Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 32 (2015) 132 – 137
www.elsevier.com/locate/procedia

The 5th Conference on Learning Factories 2015

Lean Learning Factory at FESB – University of Split

Ivica Veza[a]*, Nikola Gjeldum[a], Marko Mladineo[a]

[a]*University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, R. Boskovica 32 - 21000 Split, Croatia*

* Corresponding author. Tel.: +385-21-305-933; fax: +385-21-305-776. *E-mail address:* iveza@fesb.hr

Abstract

Globalization has created new enormous challenges for today's enterprises. The challenge is to succeed in a turbulent business environment where all competitors have similar opportunities, and where customer wants personalized product. The success can be initiated by a continuous cooperation among economies, research institutions and regional administration that goes beyond conventional limits. On the other hand, employees and its competences play a strong role in enterprises survival. Therefore, improving an education approaches for students as a future employees and utilizing Life Long Learning (LLL) for current employee increases analytical and theoretical knowledge of design, manufacturing, business realities, and professional skills.

The Learning Factory's mission is to integrate those needed knowledge into the engineering curriculum. Therefore, Lean Learning Factory at FESB (University of Split) is in continuous developing process to support practice-based engineering curriculum with possibility of learning necessary tools and methods, using real life and didactical equipment.

In this research a concept of Triple helix model connected via Learning Factory concept is presented. Learning Factory could be place where University, Industry and Government meet each other, share needs and expectations, and work on collaborative projects. It could be a solution of a missing link in Triple helix model.

Lean Learning Factory at FESB, based on a didactical concept emphasizing experimental and problem-based learning using tools and methods from Lean management, have true potential to play important rule in regional development of Split-Dalmatian County and its industrial enterprises.

Peer-review under responsibility of the organizing committee of 5th Conference on Learning Factories (CLF 2015)

Keywords: Learning Factory; Lean Management; Triple helix model

1. Introduction

Today, globalization has created new enormous challenges for enterprises [1]: fierce competition, short windows of market opportunity, frequent product introductions, and rapid changes in product demand. Many manufacturing enterprises have moved away from a mass production orientation to more agile production approaches. The challenge is to succeed in a turbulent business environment, and Traditional Flexible Manufacturing Systems are not able to fulfil those requirements. There is a need of new manufacturing systems, like the one presented by Koren in 1999 [1]: Reconfigurable Manufacturing System – RMS (Fig. 1).

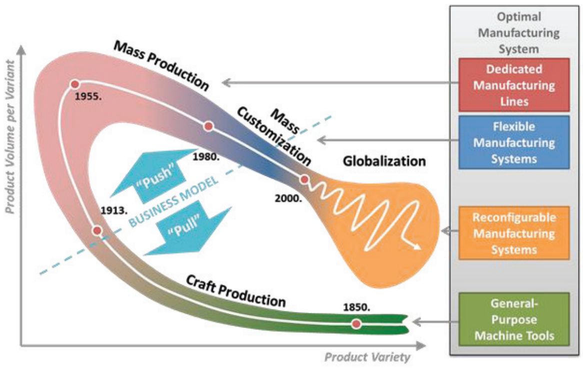

Fig. 1. Historical cycle of manufacturing paradigms [1].

Peer-review under responsibility of the organizing committee of 5th Conference on Learning Factories (CLF 2015)
doi:10.1016/j.procir.2015.02.223

Furthermore, the first three industrial revolutions came about as a result of mechanization, electricity and IT. Now, the introduction of the Internet of Things and Services into the manufacturing environment is ushering in a fourth industrial revolution: Industry 4.0 [2]. This new type of industry is based on Smart Factory model. The Smart Factory has a completely new approach to production: smart products are uniquely identifiable, may be located at all times and know their own history, current status and alternative routes to achieving their target state. Industry 4.0 requires implementation of following features into enterprise [2]: horizontal integration through value networks, end-to-end digital integration of engineering across the entire value chain, and vertical integration together with networked manufacturing systems. To implement these features, an enterprise must be Smart Enterprise, i.e. it must incorporate its machinery, warehousing systems and production facilities in the shape of Cyber-Physical System (smart machines, storage systems and production facilities capable of autonomously exchanging information, etc). The Cyber-Physical System of Smart Factory is crucial to support new business models for manufacturers called [3]: Manufacturing-as-a-Service, Industrial Product-Service Systems, or similar. The main features of Smart Enterprise can be summarized into the following:

- Smart personalized product – Requires flexibility and high level of ICT integration into manufacturing system. It can be realized through Reconfigurable Manufacturing System [1] or Industry 4.0 Smart Factory [2].
- Product and service provider – Ability to offer extended products: product and service integrated into single product for delivering value in use to the customer during the whole life cycle of a product; or to offer manufacturing as a service and become manufacturing service provider. It can be realized through specialized Internet portals and Cloud computing [4].
- High level of collaboration – Collaborative product development, collaborative manufacturing and all other value adding processes. It can be realized through vertical integration called Production Networks [5], or through horizontal integration called Manufacturing Networks.

These new requirements and conditions require a closer cooperation, not only at the global level, but at the regional levels as well. The success of a networked region is a result of a continuous cooperation among economies, research institutions and regional administration that goes beyond conventional limits. In this process the economy is concentrated on development of specific competitiveness factors (specialization of suppliers, education of work force, introduction of information network, providing of responsible management).

On the other hand, regional administration is responsible for ensuring a stronger institutional and administrative support to the economy, particularly when some decisions about investing in education and infrastructure have to be made, or when some internal regional problems have to be jointly solved. Triple helix model [6] is an empiric model that connects these three segments and which presupposes the transition of society towards knowledge (Fig. 2).

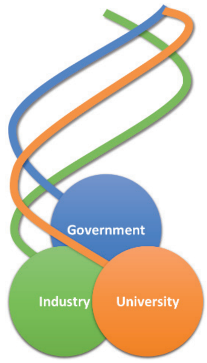

Fig. 2. Triple helix model University-Industry-Government [6].

In order to redefine the interrelationship between institutional knowledge, economy and regional administration (broadly speaking it can be Government), it is necessary to focus on enhancement of the local innovative development conditions by linking research activities with other innovative activities. In the first stage of regional economic development it is necessary to create a business environment and to encourage measures for concentration of innovative activities. Two other stages, consensus and innovations comprise ideas and strategies of multiple reciprocal relations between university, economy and regional administration. In these two stages there are some attempts to realize the strategies and the goals defined in the previous stage.

2. Learning Factory

The Learning Factory (LF) is the outcome of The Manufacturing Engineering Education Partnership (MEEP), which was formed in January of 1995 [7] as the result of a grant from the ARPA Technology Reinvestment Program in Manufacturing Engineering Education. MEEP consists of Penn State, The University of Puerto Rico - Mayagüez, the University of Washington, Sandia National Labs, and industrial affiliates. A total of 43 faculty participated either in program management, course design, Learning Factory development, or industrial advisory board coordination. The specific objectives were implementation of [7]:

- A practice-based engineering curriculum - which balances analytical and theoretical knowledge with manufacturing, design, business realities, and professional skills;
- Learning Factories at each partner institution - integrally coupled to the curriculum, for hands-on experience in design, manufacturing, and product realization;
- Strong collaboration with industry - through advisory boards and industry-sponsored capstone design projects;
- Dissemination - to other academic institutions, government and industry.

The Learning Factory's mission is to integrate design, manufacturing and business realities into the engineering curriculum. This is accomplished by providing balance between engineering science and engineering practice [8-9].

However, sometimes there is a missing link in Triple helix model – an institution or organization that would really establish a relationship between Government-Industry-University. In this paper, a Learning Factory is seen as a missing link in Triple helix model (Fig. 3). Through Learning Factory, using practice-based engineering curriculum and real life projects, a link between University and Industry can be established.

The relation between the academic environment and the political decision making is similar to the separation between politics and science [10]. It is indeed difficult to create a framework in which synergy between University and Government can be generated through the actions and interactions of governmental officers, having a limited mandate and functioning within more or less bureaucratic institutional structures, representatives of the economic environment, with their fundamental interest of profit maximization and members of the academic community, concerned more with ideas, innovation and latest methodologies and then being acquainted with the regulations of public institutions and the specific constraints of the business world. However, using Learning Factory dissemination activities, i.e. projects outputs (deliverables, analysis, etc), a link between University and Government can be established in order to identify needs of industrial enterprises and define industrial strategy, and in that way, at the same time, a link between Government and Industry is established.

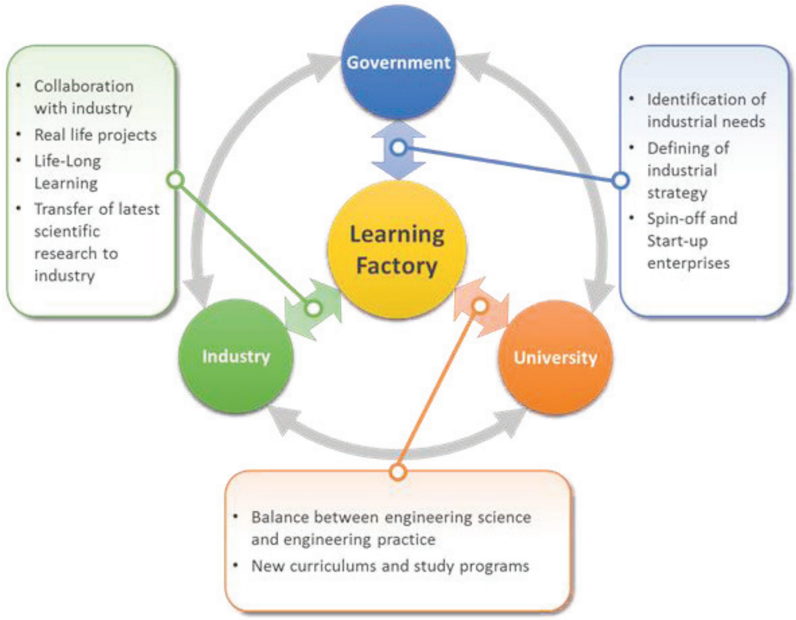

Fig. 3. Learning Factory as a missing link in Triple helix model.

Learning Factory could be place where University, Industry and Government meet each other share needs and expectations, and work on collaborative projects. It could really be a solution of a missing link in Triple helix model.

3. Learning Factory

3.1. Vision, Mission and Aims

Since 2009, Lean Learning Factory has been establishing at Laboratory for Industrial Engineering at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture (FESB) in Split. Lean Learning Factory at FESB is based on a didactical concept emphasizing experimental and problem-based learning using tools and methods from Lean management. The continuous improvement philosophy is facilitated by interactive involvement of the participants (students or industrial employees). Furthermore, Lean Learning Factory at FESB is a part of "Network of Innovative Learning Factories – NIL" (DAAD project).

Vision of Lean Learning Factory at FESB is to be a place where University, Industry and Government meet each other share needs and expectations, and work on collaborative projects.

Mission of Lean Learning Factory at FESB is to help bring the real-world into the classroom by providing practical experience for engineering students, to help transfer latest scientific research to industry through collaborative projects and LLL, and to help government identify needs of industrial enterprises.

Main aim of Lean Learning Factory at FESB is establishment of "living lab" for research, development, demonstration and transfer to economy Croatian model of Innovative Smart Enterprise (HR-ISE model) till October

2018. "Living lab" will be based on Learning Factory concept, and aims will be achieved through projects: NIL (DAAD project) and INSENT (CSF project).

In Lean Learning Factory at FESB following diversity of activities is done or in process:

- Education
- Implementation of Lean and Green concept in economy
- Scientific research activities

Lean Learning Factory at FESB profile has been defined from a typology (Fig. 4) similar to one used in survey conducted within European Initiative on Learning Factories [11].

Characteristic	Features					
Operating organization	industry	consulting	**university**	technical college	professional school	
Type of use	**education / training**	**research**	further industrial use			
Industrial target groups	**operational staff**	**engineer**	manager			
Academic target groups	**students**	research stuff / post graduated				
Other target groups	**lean experts / lean specialist**	other consultants				
Selected industries	machine building	**automotive industry**	chemical industry	electrical industry	**insurance, banks, etc.**	
Product	**real products**	**imaginary (didactic) product**				
Production process	machining	**assembly**	**logistic**	IT	indirect	production
Module content	**process improvement**	diagnosis	**system design**	**quality control**		
	quality	**material flow**	**technology optimization**	**lean transfer**		
Integrated departments	production	**distribution**	purchasing	ideas mgmt.	**design / develop.**	**prod. plan. and control**
Integrated teaching methods	**presentation**	**demonstration**	tutorial	web-based training	**simulation game**	
	discussion	case study	**role play**	**experimental game**	...	
Learning factory size	**< 300 sqm**	300 – 2000 sqm	2000 – 10000 sqm	> 10000 sqm		
Number of course participants	**< 5**	**5 – 10**	**10 – 20**	20 – 30	> 30	
Duration of module	**< 2 h**	**2 – 5 h**	5 – 10 h	10 – 20 h	> 20 h	

Fig. 4. Definition of Lean Learning Factory at FESB profile from a typology.

3.2. Education

Lean Learning Factory at FESB has been integrated into the education of students and employees on all levels:

- Undergraduate lectures: study of work and time, organization of production systems;
- Bachelor thesis;
- Graduate lectures: manufacturing technologies planning and optimization, plant layout;
- Master thesis;
- Postgraduate study lectures: Modeling and simulation, CIM, Logistics optimization
- Doctoral thesis;
- Professional study lectures: production planning and control;
- Professional study thesis.

Presentation lectures are supplemented with exercises which are held in laboratory where Learning Factory is located. Students can experience practical effects of various tools and methods implementation in environment which is simulated and simplified production plant. Laboratory set up, besides computers with PLM software, includes didactic games specially developed for simulation of production and logistic systems [12].

Fig. 5 Students balancing assembly line in Lean Learning Factory at FESB.

On the other side, real assembly tables and tools for complex product assembly, together with real products for assembly, gives opportunity to students for further development of balanced assembly lines (Fig. 5), assembly documentation and procedures, conveyor system or other transport system, clamping tools, measurement procedures and quality assurance tests.

Furthermore, establishment of new Master Study program, Product Lifecycle Management [13], together with introduction of new study courses (Project Lean Management, Lean Management etc.) gives interested students possibility to reach a certain level of specialization in field of emerging operational management methodologies.

3.3. Implementation of Lean and Green concept in economy

Lean and green concept is implemented in large and small-and-medium-sized enterprises in Croatia and Bosnia and Herzegovina (manufacturing industry, services, banks etc.).

Implementation starts with selection of implementation team (Fig. 6) consisting of enterprise's employees and external experts from University. Team consists of 15-30 employees, depending on the size of enterprise, from all departments (design, administration, production, etc) and all hierarchical levels (from top management to machine operators).

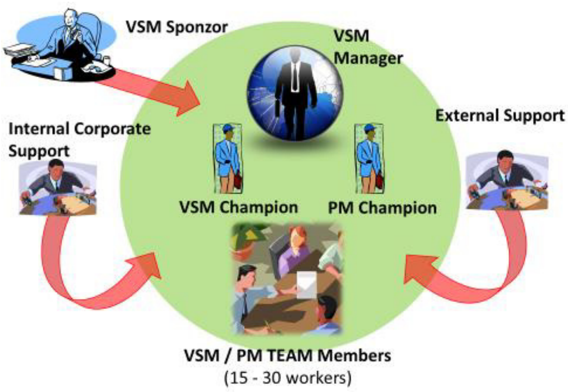

Fig. 6. Scheme of team for implementation of Lean and Green concept.

Usually, implementation of Lean and Green concept takes about 6 months. It starts with theoretical lectures, practical and didactic games, and pilot application on shop floor level. The implementation program is divided into three steps (Table 1.). It all starts with learning basics of Lean i.e. philosophy of Toyota Production System as the first step.

The second step is learning of Lean tools and methods (5S, Kaizen, VSM, etc) which employees try to apply on their work places and in their work tasks. To achieve sustainability of Lean implementation, the third step is to help top management to acquire Lean thinking. An accent is especially on Kata principle using concepts: Kata for coaching and Kata for improvement.

Table 1. Three steps of education of employees for successful implementation of Lean concept.

Step 1: Basics of Lean	**Step 2: Elements of Lean**	**Step 3: Lean thinking**
Toyota Production System	Just-in-Time	Leadership for lean
Lean principles	Heijunka (line balancing)	Lean in other areas (administration, hospital, education, government etc.)
Standardization of work	Push-Pull production	Kata for improvement
7+1 types of waste	One piece flow	Visual management (Obeya)
Quality techniques	Quick change-over (SMED)	
Didactic games (car production, beer game etc.)	Tact time	
	Supermarket	
	Kanban	
	Kaizen	
	Value Stream Mapping	

At the end of the training each employee gets its project task for his/her work place and work tasks. After consulting with experts from University, each employee presents his/her results.

Some results and problems identified in implementation of Lean and Green concept in Croatian enterprises are presented in [14].

3.4. Scientific research activities

Lean Learning Factory research group is researching and developing new methods and possibilities for implementation of Lean concept in Croatia and Bosnia and Herzegovina enterprises in relation to level of development and cultural behavior of employees, due to fact that those countries were former socialist countries [14-16].

In the September 2014 INSENT project started with the main objective of developing Croatian model of Innovative Smart Enterprise (HR-ISE model). Every global manufacturer has its unique manufacturing system (Toyota, Daimler, Bosch, etc), and some countries are developing their own unique enterprise model, like Germany – Industry 4.0. Model is aligned with their vision, strategy, values and culture. Republic of Croatia hasn't developed its own model of enterprise. The aim is to perform model's regional fit, i.e. to harmonize Innovative Smart Enterprise model with specific regional way of thinking, manufacturing and organizational tradition, and specific education. HR-ISE model could help Croatian enterprises to bridge the gap between their competencies and EU enterprises' competencies and capabilities.

The development of Croatian model of Innovative Smart Enterprise (HR-ISE model) and its transfer to economy could have a strong impact on recovery of Croatian industry. HR-ISE model could significantly improve competencies and capabilities of Croatian enterprises to make them more competitive on EU market. Additionally, Lea Learning Factory at FESB will be used as "living lab" for HR-ISE model implementation and a place for knowledge transfer from University to economy.

4. Conclusion

In this paper a concept of Triple helix model connected via Learning Factory concept is presented. Learning Factory could be place where University, Industry and Government meet each other share needs and expectations, and work on collaborative projects. Concept is presented as a solution of a missing link in Triple helix model.

Furthermore, Lean Learning Factory at FESB is presented. It uses tools and methods from Lean management for rapid analysis, identification of problems, and ideas for improvement of production systems. This concept is implemented in education, scientific research activities and in projects with industry.

Lean Learning Factory at FESB, based on a didactical concept emphasizing experimental and problem-based learning using tools and methods from Lean management, has true potential to play important rule in regional development.

5. Acknowledgement

This work has been supported by Croatian Science Foundation under the project 1353 Innovative Smart Enterprise (INSENT).

References

[1] Koren Y. The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems. New York: John Wiley & Sons; 2010.

[2] Kagermann H, Wahlster W, Helbig J. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Berlin: Heilmeyer und Sernau; 2013.

[3] Meier H, Roy R, Seliger G. Industrial Product-Service Systems - IPS2. CIRP Annals – Manufacturing Technology 2010; 59; p. 607-627.

[4] Váncza J, Monostori L, Lutters D, Kumara SR, Tseng M, Valckenaers P, Van Brussel H. Cooperative and responsive manufacturing enterprises. CIRP Annals - Manufacturing Technology 2011; 60; p. 797-820.

[5] Sturgeon TJ. Modular Production Networks: A New American model of Industrial Organization. MIT Working Paper IPC-02-003; 2002.

[6] Etzkowitz H. The Triple Helix of University-Industry-Government: Implications for Policy and Evolution. Working paper 2002-11; 2002.

[7] Lamancusa J, Jorgensen J, Zayas-Castro J. The Learning Factory – A new approach to integrating design and manufacturing into the engineering curriculum. Journal of Engineering Education, 1997; 86; p. 103-112.

[8] Rentzos L, Doukas M, Mavrikios D, Mourtzis D, Chryssolouris G. Integrating manufacturing education with industrial practice using teaching factory paradigm: A construction equipment application, Procedia CIRP, 2014; 17; p. 189-194.

[9] Wagner U, Al Geddawy T, El Maraghy H, Müller E. Product family design for changeable learning factories, Procedia CIRP, 2014; 17; p. 195-200.

[10] Slaus I. Political Significance of Knowledge in Southeast Europe, Croatian Medical Journal, 2003; 44; p. 3-19.

[11] Tisch M, Hertle C, Cachay J, Abele E, Metternich J, Tenberg R. A systematic approach on developing action-oriented, competency-based Learning Factories. Procedia CIRP 2013; 7; p. 580-585.

[12] Veza I, Gjeldum N, Mladineo M, LOPEC Logistics Personal Excellence by continuous Self-Assessment (LOPEC): Pilot-implementation case studies. Proceedings of 4th International Conference on Mechanical Technology and Structural Materials 2014; p. 39-46.

[13] Gecevska V, Lombardi F, Cus F, Anisic Z, Angelidis D, Veza I, Popovska Vasilevska S, Cosic P. PLM-Product Lifecycle Management Strategy for Innovative and Competitive Business Environment. Innovative Production Systems Key to Future Intelligent Manufaturing. Univerza v Mariboru; 2010; p. 193-208.

[14] Veza I. Application of Lean Management in Croatian Enterprises, Proceedings of CIM 2013: Computer Integrated Manufacturing and High Speed Machining 2013; p. 29-40.

[15] Gjeldum N, Bilic B, Kujundzic F. Application of Modified Value Stream Mapping Tool for Restructuring of Make-To-Order Production System, Proceedings of CIM 2013: Computer Integrated Manufacturing and High Speed Machining 2013; p. 113-118.

[16] Mladineo M, Veza I, Gjeldum N. Single-Objective and Multi-Objective Optimization using HUMANT Algorithm, International Scientific Conference KOI 2014; September 2014, Osijek, Croatia.