the fact that sustainable innovation culture plays an important role in process industries, which is similar to other manufacturing industries, where the topic has been significantly addressed both in practice and academia compared to the process industries. This topical area might be even more important for the process industries due to the rigid engineering and production culture.

4.3.5 General

The fifth topical area from the top ten list is from the general category: cross-sectoral process-industrial innovation and technology management learning—in search of and fostering adapted and improved management best practices. All participants agreed that process industries have great opportunities to learn from each other. Although process-industrial sectors are sharing many similarities and characteristics at the general level, each sector is also implementing unique and novel initiatives and efforts to cope with the emerging challenges (e.g., digitalization, circular economy, business models, and ecosystems). Process industries could leverage their competitive advantage by cross-sectorally sharing their lessons learned and best practices. One additional topical area from the general category is ranked in the top ten: new process-industrial project management perspectives and best practices (ranked tenth). Process industries will deal with more novelty or long-term innovation projects in the future due to all emerging transformations happening in the business environment.

5 A way forward for future research and industry collaboration

The five highest-rated topical areas from the workshop inquiry are presented in Figure 6. These areas capture a select number of areas in innovation and production management that ought to be addressed in future management research and in the development of industry best practice in the context of the "family" of the process industries.

The digital transformation and circular economy areas most likely depend on properly delineated work processes; in company implementation, they certainly rely on open and trustful organizational cultures. The fifth area is recognizing the most interesting cross-sectoral learning opportunities within the process-industrial cluster. This is further underscored in the synthesis of the articles in this special issue and supported by the interesting notes from the round-table discussions.

The need for cross-disciplinary innovation and production management research was one area discussed during the round-table discussions, and it was concluded that this issue is not only important for management research, but also vital for better company performance in the process industries: the process embodies the product. Two articles in this special issue ("Technology transfer"; "Start-up") emphasized the importance of production management as well as how to manage industrial projects in the early phases, commissioning phases, or plant start-up phase when there are geographically dispersed multiple actors involved from the value chain or extended ecosystem.

Regarding the interesting round-table discussion results on bridging the academy–industry interface and the promising overall outcomes from this third International workshop on Innovation and Production Management in the Process Industries, one can conclude that a continuation of this initiative would be a worthwhile activity for both academics and companies in the process industries. Scholars researching innovation and production management in the process industries and industry professionals are invited to further reflect on and discuss the outcomes from this workshop presented in this article in order to further develop this platform into a more coherent research agenda.

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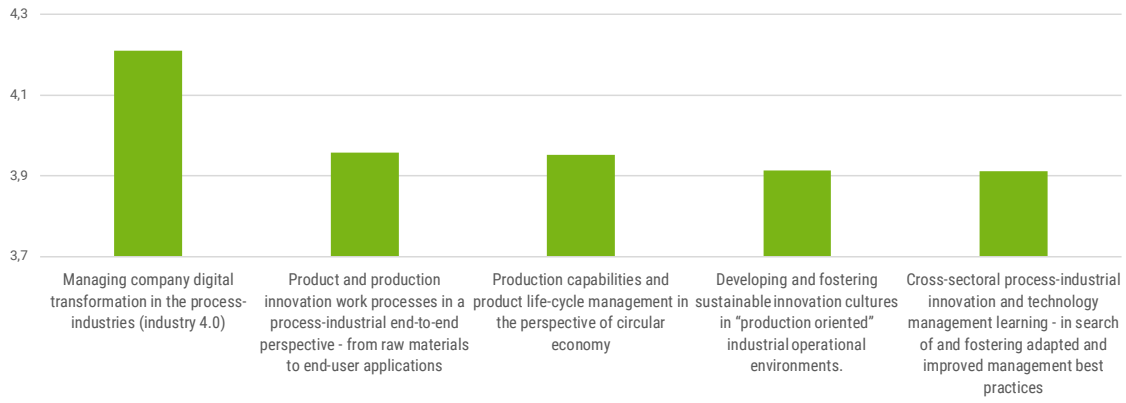

Figure 6 The five highest-ranked topical areas in the workshop inquiry (own represenation).

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Appendix

A workshop inquiry on innovation and production management in the process industries

Please give your "top of mind" perspective on the following tentative topical areas for the development of a coherent agenda for future process-industrial research.

(1 = Not important 5 = Very important)

(In this slightly simplified design of the questionnaire, mean values from the study are introduced in advance of all areas in a bold font. The overall mean and standard deviation of each category is also mentioned in parenthesis.)

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Strategy (Mean = 3.5; Standard deviation = 0.3)

(4.0) 1. Production capabilities and product life-cycle management in the perspective of circular economy.

(3.0) 2. Capturing business opportunities in the emerging process-industrial landscape - transcending sectoral demarcations and traditional technology system configurations.

(3.4) 3. Integrated portfolio planning of company products and production systems – lessons to be learned from other manufacturing industries.

(3.8) 4. Innovative new perspectives on business model development adapted to process- industrial contexts.

(3.4) 5. Strategic management of global manufacturing networks.

(3.3) 6. Industrial manufacturing and investment strategies in the perspective of dynamic market environments.

(3.6) 7. Platform-based production and design of non-assembled products – configuration modelling and integration of company raw material, production technology and products.

(3.9) 8. Strategies for fossile free production technologies.

Digital transformation (Mean = 4.0; Standard deviation=0.2)

(4.2) 9. Managing company digital transformation in the process-industries (industry 4.0).

(3.9) 10. Digitalization as a supportive instrument for improved supplier- and customer interaction – new innovation and production management tools and best practices.

(3.9) 11. Process automation and digitalization for improved product quality and production flexibility.

Product and process innovation (Mean= 3.2; Standard deviation=0.3)

(3.0) 12. Open innovation in a process-industrial context – new opportunities for consumer interaction.

(3.2) 13. Capturing value from commodity products, through expanded supplementary product service offerings or application development.

(4.0) 14. Product and production innovation work processes in a process-industrial end-to-end perspective - from raw materials to end-user applications.

(3.3) 15. New perspectives on company strategic raw materials supplies – e.g. interactive raw material and process technology innovation.

(3.2) 16. Product and process innovation strategies in the perspective of product position on the commodity/functional product scale and technology position on the S-curve.

(3.3) 17. Frugal and inclusive innovation in a process-industrial context – integrating low cost production systems, simplified product architectures and new business models for emerging and mature markets.

(3.5) 18. Customer-centric product innovation frameworks, methodologies and best practice.

(3.4) 19. Managing the "fuzzy front end" in both product and process innovation.

(3.2) 20. Pilot planting and demonstration plants in the perspective of product and process innovation total work processes.

(2.6) 21. Strategies for process-industrial Immaterial Property Rights (IPR) in the perspective of integrated product and process innovation.

Manufacturing (Mean = 3.3; Standard deviation = 0.3)

(3.3) 22. Operational excellence and management of lean production.

(3.0) 23. Open production ("wall-to-wall") company production models by the integration of raw material

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(packaging) suppliers or equipment suppliers in company production systems.

(3.9) 24. Developing and fostering sustainable innovation cultures in "production oriented" industrial operational environments.

(3.4) 25. Product introduction work processes in the perspective of "management of industrialization".
(3.5) 26. Managing process equipment and plant start-up in the perspective of product and process innovation.

(3.2) 27. Maintenance management in process-industrial production environments.

General (Mean = 3.5; Standard deviation = 0.2)

(3.6) 28. Strategic process-industrial sustainability challenges in the perspective of necessary new or improved innovation management capabilities and adapted organizational frameworks.

(3.3) 29. Company "internal start-ups" (autonomous hubs within company R&D demarcations) as new organizational solutions.

(3.7) 30. New process-industrial project management perspectives and best practce (e.g. managing long-term innovation projects in times of changing organizational company environments).

(3.5) 31. Intra- and inter-firm collaboration and technology transfer models and best practices.

(3.6) 32. Effective orchestration, coordination mechanisms and collaborative models for supplier, customer and end-user interactions in complex process-industrial supply/value chains.

(3.9) 33. Cross-sectoral process-industrial innovation and technology management learning - in search of and fostering adapted and improved management best practices.