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Bridging the qualification gap between academia and industry in India

Lennart Büth[a]*, Vikrant Bhakar[b], Nitesh Sihag[b], Gerrit Posselt[a], Stefan Böhme[a], Kuldip Singh Sangwan[b], Christoph Herrmann[a]

[a]*Institute of Machine Tools and Production Technology, TU Braunschweig, Langer Kamp 19b, Braunschweig 38106, Germany*
[b]*Birla Institute of Technology and Science, Pilani, Rajasthan, India*

Abstract

The massive demand for complementary training of engineering graduates in India indicates a mismatch between academic education and industry requirements. This paper identifies the gap between academia and industry and presents an approach to bridge it using the concept of Learning Factories. The competencies of the newly graduate engineers and the competency requirements of Indian industry for graduates have been identified based on discussions with industry professionals and literature review. It has been found that the technical and social competency requirements match, but there is a gap regarding the methodological competency. This necessitates graduate engineer trainings at the start of employment. The additional trainings prove to be time consuming and costly for the industry. To bridge this gap a Learning Factory testbed has been implemented at a premier Indian university. It is expected that the proposed Learning Factory will make the Indian graduate engineers ready for the job at university level and the additional graduate engineer training redundant. The study also provides a roadmap of utilizing Learning Factories as an integral part for the Indian technical academic system.

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Keywords: Learning Factories; Die Lernfabrik; India; competencies; gap

* Corresponding author. Tel.: +49-531-391-7634.
E-mail address: L.bueth@tu-braunschweig.de

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1. Introduction

1.1. Motivation

The KPMG skill development report for the Federation of Indian Chambers of Commerce and Industry expects labour force requirement in India to grow from 477.9 million in 2011 to 502.4 million by the end of 2017 [1]. This tremendous growth rate underlines the demand for skilled work force to fulfil. India has taken most of its growth rate in gross domestic product (GDP) from the service sector in the past ten years. The sector of manufacturing is yet to become a relevant contributor to the total GDP, with a current share of less than 15 % [2]. In 2014, the Indian government has started an ambitious plan named "Make in India". The objective of this plan is to make India a global hub for design and manufacturing. The electronics goods share for Asia, for example, is over 60 % and India wants to claim a major share of this market with a clear understanding that skilled labour becomes the essential resource for a sustainable development of an export-oriented nation [3]. The All India Council for Technical Education (AICTE) statistics show that the enrolment of youth for technical courses in India is lower than the available capacity and less than 40% of the graduating students get jobs in industry [4]. This clearly shows a mismatch between the industry requirements and academic skill development.

When talking about qualifying work forces in the course of a sustainable development, the United Nations see education of youth as the key element to cope with the goals of the Agenda 2030 [5]. However, a deeper look at the educational profile of the labour force in India reveals that only 55 % of the age group between 15 and 59 have a primary school background (up to five years of school) with merely two percent with vocational training degrees [1]. A survey of the Boston Consulting Group answered by international manufacturing leaders emphasises an urgent need for a stronger focus of the Indian government on skill development to overcome the hurdles for international manufacturing companies to settle in India. A positive trend is noticeable; the work of the Indian skill development councils is showing its effect in the rapidly growing number of intakes of diploma schools and at university level [6]. However, not only the availability of trained professionals is important but also the profile of those professionals has to include emerging topics to ensure a reliable growth of the Indian manufacturing sector. The inevitable trend of a digital penetration of conventional manufacturing processes and the proclaimed targets of energy security and climate change, calls for a much broader competency map of future engineers and technical labourers [7]. This results in the need to address emerging topics including technical, economic and ecological problems and challenges of the different industrial stakeholders with fitting teaching and learning systems.

1.2. Education system

Against the situation described in the previous section, the current academic system is mainly not able to cope with the requirements mentioned above. Therefore, the different manufacturing industry sectors are currently providing special training to the recruited graduates for a certain period, before they are ready to be fully employed in the industry. This process is both time consuming and expensive, as many decentralized practice-oriented educational infrastructures must be kept up-to-date and operated by the industry. The various stages of the Indian technical education system and the training required from the industrial perspective to make the new recruitments ready to work at the industry are visualized in Figure 1. It provides a general overview of the technical education system at various entry levels into industry; further, the additional training costs and duration of graduates entering companies are shown. It is conspicuous from Figure 1 that the training costs incurred to the industry for the newly recruited graduate engineers at level four are very high and that training is time consuming. Curtailing the time and money required for the decentralized training at industry-level can offer benefits (e.g. highly specified trainings, teaching students on a higher detailed level than universities and colleges are able to) for all the stakeholders like students, industry, and academia.

1.3. Challenges

Statistics show that almost 60 % of all graduates do not get jobs in industry right after their graduation [4]. This can implicate skill gaps as the demand for professionals at present is as described before. This leads to the hypothesis

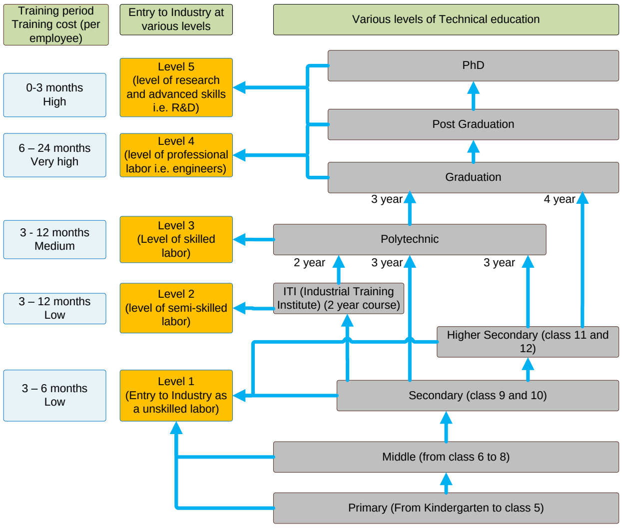

Fig. 1: The engineering/technical education system in India

that students are not readily employable for the industries, as they miss e.g. methodological and personal competencies related to self-reliant problem-solving and interdisciplinary, out-of-the-box thinking. Hence, this publication systematically identifies gaps in the competencies of young graduates in regard to future skills and mind-sets needed for emerging topics of the manufacturing industry, supporting strategical development goals (e.g. 'Make in India'[3]). Based on the competence requirements from the industrial perspective, the as-is-situation of current teaching and learning systems from the academic perspective is reflected to reveal possible deficits. Opportunities and a new approach are highlighted for improving the skill-sets of future technical professionals in India in the following.

2. Analysis

The formulated hypothesis regarding the qualification process of young engineers has been examined by conducting a two-sided analysis of the situation. In the first step, the needs of industry are analyzed by interviewing companies employing production engineers on a regular basis. Next, the situation of a university responsible for educating the young graduates is analyzed.

2.1. Industry analysis

For evaluating the needs of the industry for newly graduated manufacturing engineers, experts from the manufacturing industry were contacted. Fourteen experts from eight large-sized manufacturing companies in India responded and took part in an interview. The qualitative data collection was performed by using semi-structured interviews and analyzing the transcripts. The interviews were structured using the vocational action competency categories professional, methodological, social and personal competency [8]. The analytical results of the interviews were divided in requirements and the gap between actual competencies and requirements.

According to the interviewees the *professional competencies* (theoretical knowledge) generally depend on the industrial sector of the company, e.g. automotive industry, and cannot be generalized. It can be said that the graduates need knowledge about basic production technologies (machining, forming, casting, and joining were mentioned). Furthermore, they are expected to hold knowledge about the latest industry standards and paradigms, such as Lean Manufacturing or Total Productive Maintenance, etc. Nearly all experts agreed that theoretical knowledge is important for graduates and is seen as the foundation for being able to work and solve problems in a company. The *methodological competencies*, which mainly refer to the transfer of theoretical knowledge into real application-based problems, is generally seen more important than the theoretical knowledge itself. Applied knowledge is often mentioned as the most important skill. Another often-mentioned *methodological competency* is problem solving. It is said that theoretical problem solving is not sufficient as it differs from real life problem solving. Furthermore, planning skills, continuous improvement and project management skills are often expected. Social skills are often seen as very important skills for newly graduated engineers. Within the *social competencies* the experts commonly agree that being able to deal with people in general is important. Skills like teamwork, conflict management and interdisciplinary communication are expected. Additionally, the experts mentioned self-discipline and a positive work attitude mostly within the *personal competencies*. Furthermore, presentation skills, the curiosity to learn new things and "world-knowledge" were mentioned and desired. The *personal competency* when compared to the *methodological* and *social competency* is regarded as less important but required. The most required skills, categorized by competencies, are summed up in Table 1.

Table 1. Qualitative analysis: Requirements and competency gap regarding freshly graduated production engineers from industry perspective

Competency category	Requirements	Gap
Professional	Production machines; latest industry standards	Mostly fulfilling demands
Methodological	Applied knowledge; problem solving; planning; continuous improvement; project management	Applied knowledge and problem solving skills are gapping
Social	Dealing with people; communication	Improving in recent years, communication needs improvement
Personal	Self-discipline; presentation skills; positive work attitude	Self-discipline and positive work attitude are gapping

Subsequently, the interviews were analyzed regarding the degree of satisfaction with the mentioned requirements, resulting in a possible gap (see Table 1). It can be stated that the experts have observed an improvement regarding the competencies of new graduates over the recent years, but gaps are still present. The experts see the *professional competencies* of graduates in India as satisfying. The quality of the formation of a professional competency may only depend on the university (high-reputed university or institute with lower reputation). The *methodological competencies* are seen as highly fragmentary; nearly all experts mentioned the lack of applied knowledge, which is regarded important. The same has been mentioned for problem-solving skills. The *social competencies* are seen as satisfactory; an improvement over the last years has also been mentioned. The communication skills require some improvement. Within the *personal competencies* the experts wish for more self-discipline and a more positive work attitude. When comparing the findings with other relevant national and international studies, it can be noted that lacking soft skills (meaning methodological competency and communication) and a lack of experience and technical competency (meaning applied knowledge) is a general problem in the Asia-Pacific region [9]. Comparing the results with the United States, the most gapping competency in manufacturing is problem solving [10].

One common option to address the issue of fragmentary *methodological competencies* are finishing schools. As defined by AICTE, a finishing school is "a private school for students that emphasizes training in all around personality development, cultural, and social activities" [11]. In case of a graduate engineer, finishing school might be a manufacturing organization offering an intensive training program for six months or one year (see Figure 1, level 4). Finishing schools can be called a skill development center, which serve as an initiative to assimilate and utilize the academic knowledge gained during the course of education. The number of skill development centers across India is rising since the launch of the 'Skill India' campaign initiated by the government of India [12]. These centers aim at educating specific process knowledge otherwise taught in industrial training institutes (ITI), which are originated on a lower industry entry level (see Figure 1). It has been observed that universities also have initialized skill development centers with the aim to improve the skills of ITI graduates. Although, no such initiative from university side aims at preparing students for the technological and global challenges of a working environment in the manufacturing sector. From the current practices within the manufacturing sector, various types of industrial training are provided to the new engineering graduates once they join a company. These trainings range from a minimum of six months up to two years depending on the type of industry and job profile. Parts of the curriculum the finishing schools incorporate could be shifted to the universities, benefitting all stakeholders. Students can save training time and improve technological and methodological competence, industry can save money, time, and get employees that are more efficient and generally skilled, and universities can benefit producing graduates skilled closer to industrial needs. This approach has been implemented at ITI student level [13].

When analyzing the manufacturing industry, different emerging topics can be identified that will influence the requirements from industry for future graduates. According to the current industrial requirements identified and observed by the "Federation of Indian Chambers of Commerce and Industry" (FICCI) [14], the Indian industry is changing its way of manufacturing with global concerns, moving towards more sustainable initiatives. It has been observed that in the last decade the number of organizations reporting sustainability performance indicators has increased [15]. In recent publications from the perspective of the manufacturing sector, it has been stated that sustainability assessment of production processes [16], supply chains [17] and products [18] and processes [19] has been addressed more and more frequently. Research has indicated the importance of sustainability in the Indian manufacturing sector, addressing various issues like energy efficiency, closed loop production processes, environmental impact assessment, renewable energy integration, etc. These changes in the Indian industry demand a completely new set of skills of the newly graduated engineers joining the industry right from university. In order to handle the issue of sustainability and advanced digital technologies in the industry. To incorporate the new skills required by the engineering graduates one such program was conducted by the BRICS skill development working group to address the issue of skill development as per the requirement of the current industrial revolution 'Industry 4.0' [20, 21]. However, it will not be answered whether these changes in the industry will require completely new sets of knowledge, which most certainly might not be created without the involvement of academia at reasonable costs. To assess the involvement of academia about knowledge dissemination, this study further conducts a case study at an Indian university campus to reflect the educational stakeholder's perspective.

2.2. University analysis – case study

To get a basic understanding regarding the topic from university perspective a university was analyzed in a short case study. The university analyzed in the case study has a highly competitive entrance examination in contrast to the status quo in India. Another element that differentiates the analyzed university from others in India is an integrated practice-school that includes industry internships within the curriculum. To get an in-depth understanding of the institutional perspective, interviews were conducted with 19 faculty members of the department for mechanical and manufacturing engineering. The semi-structured interviews for the qualitative content analysis consist of three parts, oriented on similar case studies conducted in Germany [22], including the necessity of prior knowledge to study successfully, critical success, failure factors, and information about the lecture.

From the results of the interviews, some observations have been made. The interviewees suggest various reasons for the educational as-is competencies among the students. These competencies vary from personal to professional competencies and it was observed from the interviews that professional competencies are on priority within the learning objectives of the current curriculum and teaching/learning-system. The knowledge of basic and applied science combined with language proficiency was found to be most important, followed by hard working and self-organization. Similarly, other aspects of the survey included questions related to factors like prior knowledge before admission to degree program, factors of success and failures and the teaching methods.

The study conducted with the industry experts reveals that graduate engineers finish their academic education with insufficient methodological competencies. The interviewees mentioned that one of the reasons for the lack of competency could be the highly influenced decisions at the time of admission of students. The selection of degree programs is partially biased by various factors like future job offers, profile of job, continued education possibilities, family, etc., resulting in a possible underperformance of the students.

In the current curriculum of engineering education, the project-based learning makes up 30 % of the time and only 30 % of the marks. However, the remaining 70 % of the marks are still awarded by traditional written or oral examination methods. Against the background of the above-discussed factors affecting the competencies of the graduating engineers, students should be offered more practice-based learning offers to try and train methodological competencies. The content of the curricula regarding future topics of manufacturing engineering is not analyzed, but it can be assumed that the anticipation and complexity of these trends as discussed is a challenge to be addressed.

3. Approach to close the gap

Different approaches can be chosen to address the outlined qualification gaps of engineering graduates between academia and industry. The identified gap can be addressed by combining didactical approaches and existing concepts with emerging topics of the industry resulting in the concept of Learning Factories (LF).

The identified challenges of current academic teaching/learning-systems for engineering students lie mainly in the need to teach and train methodological and social competencies in extension to the very profound professional competencies. This means that the existing curriculum must be extended by didactic elements of problem-solving, applied knowledge and utilization of communication skills. A collection of different didactical approaches can be found in [23]. Regarding the identified challenges and the status quo in the university analysis, activity-based methods like problem-based learning can be relevant approaches.

An early definition of problem-based learning [24] describes the concept as real world simulations with no right or wrong answer where teams of students address defined problems and develop possible solutions. In this process the teacher merely acts as a facilitator while new information is acquired by self-directed learning. The defined goals of problem-based learning include the development of problem-solving skills, becoming an effective collaborator and increasing the intrinsic motivation to learn. Additional goals are the development of self-directed learning skills and the construction of an extensive as well as flexible knowledge base [25]. Similar approaches fulfilling the needs partly or entirely are experience-based learning, game-based learning, project-based learning and research-based learning. These action-oriented, competency based didactical methods can be promoted by LF as a real world environment [26]. Several LF have been established utilizing the mentioned methods [26-28].

Within LF students are educated in an artificial, physical environment (teaching/learning-system) which represents a realistic situation as found in industrial application. For simple professional competence acquisition the required teaching/learning systems can be represented by a single machine tool or a learning setup which allows a safe operation ranging from 'trial and error' mode up to the simulation of real-world system dynamics. According to the LF framework of [29] a LF setup can vary in scale and size from a single entity in 1:1 size up to a multi-entity factory-like setup in model-scale ratio. Depending on the given requirements (curriculum, physical restrictions, financial budget and competence target-map), a suitable LF can be designed with the help of proposed frameworks [30].

As highlighted in section 2.1, sustainable production and advanced digital technologies will be important in the future for the manufacturing industry. Due to the increasing complexity of these topics and the need for applied knowledge, the concept of LF with complementary didactical approaches is seen as a suitable option by the authors to close the existing gaps, as well as address the trending topics of future manufacturing. Several LF have been established dealing with the identified topics. [27], for example, showcase their approach to teach energy-efficiency, and [28] created a concept implementing cyber-physical production system elements in LF.

4. Roadmap of 'Joint Indo-German Experience Lab'

Analogous to the development in India, Germany has been facing similar problems in many domains of engineering education. Besides the purely theoretical knowledge, the importance of application of the learned knowledge to create competencies has gained a lot more attention. For this reason, in the last ten years, the concept of the LF has been studied by higher education didactics.

The proposed design of a LF is given against the background of a development aid project from DAAD with a German university (Joint Indo-German Experience Lab, JInGEL). The German university, the Technische Universität Braunschweig (TUBS) has already a specifically developed LF fully integrated into their lecture "Energy Efficiency in Manufacturing Engineering". The given LF was specifically designed for the demands of the German lecture, the educational system and the competence target-map. Hence, the LF is not suitable for a direct transfer into the Indian partner university, the Birla Institute of Technology Pilani (BITS), and their lecture "Sustainable Manufacturing".

To match a created competence target-map of the first Indian lecture, the possible system modules of the German LF setup were compared to identify the professional competence spectrum, ranging from the utilization of single actor-sensor systems up to the initialization and operation of complex industrial control systems. Furthermore, the methodological competencies of the lecture Sustainable Manufacturing were mapped to the possible system dynamic effects that could be realized by the smallest and the most economic possible combination of the modular teaching/learning-setup. Methodological competencies range from the systematic analysis and evaluation of energy and material flows up to complex scheduling of job orders and its mathematical optimization for green supply chains. In regard to personal competencies the concept of the whole lecture is to be altered from a conventional classroom based lecture via slide show presentations towards problem-based tutorials. The tutorials require problems to be solved by interdisciplinary teams with extension of a set of roles that the students have to fulfil. To create additional synergies to ongoing research projects the 'Joint Indo-German experience lab' is not only a means for problem-oriented teaching and learning, but also a flagship for the application of research methodologies on a system level (e.g. cyber-physical-production systems) that can eventually be transferred into new curricula.

[29] discusses various type of learning factories in different countries. When applying the framework developed within the paper the LF to be developed in India is aimed at developing the type II LF (academic application scenario). However, it can be extended to type IV (changeability scenario) and remote learning scenarios respectively (type III).

The phase-wise development plan for the proposed LF is presented in Figure 2. In the first phase an analysis of industrial requirements for freshly recruited graduates and current academic course structure has been done. Based on the outcome of the analysis, various competency gaps have been identified, which are needed to be bridged in order to meet the modern industrial demands for specific competencies. In the second phase, a scaled down production line representing an actual production environment will be set up at the university. Various layouts for this production line will be analyzed for different product and process outcomes. Students will get a chance to work in an industry-like environment and will solve the actual production challenges. The entire learning process will be well documented to facilitate learning for students from various backgrounds. In the third phase, newly developed or modified teaching modules are proposed to be implemented as an integrated part of the course curriculum. A study will be conducted to assess the performance of the students before and after implementation of the learning factory. Also, opinion from the same industries will be taken about the recruitments made after implementation of the LF concept to assess the improvements in the aforementioned competencies of the students. To meet the dynamic requirements of the industry, the process has been proposed as continuous.

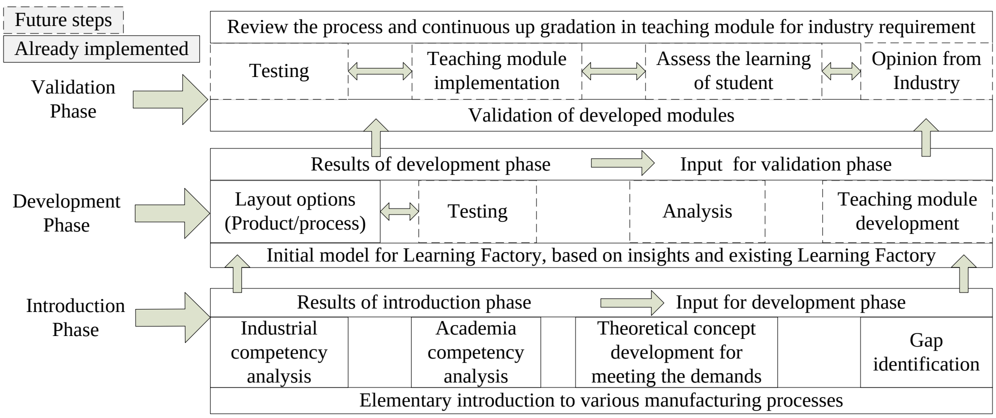

Fig. 2: Structured development plan of the Learning Factory within the 'Joint Indo-German Experience Lab'

5. Outlook and discussion

The initially formulated hypothesis was examined with a two-sided analysis. The interviews indicate an existing gap, but the analysis cannot be generalized for India as both sides have a limited view and the number of participants is too small. Although with this initial insights, a first step has been made and a procedure was proposed. The skill gap will be analyzed in more detail in parallel to the evaluation of the 'Joint Indo-German Experience Lab' in the near future.

In the scope of the DAAD-funded four-year project 'Joint Indo-German Experience Lab' the participants will set up a LF testbed in India for further research and development. With regard to the identified requirements and boundaries, the established LF concept will be custom-tailored to the Indian market. The newly created and adopted concept and infrastructure will be integrated in the facilities and the curriculum of BITS Pilani university. The teaching/learning environment will be evaluated in iterations and the approach will be generalized to allow a transfer to other institutions in India. Finally, tools shall be integrated to allow a continuous transfer of innovation of the teaching/learning environment between India and Germany in both directions.

In a long term view the project is expected to contribute to a continuous exchange, more sustainable and internationalized education structures for both India and Germany. Furthermore, the outcomes of the efforts shall impact not only the participating institutions, but can be transferred to similar institutes potentially benefitting from the developments.

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