Transferring experience labs for production engineering students to universities in newly industrialized countries

A. Leiden¹, *, G. Posselt¹, V. Bhakar², R. Singh², K. S. Sangwan² and C. Herrmann¹

¹ Institute of Machine Tools and Production Technology, Chair of Sustainable Manufacturing and Life Cycle Engineering, TU Braunschweig, Langer Kamp 19b, Braunschweig 38106, Germany
² Birla Institute of Technology and Science, Pilani, Rajasthan, India

* Corresponding Author: a.leiden@tu-braunschweig.de

Abstract. The Indian economy is one of the fastest growing economies in the world and the demand for the skilled engineers is increasing. Subsequently the Indian education sector is growing to provide the necessary number of skilled engineers. Current Indian engineering graduates have broad theoretical background but lack in methodological, soft and practical skills. To bridge this gap, the experience lab ideas from the engineering education at “Die Lernfabrik” (learning factory) of the Technische Universität Braunschweig (TU Braunschweig) is transferred to the Birla Institute of Technology and Science in Pilani (BITS Pilani), India. This Lernfabrik successfully strengthened the methodological, soft and practical skills of the TU Braunschweig production-engineering graduates. The target group is discrete manufacturing education with focusing on energy and resource efficiency as well as cyber physical production systems. As the requirements of industry and academia in India differs from Germany, the transfer of the experience lab to the Indian education system needs special attention to realize a successful transfer project. This publication provides a unique approach to systematically transfer the educational concept in Learning Factory from a specific university environment to a different environment in a newly industrialized country. The help of a bilateral university driven practice partnership between the two universities creates a lighthouse for the Indian university environment.

1. Introduction

In newly industrialized countries, such as India, the demand for skilled engineers is increasing massively. Especially the manufacturing sector is growing and skilled professionals are required to foster this development. Manufacturing is the motor to increase the wealth of an emerging economy against the background of sustainable development. To increase the number of local skilled professionals, governments increase the number of graduates by increasing the number of university placements to skill more young people. For example, in India the number of enrolled students increased from 3.6 million in 1985/86 to 19.0 million in 2015/16 [1]. However, most university graduates have a broad theoretical background but lack in methodological, social and personal skills. Therefore, many of them are not ready to be employed just after graduation and need further training to become ready for employment. For example in India 60 % of the graduates do not get a direct job placement after graduation but have to go to finishing schools organized by the Indian industrial sectors [2].
To address this gap in teaching university engineering students, learning factories were introduced in many industrialized countries during the last 25 years. Learning factories can help to increase the employability of graduates by developing their methodological, social and personal competencies [3].

The first learning factory was founded by the national science foundation at the Penn State University in the USA in 1994[4]. Tisch and Metternich identified three waves of learning factory development. The first wave lasts from the end of the 1980s to 2005, which was the beginning of the development of learning factories. During the second wave from 2005 to 2010, local learning factories were building up in Europe. The third and currently ongoing wave is dominated by networking and scientific consideration. [5] In this context, TU Braunschweig and BITS Pilani developed a concept that allows the Indian partner to build on the experience in developing and operating a learning factory at a leading German university. To date, no relevant learning factory exists in India, which bases on the learning factories concept from industrialized countries. The introduction of learning factories at Indian universities could help to overcome the lack in the demanded competence portfolio of engineering graduates, which is mainly responsible for the low employability of Indian graduates in the different industry sectors.

Transferring the learning factory concept to universities in a newly industrialized country will not only help these universities but the universities in industrialized countries also can benefit from such cooperation. Suppliers all over the world including newly industrialized countries produce most products from the manufacturing sector globally. Further, many important challenges, for example global warming, must be solved globally. The integration of these aspects into the learning factories of industrialized countries will enable their students to get a better understanding of working in a globalized working environment and deal with global challenges.

Therefore, successfully transferring the learning factory concept to a newly industrialized country could be the starting point for the next learning factory wave, which extends the existing network and includes newly industrialized countries supporting the capacity development. (see figure 1).

![Figure 1. Waves in development of learning factories.](image)

Simply copying the concept of learning factories to newly industrialized countries would not have the maximum effect of learning factories. As shown in figure 2, the setting of a learning factory is influenced by many factors. The educational system with its characteristics as well as the industry environment has a major impact on the required learning factory concept. Beside these quantifiable factors, also the culture, in particular the teaching and learning culture must be considered.

Therefore, the concept must be adapted to the local university and industry context to ensure that a maximum of competence portfolio can be effectively addressed. Against this background, this paper will present an approach to transfer single conceptual building blocks from existing learning factories from industrialized countries into learning factories of newly industrialized countries. Afterwards the approach is applied within a case study of the “Joint Indo-German Experience Lab” (JInGEL) project to evaluate the transfer of the experience lab from the learning factory of TU Braunschweig to BITS Pilani.
2. State of research
Most of the researches in the field of learning factories are focused on the competence requirements of young employees in industrialized countries. Most of these learning factories have gained a higher degree of maturity as they were developed over a longer time span with significant support from public funding organizations. To measure the maturity of these learning factories Enke et al. [6] developed a maturity model, which is still in the validation phase. It is expected to estimate the maturity state of existing learning factories before they are to be transferred to other environments.

To foster the research in the field of learning factories and increase the maturity of the learning factories, cross-national networks were established to bring researchers working on learning factories together. An example for such a cross-national network is the network of innovative learning factories, which brings European learning factories together. The goals are to support international mobility, establish innovative educational programs as well as enhance the quality of existing and future learning factories.[7] However, this network only considers developments in industrialized countries.

As the learning factories in industrialized countries gained a higher degree of maturity, learning factories are nearly unknown in newly industrialized countries. Learning factories could foster the industrial development of those countries significantly by increasing the employability of engineering graduates and make it possible to bring more practice relevant contents into university teaching. For this cross continental network or collaborations with newly industrialized countries should be established to make a knowledge transfer to the newly industrialized country possible. To the best of author’s knowledge, no such a collaboration exists to date.

Figure 2. Transfer to newly industrialized country.
3. Method
This section introduces a method to transfer learning factories from industrialized countries to newly industrialized countries. The proposed method focuses on the transfer between two universities with within one or more engineering disciplines. The following figure 3 gives a brief overview of the proposed method.

Figure 3. Structure of the proposed method.

The proposed method consists of five steps as shown in figure 3:
1. Classify existing and future systems
2. Identify commonalities
3. Identify new global issues
4. Develop global and common modules
5. Develop new local modules

This five step method fosters the transfer of an existing learning factory from an industrialized country to a university in a newly industrialized country and ensures that the new learning factory fits to the demand of the university in the newly industrialized country.

First, the existing learning factory has to be classified and in parallel, the new, yet to develop learning factory in the newly industrialized country has to be classified. For this, the Learning Factory Morphology from Tisch et al. [8] is applied. The morphology is divided into the seven dimensions of learning factories:
- Operating Model
- Purpose and Targets
- Process
- Setting
- Product
- Didactics
- Metrics

Each dimension is further specified with six to 12 subcategories. At this step, it is assumed that no learning factory exists in the specific engineering education environment of the newly industrialized country. Therefore, experts must be consulted to define the future learning factory, involving
stakeholders from industry, academia and governmental institutions. This classification step will help to point out the real demand in the newly industrialized country and ensures that the system from the industrialized country will not simply be copied without considering the specific setting and boundary conditions, including economic, technical and most importantly cultural dimensions.

In the second step, both classifications will be compared to identify commonalities. In few cases, a simple transfer to the new learning factory might be possible. For example in the process dimension both learning factories could be favored to have the same hardware setup as it enables a fast implementation and future bilateral support culture. However, there can be operational reasons, which avoid such a simple transfer, especially in terms of the operating model dimensions such as available budgets for the learning factories.

Care has to be taken if there is no commonality or a little commonality. In the worst case, an expensive learning factory will not be used and maintaining it is not adapted to the contextual, didactic or cultural demands of the teaching and learning system in the newly industrialized country. Hence, the employability of the engineering graduates will not increase.

Apart from commonalities, general global issues at the contents side (processes) should be identified. One possible global topic could be sustainable development. For this, new common modules can be developed and used at both universities. An example is the global warming challenge. As measures to reduce the rate of global warming have to be adapted by all industries in the world, the teaching modules for both learning factories can be the similar. In these cases, a long-term collaboration, for example with virtually connected modules, could be an option to be sought. The virtual linking of learning factories of two universities especially makes sense when a global supply chain connects the industries at both locations. Under such circumstances, linking the learning factories can show the impact of local decision on the global supply chain. This helps to optimize the whole supply chain instead of only the local processes.

Finally, in the last phase new modules must be developed to ensure that local requirements are considered especially for the new learning factory. The experience from the learning factory in the industrialized countries can help to build these new modules, but the modules must fit to the local requirements in the newly industrialized country. Also, new modules can be developed in the industrialized country after broadening the horizon of the involved experts. The view on different processes and structures can lead to changes in the own learning factory environment.

4. Case study JInGEL

The proposed method is applied in this case study within the cooperation between the TU Braunschweig in Germany and BITS Pilani in India. A learning factory was established at the Institute of Machine Tools and Production Technology of TU Braunschweig, Germany in 2013. The learning factory (called “Die Lernfabrik”) consists of three major pillars: the research lab, the experience lab and the education lab (see figure 4). For all three labs, the focus topics are energy and resource efficient manufacturing, industry 4.0 as well as urban production. The research lab represents a real-sized manufacturing environment consisting machine tools, technical building services and information technology. The main objective is to investigate new concepts and principles of prior mentioned focus topics at a real life scale. Although, students work in the research lab, the focus is clearly on research topics and a guided learning concept. In the experience lab, education becomes a more dominating topic. Industry processes are scaled down to small modular stations and many practical lab sessions are held here. Although the focus is set on practice and research-oriented learning, it is also possible to investigate new technical and didactic concepts within this infrastructure. The third pillar consists of education lab, which is used to educate the apprentices of TU Braunschweig, like industrial mechanics or precision mechanics. In this learning environment, real life scaled machine tools slimed down to educational demands are used for practice-oriented learning under supervision.
For the transfer process to BITS Pilani, in the initial stage, only the experience lab is taken into consideration (see Figure 5). It consists of customized adapted Modular Productions System (MPS) from FESTO Didactic SE. Each station is part of a fixed process chain and represents a scaled-down production process. Over the period of five years, the use of the experience lab at TU Braunschweig was synergetically extended and used by four different engineering lectures. The most important topics are energy and resource efficiency in manufacturing and cyber physical production systems. The specific developments and adaptions are results of educational and research projects, which are well documented and evaluated in the literature. [9], [10]

Since 2009, the TU Braunschweig maintains a close collaboration with BITS Pilani (examples for project results: [11], [12] or [13]). Büth et al. [2] showed already that there is a qualification gap between academia and industry in India. The department of mechanical engineering of BITS Pilani invested into a new workshop building with space for an experience lab.
First, the experience lab of “Die Lernfabrik” was classified with the learning factory morphology. Afterwards, through collaborative work with BITS Pilani researchers, the learning factory morphology is used to investigate the demand of BITS Pilani for a learning factory.

Next, the results of the classifications are compared. Table 1 summarizes the results of the comparison. In general, both experience labs are comparable in most dimensions. The main goal of both universities is to train their production-engineering students in the topics of sustainable manufacturing and cyber physical production systems. The industrial processes are scaled down to ensure that the students can work self-guided in the experience labs without any safety risks. However, within the process dimension some differences are identified for which specific modules are to be developed. While the TU Braunschweig is focusing on cutting, additive manufacturing and changing material properties in their learning factory, BITS Pilani is focusing on cutting and joining. Therefore, modules with focus on joining should be developed to ensure that this topic would be addressed within the experience lab. Another relevant difference from the metrics perspective is the number of participant per year. While at TU Braunschweig 200 to 500 students use the experience lab, at BITS Pilani only 50 to 200 participants use the infrastructure. One of the reasons for this is the size of the universities. At TU Braunschweig 20,000 students are enrolled and at BITS Pilani, Pilani campus only 5,000. Also, the available space at BITS Pilani is 70 sqm which significant smaller than at TU Braunschweig.

The universities in India particularly technical universities/institutes are not big. Therefore, in India, the learning factory should be designed to use less space and bring different topics together within the same hardware. This not only reduces the necessary amount of space, but decreasing the demand for available space can reduce the cost for a learning factory.

Table 1. Summary of results of classification.

| Dimension          | Degree of accordance | Similarities                  | Differences                                             |
|--------------------|----------------------|-------------------------------|---------------------------------------------------------|
| 1. Operating Model | Very high            | Similar funding structure     | Involvement of professors at BITS                       |
| 2. Purpose and Targets | High                  | Focus on trainings for students | Students and employee trainings at TU BS               |
| 3. Process         | High                 | General industrial process are the same | Differences in manufacturing methods                     |
| 4. Setting         | Very high            | Scaled down processes in factory environment | None                                                  |
| 5. Product         | Very high            | Same product                  | None                                                    |
| 6. Didactics       | High                 | Self-guided trainings for students | Focus on standardized trainings at BITS                 |
| 7. Metrics         | Medium               | Number of participants per training | Size and number of trainings per year                  |

TU BS = TU Braunschweig  
BITS = BITS Pilani

Global issues, which are addressed by both universities, are sustainable manufacturing and global warming. Energy and resource efficiency are relevant at both locations and should be taken into consideration. At TU Braunschweig these aspects are integrated into each MPS station. As the use of electrical energy drives CO₂ emissions, it could make sense to integrate renewable energies into the experience labs. At TU Braunschweig, solar panels are already installed close to the experience lab. Also BITS Pilani has a high potential for solar power. Thus it makes sense to integrate the topic of renewable energies with a commonly developed MPS station.

Recently a setup of five MPS stations has been installed at BITS Pilani (see figure 6). These stations were carefully selected considering the boundary conditions at BITS Pilani. Currently new lecture units, which will take place in the new experience lab, are in development and will be held by BITS Pilani lecturers. In the next steps, new common modules and specific modules for each learning factory will be developed. In addition, psychologists are tracking the success of this project by testing the employability of the BITS Pilani graduates before and after the introduction of the experience lab.
5. Conclusion
The learning factories can be used economically and effectively to enhance the employability of young engineering graduates in newly industrialized countries. This paper applies the generic five step approach to transfer learning factory to other environment. A study has been within the cooperation between the TU Braunschweig and BITS Pilani. Proper care has been taken to develop learning factory at BITS Pilani to take care of the differences in the size and education methods of the two universities. Also, the cultural dimension, for example the learning and teaching culture, has been synchronized in the transfer. Currently, the learning factory is build up at BITS Pilani and the development of local modules has just started.

6. Outlook
The proposed approach is very generic and it could be used for other institutions and must not necessarily be applied for collaboration between industrialized and newly industrialized countries. Further, during the transfer of the experience lab to BITS Pilani many other universities and institutes showed high interest in the project JInGEL. As BITS Pilani is one of the highest ranked universities in India, many small universities and institutes in India, which train the majority of Indian graduates can also benefit from the learning factory at BITS Pilani. The new learning system should become ready to be transferred to these universities and institutes to ensure that a large number of graduates can benefit from the learning factory concept.

Acknowledgement
The mentioned practice partnership “JInGEL – Joint Indo-German Experience Lab” is supported by the DAAD – German Academic Exchange Service (Project ID 57219215) and FESTO Didactic SE. It aims to transfer the positive experience from the TU Braunschweig experience lab MPS stations to the teaching environment of BITS Pilani.

References
[1] University Grant Comission 2016 Annual Report 2015-16, Delhi, India, URL: https://www.ugc.ac.in/pdfnews/3710331_Annual-Report-2015-16.pdf, accessed on 16/10/2017.
[2] Büth L. et al. 2017 7th Conf. on Learning Factories (Darmstadt, Germany)
[3] Müller-Frommey L. et al. 2017 7th Conf. on Learning Factories (Darmstadt, Germany)
[4] Abele E. et al. 2015 5th Conf. on Learning Factories (Bochum, Germany)
[5] Tisch M and Metternich J 2017 7th Conf. on Learning Factories (Darmstadt, Germany)
[6] Enke J, et al. 2017 7th Conf. on Learning Factories (Darmstadt, Germany)
[7] ESB Business School, Hochschule Reutlingen 2017 NIL Network Innovative Learning Factories, Reutlingen, Germany, URL: http://www.esb-business-school.de/en/research/research-activities/nil-network-innovative-learning-factories/, accessed on 14/08/2017.

[8] Tisch M, et al. 2015 The Turkish Online J of Educational Technology 14(2) pp 356-363

[9] Thiede S, et al. 2015 6th Conf. on Learning Factories (Gjøvik, Norway)

[10] Blume S, et al. 2015 6th Conf. on Learning Factories (Gjøvik, Norway)

[11] Juraschek et al. 2016 Indo German Conference on Sustainability 2016 (Chennai, India)

[12] Bhakar V, et al. 2015 The 22nd CIRP Int. Conf. on Life Cycle Engineering (Sydney, Australia)

[13] Mittal V, et al. 2012 The 19th CIRP Int. Conf. on Life Cycle Engineering (Berkeley, USA)