Learning Factories towards Industry 5.0: Evolutionary or Revolutionary?

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Abstract – **Rather than representing a technological leap forward, Industry 5.0 actually nests the Industry 4.0 approach in a broader context, providing regenerative purpose and directionality to the technological transformation of industrial production for people-planet-prosperity [1]. Consequently, Industry 5.0 can be considered as the new engine of the economic and societal transition with a societal concept which can mean more distributed well-being with human-centric and sustainable, resilient industry. The advantage of the learning factory concept therefore lies in the combination of the realistic factory environment, processes and transparency of the structured activities which can provide testing of new features, modules, functionalities, tools, and technologies based on the existing Industry 4.0 framework. Especially, the concepts of implementing new business models with benchmarking emphasise the major difference in achievable results. Transition to a circular economy can only be achieved if up-skilling and re-skilling of workers can also be done which is the core function of the learning factory.**

Keywords – Industry 5.0, Learning Factory, Sustainable and Resilient Industry, Responsible Consumption and Production

I. INTRODUCTION

The human-centric approach in industry has gained momentum during the past decade. Many drivers contributed to this, like mass customization and digital transformation which have increased the need for more and quite different competencies. Some other drivers that are definitely worth highlighting are the human-machine collaboration as a major enabler for more sophisticated ergonomics at the shop-floor level; new business models – servitization – transforming the processes and organisation charts of any industrial operation and supply chains; and industrial transition in general, challenging the political agenda with new aspects of the digital (societal, territorial) gap. What we can see at this moment is more or less about retaining industrial excellence and leadership in advanced manufacturing, but also integrating the major elements of the digital and green transition and creating the main concept of Industrial 5.0 as the new engine of the economic and societal transition. Because Industry 5.0 is mainly a societal concept, a might be beneficial for society, as an opportunity for cohesion, more distributed well-being, for having "better" perspectives in industrial jobs and to incubate more resource-efficient economic activities to create a human-centric and sustainable, resilient industry. But – how to make it happen? Sure, relevant digital and key enabler technologies (like AI), up-skilling and re-skilling of workers, and transition to a circular economy might give some leads to have a broad view, but more insight would be useful to have a clearer view on gaps and challenges, and to have a more detailed roadmap at micro-level. The operational model of the learning factories as a framework gives such a unique opportunity. The advantage of the learning factory concept lies in the combination of the realistic factory environment, processes – and transparency of the structured activities. It might give a real opportunity to elaborate insights; to go beyond individual solutions and use cases – e.g., using Cobots – in order to incorporate further topics, like the content and form of interactions, learning outcomes, the composition of the main customers and the customer journey, the main services, new interfaces and new partnerships. Based on this evaluation, the paper will prove that implementing Industry 5.0 (I5.0) is indeed evolutionary, in the sense that it is based on existing Industry 4.0 (I4.0) framework, testing new features,

modules, functionalities, tools and technologies ("setting" and "product"). The transformation is more fundamental, even at micro-level, considering the highlighted transformative (e.g. circular) business models ("processes"); learning targets ("didactics"); the change in the composition of the main target customers like Small-, and Medium Sized Enterprises (SMEs) and age-cohorts ("purpose", "domains") and the increasing demand for mission-driven, societal impact ("operational model"). In general, a learning factory - as a specific hub for innovation and collaboration – may be the best tool for promoting an "Industry 5.0-led transformation". To prove this statement, the distinction between evolutionary and revolutionary transformation had to be specified at first, using analogies like business model transformation, business process re-engineering and finally, benchmarking. Especially the concepts of implementing new business models – an in-depth transformation – emphasise the major difference in achievable results, using either continuous development with steady, promising perspectives or implementing a more ambitious strategy to realize a stronger (steeper) increase in KPIs and re-structuring in fundamental business processes, at least, during a specific period of time. In light of these analogies, it is considered that a real potential exists for ambitious transformation paths. It is based upon restructuring the business models, primarily focusing on processes and organisation, instead of introducing new products and services. They are realized by discrete projects using e.g., agile methods, or as part of mergers and acquisitions. The difference in the approaches leads to the conclusion that introducing Industry 5.0 indeed may be a transformation of fundamental processes, much more than introducing new – even if human-centred – technologies, production systems and modules.

II. RELATIONS BETWEEN INDUSTRY 4.0 AND 5.0

Three factors are appointed for the specific comparison between Industry 4.0 and 5.0 approaches.

A. Projects vs. processes

The first is the distinction between "projects" and "processes". Underlying discourses on Industry 4.0 and 5.0 may give the impression that stakeholders tackle mainly with project management, realizing results and impacts through the successful implementation of *discrete efforts* (projects). The transformation of processes or business models has, on the contrary, a different meaning, emphasising the long-term, sustainable change in the fundamental structure, organisation, strategy, and culture. Consequently, there are limited opportunities for separated, out-of-the routine activities and sand-box-like departments or flagship projects, but an increasing demand exists for scaling-up the results, to achieve a company-wide outreach, introducing new values, metrics and systematic, educative and engagement-based change

management. However, "restructuring- and transformation processes are not (successful), 50–80% fail to attain their goals" – primarily due to distrust of the workforce and of several bottlenecks in internal communication, staff participation and engagement, and in leadership [2]. So, being Industry 5.0 means being human-centric, besides sustainability and resilience, and it increases the demand for a complex intervention and customer journey, beyond the classical project management.

Table 1. Comparison of Industry 4.0 and 5.0 based on [3].

Industry 4.0	Industry 5.0
Efficiency through digital connectivity and artificial intelligence	Competitiveness based on human-centric design, sustainability, and resiliency
Cyber-physical objectives	Sustainability and resilience
Optimisation of business models within existing capital market dynamics and economic models	Indicators show the progress achieved on the path to well-being, resilience, and overall sustainability

B. Existence of a "transitional period"

The above-mentioned analogies as mainframe models specify the existence of a specific transitional period. It is a rapid development phase, based on specific (mostly external) information, acting as business intelligence. It consists of several particular implementation steps, and of rather specific efforts in unique circumstances. These models are based upon the assumptions that for accelerated (extra, added) growth and/or systematic adjustment of the processes, management has to create and maintain a rather exceptional situation and unusual (temporary) actions for months.

Attention should be devoted to additional factors of sustainability of the outcomes of these temporary interventions, which are necessary for the prolonged consolidation, because of the role and importance of the corporate culture and informal networks.

C. Intelligent benchmarking

Intelligence is the third specific factor, which has to be appointed, as the most characteristic pattern of the benchmarking-based concept. It is the source of the knowledge for change, it serves with an existing, functioning, and realistic model of one or more business entities for systematic inspection, comparison, assessment and identification of achievable KPIs, and applications. This information is a key to realise the "significant leap" via several systematic, small-scale or major, interventions.

III. REALIZING THE INDUSTRY 5.0 ENCOURAGING LEARNING FACTORY

Learning Factories have huge experience in supporting continuous development, e.g. by the implementation of lean principles, the introduction of digital solutions, and realizing even vertical integration: modularity, flexibility, the inclusion of additive manufacturing into the workshops etc. In Leaning Factories, several challenges related to the Industry 4.0 implementation can be tested and managed step-by-step, based on carefully executed experimentations. Indeed, this is the core of the value proposition of the Learning Factory (LF) centres. Consequently, Industry 5.0 shouldn't be understood as a need for a new generation of LF centres, but the clear justification is, that LF centres may be the best entities for this transformation support. It is served by adding new, complementary activities, like supporting unique transformation projects, focusing on leadership and strategy, audit of key processes and organisations, and specific comparative KPIs to accelerate change and enable sustainability. Additionally, for realizing the Industry 5.0 oriented Learning Factory, the following subtopics have to be taken into account.

A. Customer journey and embeddedness

Learning Factories have modular, flexible, and diverse settings, didactics and partnerships for providing customized services according to the individual needs and specific situation. Customer relations has already been evolved as demand-driven and diverse portfolio for increased trust regarding the application and implementation of respective technologies and solutions – based on articulated or hidden needs. However, for supporting an in-depth transformation, the operational business model has to become real, based on strategic collaboration, provided either by the LF staff or by external strategic partner (e.g., a competence centre, agency or consultancy), following a specific agenda: *the individual customer journey*.

Transformational projects are proactive in the sense that there is a main target of introducing a systematic change at a specific partner, based upon interrelated steps of awareness building, engagement, measurement and strategic planning, project development and implementation. Most of these services are being provided according to the articulated or hidden (e.g., latent) needs. For this purpose, before using the core LF services, it is beneficial that a customer journey includes comprehensive regional business intelligence and insights, sophisticated customer audit (e.g., digital maturity) and also, a many-layered awareness campaign. Along the journey, the *LF services are identified not being the end of the collaboration*s but are linked deliberately to individual and complex consultancy, engineering and/or Research & Development & Innovation activities, in a form of a coupled strategic collaboration. Additionally, this journey

is definitely not linear, as the development process is gradually iterative, using learning factory training, testing and experimentation services repetitively during the collaboration.

LF centres have already implemented different types of long-term partnerships, e.g., with solution providers (service offering, infrastructure, R&D), and with customers (SMEs), e.g., having a long-term framework. Ensuring stability in partnerships and customer relations is already one of the main a success factors. The difference, comparing the traditional operations to transformational projects, is that *LFs may have more focus on strategic customer collaborations*: they are 6-12+ months long and implement several development phases instead of transactional services and a reactive value proposition. It is important to note, that this extended service offering – including before/after services and even onsite activities – shall be provided efficiently and in a sustainable way.

B. Learning factory activities and fields of transformation

It is important to emphasize, that the service model of the Learning Factories is essentially human-centric, and the main added value of the LF centres is building up trust, based on participation and experimentation, consequently, this model of intervention, both education and training (re-skilling, up-skilling) or SME development is Industry 5.0 compatible, naturally.

C. Industry 5.0: Evolutionary or Revolutionary?

Several LFs focus on basic principles and underlying elements of the corporate culture and operations in manufacturing, like lean management, and some of them initiated the concept of Lean 4.0 [4]. From this point of view, the forthcoming Industry 5.0 transformation rather seems as an evolutionary because of:

- the human-centric approach of the lean management [4],
- the worker's engagement in process development [5], and
- The participation of stakeholders as highlighted preliminary requirements of competitiveness [2].

This continuity is even stronger in the comparison of the human aspect of Industry 4.0 and Industry 5.0 models. Not only the worker's participation, but the level of involvement of further stakeholders is an indicator of an evolutionary – rather something new, even radical – change inside the human aspect. Industry 5.0 concepts have more stakeholders' contributions to create "truly individual", even personalised products and services, instead of "mass" customized ones [6]. Although the conceptual difference is transparent, no radical difference is emerging in reality as co-creation, customer involvement, personalised products, and cross-engineering, together with education, leadership, communication, empowerment and organisation that are

already part of the Industry 4.0 concept [5], under the premise, that Industry 4.0 mainly focuses on technology, instead of sustainability etc.

From the addressed key points in [3], three important aspects receive significantly more emphasis than in the classical key fields of Industry 4.0: circular economy, resilience and self-sustainability. From this point of view Industry 5.0 can be considered as a clear, additional revolution, however, probably the Industry 4.0 should be "over its end", moreover these three topics are only partly covered in Industry 4.0 [7].

Anyhow, independently of this deliberation the importance and involvement of Learning Factories is clear in both the Industry 4.0 and 5.0 approaches as well. It is particularly important to distinct micro-level business and aggregated-level economic transformations. For developing an efficient, impactful governmental intervention framework, the first and most important fact is that Industry 5.0 transformation is a major issue for the majority of SMEs, even with improved I4.0 maturity, because I5.0 projects are affecting partners and resources, so, the core value proposition, the relation with customers, cost and revenue structures, For a human-machine integration, e.g., a specific SME has to improve digital maturity, has to manage deep tech (AI) integration and competence development, develop new partnerships, implement changes in organisation.

The evaluation of the subject of systemic change is rather controversial, as the transformative shift of the focus from technology to the human, from business to the social is indeed a transformative perspective, but also continuity and additionality are highlighted in Industry 4.0 and 5.0 comparisons (e.g., lean management is essentially a human-centric concept). The issue is, that relatively few scientific paper available describing the level and scale of the predictable change in industrial and economy structures, impacts on the factors of production, cross-sectoral relations, capital/labour intensity, entrepreneurship and competition, (re-)locations of business. Consequently, the discussion on Industry 5.0 as revolution or evolution is incomplete for a comprehensive strategy at aggregated level, discussing strategic factors, scenarios and roadmaps, including the particular role of the stakeholders [8]. However, there is 6 major topics worth to be highlighted:

- The emergence of processes, transactions outside of the existing partnerships (circular material flow);
- Organisational changes and the composition of the workforce;
- The structure of key processes, direct and indirect areas;
- The value proposition (servitization));
- The role and type of key partners;
- The direct involvement of customers in the value creation.

These are key areas, so the main question is the prospective scale of the change.

Industry 4.0 has already employed all the technologies that are behind Industry 5.0 as enablers including artificial intelligence, as well. The advantages in different technologies, however, call for increased level of automation that cannot be handled without the utilisation of artificial intelligence. Optimisation of the different processes requires computational resources that are available only now with the newest technological solutions. The extent of this change in the different segments of society and economy, however, are so great that anything less than a "new revolution" would be considered an understatement. E.g., a fundamental change in the composition of the workforce (let's say, a 50% ratio of engineers in production plants), or in business partnerships (let's say a 40% ratio of transactions following the circular material flow) would create a disruptive transformation at aggregated level as well– hence, the *general impact, so, the complete transformation would be revolutionary*. Haas [7] defined this scenario as new development of Industry 4.0 based on advances in communication and connectivity which are marked by breakthroughs in emerging technologies in field such as robotics, artificial intelligence, nanotechnology, quantum computing, biotechnology, the Internet of Things, the Industrial Internet of Things, 3D printing and fully autonomous vehicles.

Likewise, to the above-described development of Industry 4.0 toward Industry 5.0, Society 5.0 has been defined in 2017 by the government of Japan as a new framework in the progress of society based on the utilisation of new advancements of technology. It can therefore enable the society and the industry (the "people" and the intelligent "machines" and systems) to create fundamentally new solutions in practice.

Keidanren (the Japan Business Federation) has stated in their publication "Toward Realization of the New Economy and Society" in 2016 [9] that the new age – which has leading-edge technologies as its foundation – is not necessarily on the extension of the current line of progress. Logically, the fundamental changes in Society mean also important changes in economy therefore current research is conducted on the creation of digital architectures under Society 5.0 [10]. Consequently, Society 5.0 defines a social agenda based on advancement of technology whereas the European Commission defined a new policy agenda in 2019 by Industry 5.0 that is based on value networks with social and environmental implications.

D. Learning Factory as a Systematic Approach to Industry 5.0

The customer journey in the Industry 5.0 viewpoint, because of sustainability and resilience, may include a different – a systematic, complex and cross-disciplinary –

maturity assessment of the SMEs, operation and strategy as well, with new dimensions and aspects, comparing to the existing I4.0 assessment tools. At this moment, there are several expert made I5.0 assessment framework available, but typically in a not standardized form. However, they are coherent enough for assessment and conceptualisation, and for comparative evaluation, e.g., benchmarking of KPIs, and in the future, they are appropriate for supporting in-depth transformations [11]. Learning Factories have to do maturity assessment as part of the core services and as part of a customer journey. In addition to maturity assessment, new dimensions of the Industry 5.0 influence the need for necessary expertise e.g., resource-efficiency and ecological challenges, trustworthiness and ethical design, data security, emerging dependencies, robust supply chains and sustainable value "networks", circular material streams and supporting critical infrastructure [11]. There is also an increasing requirement on further soft skills and competencies, like developing cross-sectoral collaborations, stakeholder integration and a comprehensive business intelligence [12]. There is an increasing need for the related ecosystem building, either as part of the partnership and of the individual LF organisation, or as a digital innovation hub, or as a Mittlestand competence centre.

In order to support ambitious I5.0 SME transformation, impacting the main elements of the operational and business model, a more complex consultancy and engineering support hast to be offered as part of the core service portfolio. Before, along and after the usage of the traditional learning factories can't be demonstrated and developed as discrete solution only. Consequently, the micro-level corresponds with the macro-level in the sense that Industry 5.0 is about shifting "the focus from individual technologies to a systematic approach" [13].

E. Transformational elements for Learning Factories

There are major transformational elements in I4.0 and I5.0 comparison, first of all, to articulate societal goals beyond jobs and growth, the well-being of workers, and to be value-driven. The Industry 5.0 present some unique challenges that are not seen in the past [14], such as social heterogeneity; measurement of environmental and social value generation; integration from customers across entire value chains; interdisciplinarity of research disciplines and system complexity and ecosystem-oriented innovation policy. In particular, the human-centred approach also brings to the forefront those services, which are supporting SME transformation. The first and most important element is a possible need for a comprehensive maturity assessment, strategy and organisational development. One of the main topics and solutions of this type is human-robot collaboration and collaborative workplace (with sub-topics of safety, ergonomics, reskilling and upskilling, but also business and operations management) [15]. Even particular applications, like Production Planning and

Control (PPC) systems with I5.0 focus may have such a cumulated implications , which impacts the fundaments of the operational model [16]. In order to develop personalised working conditions, adjustable autonomy, mutual learning, etc. are needed for "socio-technical system" based on "joint cognitive systems" [17].

IV. WORKING STRUCTURE OF LEARNING FACTORY WITH FOCUS ON INDUSTRY 5.0

Learning Factory – as a concept - is fully in line with the above-described major trends, creating an integrated, realistic learning environment, combining didactics, layout and processes with testing and experimentation opportunities. The learning factory can therefore be defined as an experiential learning environment that contains up-to-date manufacturing infrastructure [18]. The comprehensive set of expectations for the learning factory were defined through the identification of the key target groups and their objectives. Three main pillars were described which are strongly interrelated: "A": Regional and market connections, "B": implementation and operation of the physical and virtual Learning Factory and "C": development and delivery of customised Learning Factory services. The complete structure of the planned Learning Factory broken down into realizable 10 Work Packages (WPs) is described as "Operational Structure for an Industry 4.0 oriented Learning Factory" in [19]. The planned learning factory operates as pilot project within an integrated business model (in a set of business models) to achieve its objectives. The physical and virtual infrastructure and services provide both the framework for awareness raising, engagement and systematic competence development; the testing environment for effective iteration; and the structural conditions for experimentation. The Learning Factory has set out mutually reinforcing industrial objectives in four areas:

- Entrepreneurship development, strengthening technological and business competences;
- Developing and testing AI-based technologies and services;
- Demonstration and testing of the application and implementation of AI-based technologies and services;
- Rapid and effective implementation and application of the results of international, in particular European, initiatives.

In synergy with the technology areas described in the previous section, it is a fundamental challenge that the learning factory should be supported by the national policies for SME development and industrial modernisation.

However, the actual Learning Factories have to satisfy the needs of Industry 5.0, so, this concept had to be extended as described in the next paragraph.

A. *The impact of Industry 5.0 topics on the existing Learning Factory functionality*

At first, in the extension, the impacts of the Industry 5.0 were identified individually for each already existing WPs as shown in Table 1.

Table 2. The effect of Industry 5.0 on the Learning Factory (functioning)

Work Package of the original concept	Industry 5.0 impact on the existing Work Package
WP1: Facility and project management	• Highlighting Industry 5.0 aspects in the brand name
WP2: Regional market intelligence	• Extended scope of Industry 5.0 of the market intelligence • Extended scope of Industry 5.0 of the technology scouting • Composition of the highlighted use-cases – extension to comprehensive value-network
WP3: Shop Floor Production System (SFPS)	• Industry 5.0 ready shop floor building (e.g. human – machine integration, disassembly, circular aspects)
WP4: Demo showroom	• Composition of the promoted solutions & use cases – presentation of Industry 5.0 demos as well
WP5: Manufacturing as a service (MaaS)	• Composition of specific services based on circular principles
WP6: Virtual (cloud) production services	• Explicit IoT support for the WP11 activity (Collaborative developments, integrated Industry 5.0 projects) • Manifold access to virtual production services for the complete value network (horizontal integration)
WP7: Value added services	• Composition of expert pool – Industry 5.0 know-how has to be also covered by some experts • Composition of the SME consulting – Industry 5.0-related services are also available • Maturity assessment for Industry 4.0 and Industry 5.0 as well
WP8: Collaborative innovation	• R&D&I and pilot projects in the Industry 5.0 field as well • Incubation of Industry 5.0-oriented start-ups, too
WP9: PilotFactory Partnership Network	• Composition of Industry 4.0 and also Industry 5.0 competence centres as prospective partners
WP10: Future Business Model	• More diverse opportunities in developing the specific business models

Extension: WP11: Value-Network Journey: Dedicated support for the value-network journey

B. *The need for developing a novel WP11: Value Network Journey (roadmap)*

The main purpose of the implementation of this novel work packages is to accelerate the transformation of existing partnerships along the new, emerging value chains – value networks – by offering multiple services and collaboration opportunities for a consortium of interlinked customers (Fig. 1.). As one of the major impacts of the industry 5.0 transformation is disrupting traditional supply-chains, improved services may target new potential strategic partnerships in the areas of, e.g.:

• Material flow and product cycle (circularity, resilience);
• Knowledge sharing and competence development (human-centric);
• Co-engineering of products, production and processes (resilience);
• In-depth integration of final customers into the value creation (circularity, human-centric).

In order to understand the need for new activities under this WP, it is worth highlighting that the proposed customer journey and some WPs – especially WP6-8, i.e., the virtual services, value added services, collaborative innovation, already offer a proper base for mapping and in-depth understanding of transformative opportunities and possible collaborations for transformative projects. Hence, the main added value of this new WP shall be explicitly the creation the development of industrial level lighthouse projects based on a "strategy roadmap" and new type of "stakeholder integration". This new integrated approach is in accordance with the prospective transformation of markets and industries (i.e., sustainable value networks); also, it creates a direct link to the European regional smart specialization policies and intervention framework as well. The Value Network Journey (VNJ) is an extended version of the Customer Journey (CJ). CJ manages a customer of the LF over pre-planned improvement steps and handles all the aspects of this journey. The key difference is to manage a Value Network (VN) but (not only) a Customer. Values Network is a set of stakeholders (companies, public institutions etc.) connected directly to the value creation steps of the original customer of the LF. Consequently, instead of managing of a customer, the VNJ means the management the customer plus all the relevant stakeholders involved in the value creation process of the selected customer, so, the assignment is much more

difficult, instead of managing a company, a set of "companies" have to be managed by the LF. As result, thanks to the VNJ a much stronger effect can be reached by the I4.0 or I5.0 developments and has significantly smaller risk around these improvements. On the other hand, the management of a (company) network is a much

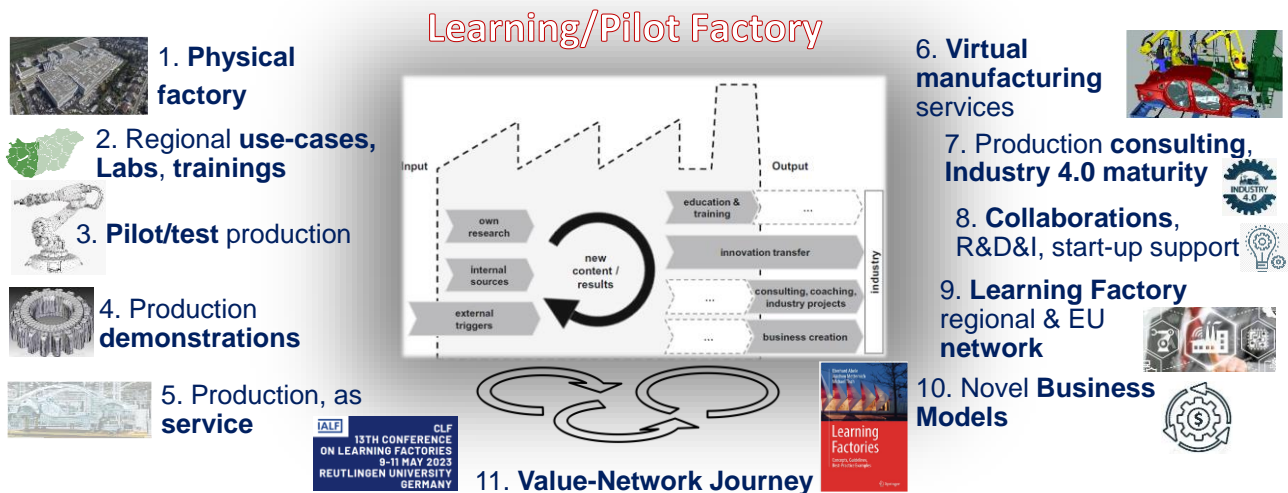more difficult challenge that shall be solved by the modern Learning Factories.

Fig. 1. Main, extended Work Packages of the developed Learning Factory concept [19].

V. CONCLUSIONS AND OUTLOOK

Rather than representing a technological leap forward, Industry 5.0 actually nests the Industry 4.0 approach in a broader context, providing regenerative purpose and directionality to the technological transformation of industrial production for people-planet-prosperity. Consequently, Industry 5.0 can be considered as the new engine of the economic and societal transition with a societal concept which can mean more distributed well-being with human-centric and sustainable, resilient industry.

The paper analyses the differences and relations between the Industry 4.0 and 5.0 approach, especially considering the customer journey, the transformative elements, the approaches and it concludes that Industry 5.0 is a real novel revolution not (only) an extension or improvement of Industry 4.0.

In the second part of the paper, the previously appointed relation elements between Industry 4.0 and 5.0 are applied in the derivation how to extend a previously defined, Industry 4.0 oriented working structure (in [19], having 10 Work Packages (WPs)) of a Learning Factory (LF) to establish a LF that fits to both of the Industry 4.0 and 5.0 trends as well. At first, the effects of Industry 5.0 on the already given Learning Factory Work Packages were identified, and second, the paper concludes that the importance of the Value Network Journey is so high that an additional, novel Work Package (WP11) was defined. The paper also highlighted the transformation of the

Industry 4.0 oriented Customer Journey into the Industry 5.0 (and 4.0, too) oriented Value Network Journey. Value Network covers not only a customer of the LF but also its closely connected partners and shareholders as well, consequently, the Industry 4.0 & 5.0 directed Learning Factory has to manage in its transformations this significantly more complex structure of the Customer Value Network. As result, beyond the tight connection between the Learning Factory and its Customer, the LF (in collaboration with its customers) has to establish and manage also the connected stakeholders of the customers as well, this extension was not expressed in such direct way in case of I4.0 oriented LFs.

The future research directions are to break down this novel activity into concrete LF actions and to define an easy to handle, more formal characterisation which members of a customer's value networks have to be managed by a Learning Factory.

VI. ACKNOWLEDGMENTS

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