13th Conference on Learning Factories, CLF 2023

Upskilling SME workforce by Learning Factories

Tamás Gyulai [a,b], Zsolt János Viharos [c,d,*], Ferenc Kása [e], Péter Wolf [e,f]

[a] *IQ Kecskemét Industrial Research Ltd., Izsáki u. 8/d., Kecskemét H6000, Hungary*
[b] *Pannon Business Network Association, Zanati út 32-36., Szombathely H9700, Hungary*
[c] *Institute for Computer Science and Control (SZTAKI), Centre of Excellence in Production Informatics and Control (EPIC), Centre of Excellence of the Hungarian Academy of Sciences (MTA), Eötvös Loránd Research Network (ELKH), Kende u. 13-17., Budapest H1111, Hungary*
[d] *John von Neumann University, Izsáki u. 10., Kecskemét H6000, Hungary*
[e] *Neumann Nonprofit Ltd., Naphegy tér 8., Budapest H1016, Hungary*
[f] *Local Government of Pest County, Városház u. 7, Budapest H1052,, Hungary*

Abstract

The green and digital transition is particularly challenging to Small and Medium-sized Enterprises (SMEs); therefore, companies need to quickly adapt to current challenges at all levels. In the past few years, Learning Factories (LFs) as close-to-industry environments for education and research have proven to be an effective concept in addressing these challenges. LFs for education, training and research have been established by industry and academia as epical case studies e.g., all over Europe and therefore policies should initiate actions that support digitalisation and uptake of Artificial Intelligence (AI) by LF. This paper highlights the role of learning factories in this process by analysing AI strategies and programmes. The research investigated the role of LF in AI strategies, the type of LF functions and their possible synergies with other initiatives. The paper also describes the recently developed LF business concept that is in strong synergy with the national AI strategies and also with the relevant European policies.

Peer Review statement: Peer-review under responsibility of the scientific committee of the 13th Conference on Learning Factories 2023.

Keywords: Learning Factory; Artificial Intelligence strategy; Green and digital tranformation; Extended LF business concept

1. Introduction

The recent global pandemic drove demand for automation which is more and more based on advanced technologies, such as cloud computing services, big data and Artificial Intelligence (AI) therefore solid computing capabilities and sophisticated software algorithms can be coupled with creative business and organisation models. *As new „smart services" increase innovation in business and society, this trend accelerates as high-value, data-driven, science-based service innovation with increasing productivity and quality.*

The European Commission and EU Member States, together with industry and other stakeholders, prioritise strong industry involvement and commitment as well as scalable sectoral ecosystem training solutions [1]. It is recommended that industry-led multi-stakeholder partnerships should develop "just enough, just in time, just for me" training formats, meeting the requirements of modern workflows and adapting to the respective target groups. Data-driven, science-based service innovations are key to success because further research based on big data and artificial intelligence has huge potential for achieving this goal. This is also supported by a recent study by LinkedIn [2], where *it is highlighted that required skills include a mix of hard skills and soft skills*. Demand is increasing for highly technical software, AI and robotics talents with a background in computer science or engineering to research, design, develop, test, launch, and maintain these highly sophisticated service system platforms. Another example for upskilling of the workforce is described in the White Paper: "*Succeeding Through Service Innovation: A Framework for Progress"* [3] which has been developed by Cambridge University Service Alliance and IBM

* Corresponding author. Tel.: +36-1-279-6245
E-mail address: viharos.zsolt@sztaki.hu

together. It calls key stakeholders to action for advanced service innovation, creates Service Innovation Roadmaps and doubles service research and development investments.

The paper is intended as a contribution to the line of research on Learning Factories (LF) to investigate the role of LF in AI strategies and service development, the type of LF functions and their possible synergies with others e.g., European initiatives. Analysis of AI strategies and programmes is also given, together with the recently developed LF business concept that is in strong synergy with the relevant European and Hungarian policies.

AI strategy relation to LF is presented in the next paragraph, followed by the illustration of LFs for AI upskilling and by training functions for AI. The next paragraph describes the required training function for AI that is included in the subsequently introduced Hungarian LF initiative as a concrete definition use case. Summary with outlook, acknowledgement and references close the paper.

2. AI strategies in relation to LFs

In the Commission Work Programme 2022 [4], e.g., the EC outlined the next steps towards realising a more digital economy that will digitally transform the EU by 2030. As a part of the effort to digitise European industries and Small and Medium-sized Enterprises (SMEs), the European Commission has also launched several initiatives focusing on innovation and the use of enabling technologies, such as AI. Some AI-specific and related initiatives include ADRA (AI, Data and Robotics Association) which is a partnership focusing on driving acceptance and uptake of AI, Data and Robotics [5]. In December 2018, the EC also published its Coordinated Action Plan on AI, which presented its strategy on AI with a focus on increasing investment, making more data available, fostering talents, and ensuring trust [6]. This strategy was then revised in 2021 [7].

Learning Factories (LFs) play a central role to form the bridge among training (as Training Factory); research & technology development that is called typically as test before investment (as Research LAB) and pre-production validation (as Pilot Factory). They incorporate many "technology enables", one of these key enablers is Artificial Intelligence (AI), which giant trend influences all humankind areas. For having a structured overview and control on AI activities, states typically formed their AI Strategies in recent years which are summarized and presented by the Organization for Economic Cooperation and Development (EOCD) through their collection site called "Policies, data and analysis for trustworthy artificial intelligence" [8]. Most of the strategies offer a comprehensive and complex framework for a set of interventions and targeted areas, like dissemination, R&D, technology transfer and collaboration, metrics and measurement, regulations, etc. In the absence of a relevant learning factory (or equivalents), however, there may be critical elements missing, or not elaborated in the macro-level strategy. Although LF is a demonstration space for digital and enabler technologies, the core of its value proposition is holistic: to integrate the customer journey (SME transformation, industry projects), the innovation value chain (R&D and innovation transfer), and training (upskilling, reskilling) – based on experimentation. It is crucial to understand how the collaborative models of the learning factories may support to have greater transparency and trust - reducing the information gap and replacing traditional standards and certifications. AI also challenges core, fundamental topics of manufacturing like lean management, corporate culture, didactics to be used and processes to be maintained. AI strategies also describe how an enabler technology may trigger a human-centric operation (Industry 5.0), or circular operations (material flows), also heavily impacting the highlighted topics and targets of the LF centres – and the necessary resources, partnerships, services, etc.

A series of pioneering LFs were explored mainly with the focus on which year they were founded, the key question was whether pioneering LFs supported the formulation of the related parts of the countries' AI strategies, or the AI strategies appointed the LF initiatives, more generally, the relation between LFs and national AI strategies were analysed. 41 LFs were reviewed, and slightly more than half of them are detailed in the basic book of LFs by Abele et al. [9], information about the remaining LFs was collected through publications and internet searches.

The AI strategies of those countries were reviewed in which also at least one already available, published Learning Factory exits (plus Hungary), with a special emphasis on when these AI strategies were released. Finally, AI strategies of 14 countries were considered (Austria, Bosnia and Herzegovina, Canada, China, Croatia, Germany, Hungary, Italy, Luxemburg, Malaysia, Romania, Singapore, South Africa, United States of America), the Fig. 1. represents the number of LFs' initiation by years and the number of AI strategy releases by years. It shows that after some pioneering factories in the 2000s, a ramp-up of LFs happened after 2010, while after 2017 the first AI strategies were also released. *It serves with the conclusion that AI strategies "only" follow the LFs trends*, even if some of these strategies are over their first revision/revitalization stage.

The ratio of these three, main functionalities is shown in Fig. 2. *The Pilot Factory aspect is the most dominant one*, *the Learning LAB activities* (research & development) *are less dominant*, while *the Training Factory function receives more and more emphasis*. Special consequences can be drawn when analysing these functionalities over the years: the Pilot Factory, so, the "Test before invest" is continuously ensured by the LFs with some increase of this activity ratio, the research & development activities (called Learning LAB) significantly fluctuate, while in the recent years, the training functionalities receive more and more emphasis among the activities of the LFs.

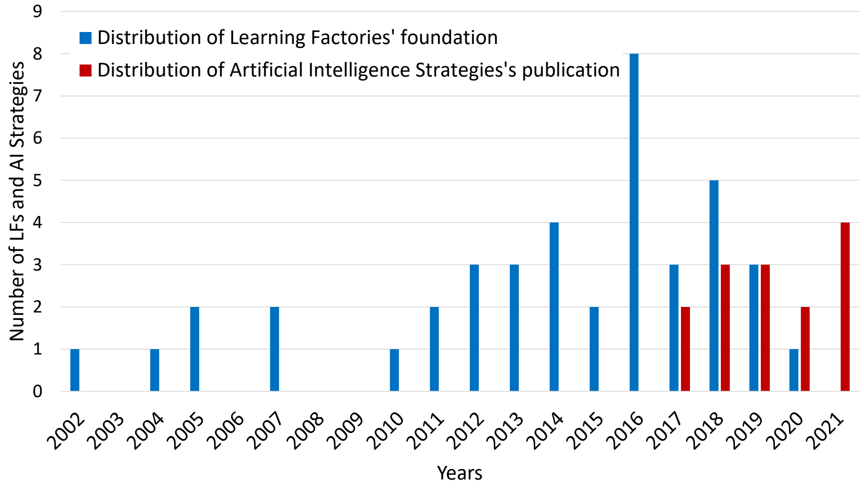

Fig. 1. Number of LF their foundations (blue) and AI strategy releases (burgundy) by years. It shows that AI strategy formulation "only" follows the LF initiative.

It has to be mentioned that in some cases, stakeholders communicate a "simple" Learning LAB as a Learning Factory, without the significant ratio of the Pilot-, and Training Factory functionalities, however, the authors do not consider such cases as a real LF, especially, because the increasing Training Factory direction is also in line with the recently increasing Industry 5.0 trend and the Pilot Factory functionality is also a basic component.

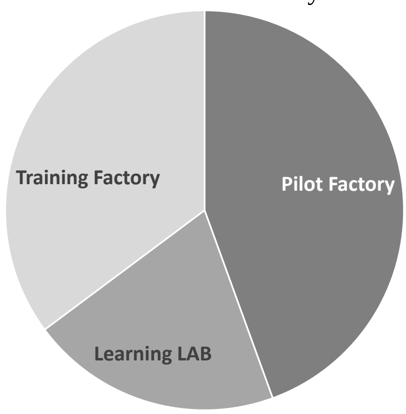

Fig. 2. Distribution of the three main LF functions: the Pilot Factory aspect is the most dominant one, the Learning LAB activities (so, the research & development) are less dominant, while in recent years the Training Factory function receives more and more emphasis.

On the other side, the AI strategies were also reviewed according to their manufacturing and other related LF considerations. *More than 70% of the AI analysed strategies appointed manufacturing as one of the key, highlighted exploitation (and party as initiator) sectors (it is missing only for Luxemburg, Croatia, Bosnia and Herzegovina and Canada)*, so, the connection of manufacturing and AI is a clear, key direction for the future. Even if the AI strategies arose much later than the LF foundations and manufacturing receives special attention, *much less than 30% of the AI strategies mention the need for LF factories (or similar foundations as already appointed by USA, China, Singapore, and Hungary)*, however, *around half of them appoint the necessity to establish pilot production projects*. *Consequently, the inclusion of LF is a need for a modern enough national AI strategy*.

3. Learning Factories for AI upskilling

The activities that shall be implemented within *the Learning Factory as model action for AI upskilling can be summarised in three action lines*. *The educational action line* covers entrepreneurship development by strengthening technological and business competencies. It includes matchmaking, coordination, business intelligence, technology scouting, insights, demonstration of use cases, training, experimentation and testing, access to experts, and demonstration of technologies and solutions. *The experimental action line* focuses on the development, test and demonstration of the application and implementation of AI-based technologies and services with Industry 4.0 objectives. It includes Manufacturing as a Service (flexible access to critical infrastructure and manufacturing capacities), virtual services (AI and DATA based new services with critical importance), high value-added services (access to expertise, maturity assessment, certification, quality assurance) and R&D&I activities (accelerated and collaborative innovation (proof of concept, prototype, and feasibility of pilot lines). *The exploitation action line* complements the service portfolio with rapid and effective implementation and application of the results from international, in particular, European, initiatives. It will create a partnership network that fosters more outreach, and more use cases as well as provides opportunities for future business models.

The action lines for education, experimentation and exploitation shall make together the complex contribution of the learning factory for industrial development with a strong SME focus, therefore, the *upskilling for AI can produce tangible outputs by the learning factory*. *The objective of the Hungarian LF* is the dissemination toward 2500 SMEs (as a minimum result) during the 3 years of the implementation period. Knowledge sharing and competence development shall reach at least 250 SMEs by, primarily, consultancy actions and this will contribute to transformative projects as twin transition pilots for 25 SMEs. In addition, R&D projects shall also be developed (with a minimum of 10 SMEs), enabling the learning factory to act as the core of a national network of test and demonstration centres.

The results shall be especially relevant on a sectorial level because the learning factories shall contribute to more efficient regional ecosystems by enhanced transparency in standards, certifications, digital maturity (Industry 4.0) and accelerated modernisation and restructuring (Industry 5.0). New services and business models can be developed for business incubation services for AI utilisation which can also lead to new markets within cross-sectoral value chains (like the circular economy) and horizontal integration (supply chains).

The learning factories shall benefit developers and solution providers with a geographical focus on selected target regions. Apart from access to the market by accelerated entry and scale-up, the learning factory shall explore new ideas and services by proof of concepts for feasibility by system integration and collaborations with validated solutions and product market fit. It will increase the usability of service concepts and business models by simultaneous engineering through shared resources and more collaboration.

The final beneficiaries of the learning factories are the customers (SMEs) who experience more trust (in ROI and feasibility) and realise transparent and customizable customer journeys. Test before invest concept will offer them a secure but realistic environment without interrupting their processes. Their competence development shall follow the “just for me, just in time, just enough” concept. It shall lead to higher productivity through accelerated digital transformation, bringing new business partnerships and collaborations.

3.1. The relation of AI to EDIH

One of the initiatives of the European Commission aimed at fostering the development and adoption of enabling technologies on a regional level is the Digital Innovation Hubs (DIH). These DIHs were introduced as a crucial pillar of the Digitising European Industry (DEI) initiative [10] which also supports the uptake of AI in Europe but from a regional dimension. *DIHs can act as brokers between user companies and technology suppliers and offer support with testing and experimentation with advanced technologies on different market segments but focused on a regional level [11]. The concept of ‘E-DIH’ is not just for demonstrating the capabilities of technologies, like AI and further ‘deep’ technologies and Industry 4.0 in general, but to have experience with them as well [12]*. Recently, the DIH service categorisation has been applied to DIHs focusing on AI [13].

4. LF with training functions for AI

To keep up with the needs of today's industry, learning and training processes in the field of industrial production need to be developed and updated using digital tools. Thus, *in recent years, new learning technologies are applied more and more frequently in education [14] and the concept of LF can meet the current requirements of learning and training*. Over the last 10 years more and more learning factories evolved around the whole world and especially in Europe and these existing learning factories have taken many different forms. They vary in size, topics, products and other factors [15]. *A common aim of almost all of these facilities is the hands-on qualification of the participants*.

The Learning Factory is most often referred to in the literature as an educational, competence development environment. The descriptions, therefore, focus on the didactics of the training and experiential learning opportunities, including the horizontal themes of industrial culture (Industry 4.0, lean management, circular economy) and the main technical and professional competencies that can be acquired here. A distinctive feature is that *it offers the opportunity to gain experience in a closely realistic or explicitly realistic manufacturing environment. This is the first, training pillar*.

The descriptions of *LFs show that the promoters are also taking advantage of the research opportunity. This is the second pillar*. The Learning Factory provides an opportunity to test and develop R&D results in the area of excellence, across a broad spectrum of technological maturity levels. From the academic’s point of view, an LF centre is therefore not only a "teaching workshop", but also a research laboratory, demonstration, and testing environment. E.g., in the LF, an autonomous Unmanned Autonomous Vehicle (UAV) is carrying robot arm(s) that can perform various manufacturing tasks, e.g., they can bring a cutting tool, fixture or workpiece from the warehouse, autonomously bring it to the machine and change the tool-fixture-workpiece triad on the machine, as result, highly automated machining can be realised.

However, a significant part of the Learning Factories is also open to external partners for experimental experience, i.e., they host technologies, systems, and IT solutions. Support for specific engineering and IT projects for companies and SMEs can be adapted to the activity along customer pathways or complementary characteristics. In the LF centres model, *this is the third pillar alongside training and R&D for the implementation of customised projects through pilot testing and experimentation*. E.g., the LF act also as a manufacturing data lake that collects and shares various collected manufacturing data from and among its partners.

The quantitative analysis of the examined LF centres has concluded that the LF training function has already reached an important share, therefore, *the role of LF services in upskilling SMEs can be an important contribution to the national AI strategies, as well* (see Fig. 2 for details). E.g., the LF serves the manufacturing companies with a measurement and data collection package that incorporates various (type and number of) sensors, cables, data processing and storage tools which can be applied by the companies in their own facilities. They can apply it for a certain period and can learn how to exploit this sensing environment before investing in their own dataflow.

Since the beginning, most of the LF centres have been described as discreet, standalone services for dedicated clients and goals: training and collaboration. LF services have always highlighted the importance to collaborate with manufacturing SMEs, as one of the major target groups in training and competence development. Especially mid-cap organisations, large enough to have complex systems and processes, but without existing, corporate-level, in-house solutions for that purpose. However, *not many details are available about what is (should be) happening with the clients before and after the collaborations*; or who might be the strategic partners of the LF centres to reach them, and to exploit and scale up new opportunities, after the collaboration. Consequently, it is one of the targets of further research by the authors.

5. Use case description

The "AI & Industry 4.0" working group of the Hungarian National AI Coalition has defined the LF concept which formed the core of the project documentation for LF implementation in Hungary during the period 2021-2022. The comprehensive set of LFs' expectations is defined through the identification of the key target groups and their objectives together with the three main related *pillars of "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*. A detailed description of the developed business model was presented by the authors in Gyulai et al. [16]. Learning Factory (LF) – as a concept - is fully in line with this major trend, creating an integrated, realistic learning environment, combining didactics, layout and processes with testing and experimentation opportunities. An LF can be defined as an experiential learning environment that contains up-to-date manufacturing infrastructure [17].

The Learning Factory operates 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:

1. Entrepreneurship development, strengthening technological and business competencies.
2. Developing and testing AI-based, Industry 4.0 technologies and services.
3. Demonstration and testing of the application and implementation of AI-based, Industry 4.0 technologies and services.
4. Rapid and effective implementation and application of the results of international, in particular, European, initiatives.

A fundamental challenge is that the LF concept should be an intervention that is integrated with the national AI Strategy and its objectives of SME development and industrial modernisation. It is equally important that I4.0 impacted manufacturing education and training in several and multiple ways, at the level of content, context, places, and frequency as well. Therefore, the following statements were given:

- The future of manufacturing has to be more human-centric, with the scope on workforce transformation ergonomically, and psychologically (empowerment, acceptance) [18].
- Supporting manufacturing SMEs should be a priority.
- It is required, to continuously explore and adapt quickly to new technical (STEM, AI), to soft or transversal and to sectoral competencies.
- "Upskilling" and "reskilling" need to be standard-based and translated into new job profiles.
- Didactics have to be based on smaller (modular) quantities with high-frequency learning situations, using a

flexible – "just-enough, just-for-me, just-in-time" – training approach [1].

6. Summary and outlook

The paper describes the developed concept of a learning factory for upskilling for AI, which is become part of the strategic initiative of the Hungarian National AI Coalition. The learning factory addresses training on AI through practical tasks including e.g. additive manufacturing, human-robot collaboration and digital twins. LF participants should not just get to know technologies, but they should learn how to choose the right technologies and how to implement AI applications in their own workspaces and factories. To support this process, the learning factory also includes a demonstration centre where equipment from successful industrial application projects can be shown. Since the concept of the authors is still in the implementation phase, the planned monitoring of learning success by defining measurable goals for projects after the training is of high interest. It will be seen if the described approach of coaching and pilot projects will work, therefore, it will be experienced which special topics are taken on by trainees at the highest priority because it is planned to introduce special topics for AI, particularly in smart manufacturing. Additionally, the extension of the learning factory is to be realized by the creation of a national network of pilot factories, research laboratories and training centres as natural virtual extensions of the initiated learning factory.

Acknowledgements

The research in this paper was supported by the European Commission through the H2020 project EPIC (https://www.centre-epic.eu/) under grant No. 739592, by the Hungarian ED_18-2-2018-0006 grant on a "Research on prime exploitation of the potential provided by the industrial digitalisation" and by the Doctoral Student Scholarship Program of the Co-operative Doctoral Program of the Ministry of Innovation and Technology of Hungary financed from the National Research, Development and Innovation Fund.

References

[1] C. Schulz, W. Korte, Y. Moghaddam et al., Skills for industry: upskilling and reskilling in the post-covid era: fostering new services and jobs creation: three scenarios for 2030: final report, European Commission, Executive Agency for Small and Medium-sized Enterprises, Publications Office (2021) https://data.europa.eu/doi/10.2826/59135

[2] LinkedIn study, https://learning.linkedin.com/blog/top-skills/the-skills-companies-need-most-in-2019--and-how-to-learn-them

[3] The University of Cambridge and IBM: Succeeding through service innovation – A perspective for education, research, business and government (White Paper) (2010) https://www.ifm.eng.cam.ac.uk/uploads/Resources/Reports/080428cambridge_ssme_whitepaper.pdf

[4] Commission Work Programme 2022 (COM(2021) 645 final), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0645

[5] Draft proposal for a European Partnership under Horizon Europe AI, Data and Robotics (2020) https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/ec_rtd_he-partnerships-artificialintelligence-data-robotics.pdf

[6] Coordinated Plan on Artificial Intelligence (COM(2018) 795 final) https://knowledge4policy.ec.europa.eu/publication/coordinated-plan-artificial-intelligence-com2018-795-final_en

[7] Communication on Fostering a European approach to Artificial Intelligence (2021) https://digitalstrategy.ec.europa.eu/en/library/communication-fostering-european-approach-artificial-intelligence

[8] OECD, Policies, data and analysis for trustworthy intelligence (2022) https://oecd.ai/

[9] E. Abele, J. Metternich, M. Tisch, Learning Factories Concepts, Guidelines, Best-Practice Examples, Springer Nature Switzerland AG (2019) ISBN 978-3-319-92260-7

[10] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Digitising European Industry, Reaping the full benefits of a Digital Single Market. COM (2016) 180 final,

[11] European Commission, Digital Innovation Hubs as policy instruments to boost digitalisation of SMEs, JRC 121604 (2020) https://publications.jrc.ec.europa.eu/repository/handle/JRC121604

[12] Horizon 2020 - LEIT - Work Programme 2018-2020, Information and Communication Technologies https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-leit-ict_en.pdf

[13] AI-DIH-Network, Blueprint for cross-border collaboration among DIHs https://d1dxeoyimx6ufk.cloudfront.net/uploads/NA5/OD8012/F445A87B.pdf

[14] T. Riemann, A. Kreß, L. Roth, S. Klipfel, J. Metternich, P. Grell, Agile implementation of virtual reality in learning factories Procedia Manufacturing 45 (2020) 1-6 https://doi.org/10.1016/j.promfg. 2020.04.029

[15] U. Wagner, T. AlGeddawy, H. ElMaraghy, E. Müller, The State-of-the-Art and Prospects of Learning Factories, Procedia CIRP (2012) 3:109- 114.

[16] T. Gyulai, P. Wolf, F. Kása, Z. J. Viharos, Operational Structure for an Industry 4.0 oriented Learning Factory, The 18th IMEKO TC10 Conference "Measurement for Diagnostics, Optimisation and Control to Support Sustainability and Resilience", Warsaw, Poland, September 26–27., (2022), pp. 83-89.

[17] E. Abele, G. Chryssolouris, W. Sihn, J. Metternich, H. ElMaraghy, G. Seliger, G. Sivard, W. ElMaraghy, V. Hummel, M. Tisch, S. Seifermann, Learning factories for future-oriented research and education in manufacturing, CIRP Annals, 66, (2017) 803-826

[18] MWI - Federal Ministry of Economic Affairs and Energy, Germany, Case study on the Mittlestand 4.0 Competence Centres, Germany "Case study contribution to the OECD TIP Digital and Open Innovation Project" (2019)