UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot·your knowledge partner

INTERNATIONAL CONFERENCE ON COMPETITIVE MANUFACTURING

COMA'16

PROCEEDINGS

Resource Efficiency for Global Competitiveness

27 – 29 January 2016
Stellenbosch, South Africa

Organised by
Department of Industrial Engineering
Stellenbosch University

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

International Academy of Production Engineering

PROCEEDINGS

International Conference on Competitive Manufacturing

COMA '16

27 January - 29 January 2016
Stellenbosch, South Africa

Organised by the

Department of Industrial Engineering
Stellenbosch University

Editors:
Prof Dimiter Dimitrov
Dr Gert Adriaan Oosthuizen

ISBN No: 978-0-7972-1602-0

Global Competitiveness Centre in Engineering
Department of Industrial Engineering
Stellenbosch University
Private Bag X1
Matieland 7600
Stellenbosch, South Africa
Tel: +27 21 808 4234
Fax: +27 21 808 4245
E-mail: dimitrov@sun.ac.za; tiaan@sun.ac.za

About CIRP

CIRP was founded in 1951 with the aim to address scientifically, through international co-operation, issues related to modern production science and technology. The **International Academy of Production Engineering** takes its abbreviated name from the French acronym of **C**ollege **I**nternational pour la **R**echerche en **P**roductique (**CIRP**) and includes ca. 500 members from 46 countries. The number of members is intentionally kept limited, so as to facilitate informal scientific information exchange and personal contacts. In a recent development, there is work under way to establish a CIRP **Network** of young scientists active in manufacturing research.

CIRP **aims** in general at:

- Promoting scientific research, related to
  - manufacturing processes,
  - production equipment and automation,
  - manufacturing systems and
  - product design and manufacturing
- Promoting cooperative research among the members of the Academy and creating opportunities for informal contacts among CIRP members at large
- Promoting the industrial application of the fundamental research work and simultaneously receiving feed back from industry, related to industrial needs and their evolution.

CIRP has its headquarters in Paris, staffed by permanent personnel and welcomes potential corporate members and interested parties in CIRP publication and activities in general.

CIRP Office, 9 rue Mayran, 75009 Paris, France. Web : http://www.cirp.net

The Learning Factory: A Didactic Platform for Knowledge Transfer in South Africa

A. van der Merwe[1], V. Hummel[2], S. Matope[1]

[1]Stellenbosch University/ Department of Industrial Engineering, South Africa
[2]Reutlingen University/ ESB Business School, Germany

Abstract
During the first years of their employment, the graduates are a liability to industry. The employer goes an extra mile to bridge the gap between university-exiting and profitable employment of engineering graduates. Unfortunately some cannot take this risk. Given this scenario, this paper presents a learning factory approach as a platform for the application of knowledge so as to develop the required engineering competences in South African engineering graduates before they enter the labour market. It spells out the components of a Stellenbosch University Learning Factory geared towards production of engineering graduates with the required industrial skills. It elaborates on the didactics embedded in the learning factory environment, tailor-made to produce engineers who can productively contribute to the growth of the industry upon exiting the university.

Keywords
Learning factory, university graduates, competences, didactics, industry

1 INTRODUCTION

South Africa, as an emerging economy relies generally on the manufacturing sector for its growth. The industries which make this sector get their top-brass workers from the universities. Upon employing them, they find that some university graduates are still raw. They are unproductive during their early period of employment. Some of the graduates receive a cultural shock from the work environment in industry. They are simply a liability during the early phases of their employment, which at times deters some industries from promptly engaging university graduates upon exiting the university. Industry at times goes an extra mile to train them so that they reach a level on which they would be productive. However, not all industries are forth-coming to take up this burden. They would rather employ an experienced person than newly graduated university students. Therefore, the paper postulates a solution to this problem by presenting a Stellenbosch University Learning Factory (SULF) as a viable solution within the South African context. It reveals the competences required by industry on university graduates as they join the labour market. It also reveals some expected outcomes of Engineering Council of South Africa (ECSA) upon university graduates. Furthermore, the paper elaborates how the gap between industry and university may be mitigated by a learning factory approach in the educating of students.

2 LEARNING FACTORY APPROACH

Special skill requirements, demanded by industry and ECSA, require special use of appropriate teaching and learning methods, which meet specific training objectives in the fields of planning, implementation and optimization of production and manufacturing systems. Overally, there is a growing interest in practical and experiential learning environments. As a result, leading universities and colleges react by establishing learning factories [1-4].

These physical, operational factories usually cover the whole creation process of a product selected in accordance with didactical criteria and serve as exemplary and realistic hands-on learning environments. The concept of learning factories integrates self-directed and action-oriented learning in heterogeneous groups to encourage experiential knowledge, integrated into a formal didactical concept. This enables the trainer to address the intended competences systematically by guiding the learners through the processes necessary to acquire the intended knowledge and professional and/or vocational competencies. This symbiotic combination of the teaching of professional expertise, methods, individual competencies and soft skills [5, 6] may be achieved by combing traditional, instructor-based teaching methods with hands-on sessions held in teamwork to improve social and group work competencies. The tasks or problems students get confronted with are inspired by issues of high practical relevance and designed openly to avoid predefined solutions or approaches. By using mostly commercially available technologies in learning factories, a very authentic learning environment may be created, resulting in a highly immersive learning experience for the learners [7]. Additionally, high learning success is achieved by including the self-actions of and the interactions between the learners into the learning experience [4, 8].

Hence, the learning factory approach is seen as a didactical approach of learning which aims at producing graduates who have competences required in a real working environment [9]. These competences are acquired by students when exposed to real or simulated working environment during their university education [9].

2.1 Resources in a Learning factory environment

For a learning factory to produce the required calibre of graduates it should have a competent personnel (who may be lecturers, engineers and technicians). These should be able to interpret the requirements of industry and translate them into objectives of their specific modules and then create the appropriate content of study. They should be competent enough to communicate effectively those objectives to the students and be able to convey, using an appropriate methodology, the contents during the teaching period. A real work environment similar to an industrial set-up should be availed to university students to experiment in, as has been established in the case of Ruhr University, Darmstadt University [9] and Reutlingen University. The environment may be a physical room with the necessary equipment used in a real industrial set-up. In the case where such is not possible to achieve, a simulated environment may be a viable option. Videos of the real world of industry may also be used and video conference between students and engineers in their working environment as in the case of Greece [10].

2.2 Didactics in a learning factory

Learning involves mainly two parties: the students/ trainees and the educators/facilitators. The educators (in this case include lecturers, practising engineers, technologists and technicians) facilitate the learning of the students and industry's trainees in a learning environment. They facilitate in the sense that they expose the students and trainees to the learning factory modules (or subjects) and then allow them to methodologically apply the concepts in a hands-on session within a real industrial environment or simulated environment. In this learning factory environment, the lecturer does not use a teacher-centred approach to learning [11, but rather a student centred approach [11] in which the students or trainees empirically apply the knowledge obtained from the theoretical contents of the modules to a pseudo or real world environment at a level higher than simply doing an experiment in a laboratory. In some cases the students are given open-ended tasks without predefined solutions to allow them to develop the critical competences required in industry. Learning factories add flair to the learning environment by affording a "trial and error playing field" in which students and trainees may sharpen their competences by attempting to solve problems of industrial nature within the university premises [12].

3 SOUTH AFRICAN INDUSTRY AND ECSA REQUIREMENTS FOR LEARNING FACTORIES

3.1 ECSA Requirements

Generally the requirements of South African industry on university graduates are enshrined in the Engineering Council of South Africa (ECSA) outcomes and competences [13, 14]. These ECSA outcomes require university engineering graduates to have, among others, the following competences: problem solving capabilities, ability to apply scientific methods and tools to solve problems, capability to solve inter-disciplinary problems, capability to work independently, ability to work productively in teams, ability to solve as well as manage ambiguous and complex engineering problems [13, 14]. Although universities are trying to inculcate these competences in their students before existing the university, they are failing to adequately achieve this as revealed by some delegates who attended the South African Institute of Industrial Engineers Conference in 2013 (SAIIE 2013). The SAIIE 2013 delegates, during a discussion after an initial presentation on learning factory concepts, asserted that some engineering graduates are falling short as far as these competences are concerned, they even stated that some of them suffer a cultural shock, such that they are unproductive during the first period of their employment.

Currently, to improve the graduate engineers' competencies after leaving the university, South African companies have to train the graduates for some time to make them competent engineers. Normally the training is conducted under an ECSA registered mentor (a registered ECSA practising engineer). In some cases such training may take even more than two years. This paper proposes that the length of such training may be reduced if a learning factory approach is introduced at some point during the training of engineers.

3.2 Industry requirements for South African Learning Factories

In order to get the most benefit out of a Learning Factory; the taught competencies, processes and topics as well as the deployed infrastructure in the form of hard- and software have to be aligned with the requirements and needs of South African industry and academia. This alignment would at least partially bridge the mentioned gap between university and industry. Hence, approaching both parties before establishing a Learning Factory and developing learning modules is crucial.

3.2.1 Method

For this purpose, carrying out a workshop is an appropriate method of gathering special requirements for a South African Learning Factory. As in the case of the Stellenbosch University Learning Factory, such a workshop was carried out at a Conference of the International Academy for Production Engineering (CIRP) General Assembly which was held in Cape Town in 2015. In a four-hour workshop, participants from industry, academia and consulting were first introduced to the term ‘Learning Factory’ followed by an introduction into industrial engineering and its education in Learning Factories. On this theoretical base, two examples of Learning Factories were presented, the ESB Learning Factory of Reutlingen University and the Stellenbosch University Learning Factory which is currently in a developmental status. In order to tailor the Stellenbosch University Learning Factory to the needs of the local industry, specific requirements from industry were interrogated within a brainstorming session by posing three question:

- Question 1: What are the most relevant topics to be covered in the Learning Factory?
- Question 2: What processes should be presented in the Learning Factory?
- Question 3: What technologies are relevant; which IT-systems have to be integrated in the Learning Factory?

The workshop closed with a panel discussion with reference to the stated questions.

3.2.2 Main results of the workshop

Operations management methods, such as lean management, process optimisation and change management; and soft skills such as communication, team work, project management, intercultural and leadership skills, were among the most mentioned topics to be taught in Stellenbosch University Learning Factory. Besides those two learning areas, smart factories: including both the digital world and human/machine interface were also identified as relevant learning topics for a South African Learning Factory. A small number of participants mentioned also advanced design, product lifecycle management and networks as other topics to be included.

The most remarkable response to the question concerning processes which should be presented in the Learning Factory was that the entire product life-cylce, from the digital design and simulations stage through real production and assembly processes, including logistics and recycling, should be integrated in an Learning Factory environment by using cloud engineering and manufacturing exceution systems.

Concerning Information Technology (IT) and Technologies questions, answers were given in line with relevant processes which can be realised and supported by IT. Software for desiging and simualtion, software for planning and controlling manufacturing and production as well as software for allocating human resources and managing projects were recommended to be integrated in an South African Learning Factory environment.

3.2.3 Way forward

As a way forward, the knowledge gained from the workshop would be transferred into learning concepts that form the base for the development of learning modules for students and industry’s participants who would be trained at the Stellenbosch University Learning Factory. Synthesising the outcomes of the learning factory through the internal enterprise architecture in Figure 1, the Stellenbosch University Learning Factory would in its initial phase cover the areas highlighted in yellow.

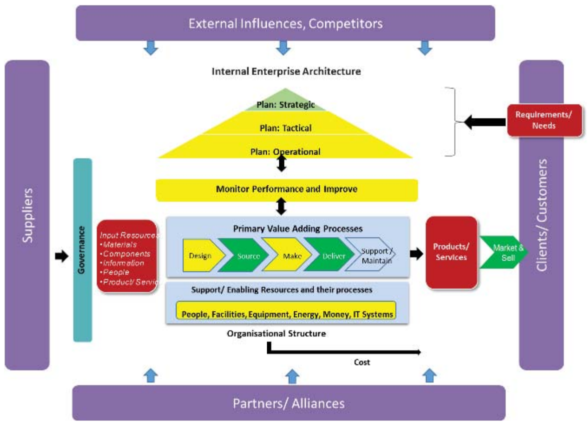

Figure 1 - Areas covered by Stellenbosch University Learning Factory

The Production Management modules would initially cover the operations management aspects (lean management, logistics, process optimisation and team work) the Quality Assurance module would cover aspects related to performance monitoring and improvement as well as product life cycle; Industrial ergonomics would cover aspects to do with the interaction among human resources, machines and the environment with respect to safety and ethical requirements. Manufacturing processes and Manufacturing systems would cover competences to do with design, production, assembly processes and simulation. Since a product is required in the morphology of a learning factory [15] alongside the learning modules, a collaboration with the Passenger Rail Agency of South Africa (PRASA) Research Chair has been initiated in which physical rail wagon models would be used in the Stellenbosch University Learning Factory.

With respect to the required ECSA competences [14] upon engineers, Table 1 shows a synthesis of some of the broad competencies engineering graduates are expected to have after undergoing Stellenbosch University Learning Factory environment.

Modules	Broad Competences
Production Management	Competency to manage complex engineering activities [14]
Manufacturing Processes and Manufacturing System	Competency to design and develop solutions to complex engineering problems [14]
Industrial Ergonomics	Competency to make ethical decisions [14] .
Quality assurance	Competency to meet standards expected independently in employment or practice [14]

Table 1- Module Competences

Figure 2 shows the educational pyramid, revealing the gap a learning factory fills in the production of engineering graduates who are better geared for the working environment in industry. In a university set-up, normally students firstly attend lectures, secondly they do tutorials, thirdly they may do experiments in laboratories, and fourthly they should then be exposed to the learning factory before they exist the university as indicated in Figure 2.

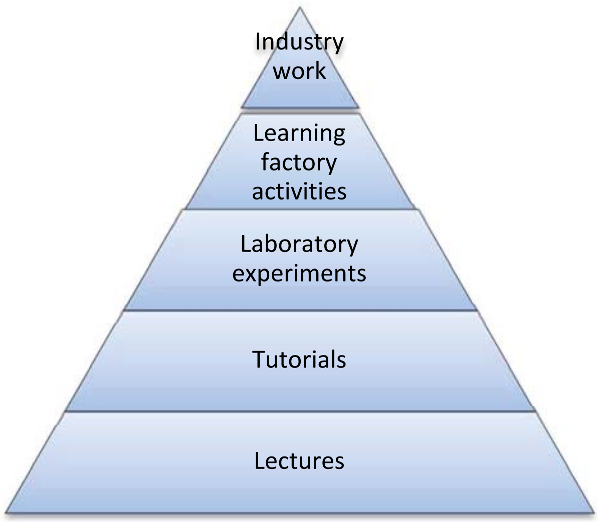

Figure 2- Learning factory - gap filling

In the learning factory environment, students attempt to solve a real world problem using a systematic, integrative approach applying various concepts they would have learnt in their learning-factory-tailor-made modules [12]. The problems could be holistic and complex in nature, not unidirectional – affording students various options as solutions, thereby necessitating the need to brainstorm, analysing the problem before synthesising a solution. This affords them the opportunity to work as a team in solving multi-directional and multi-disciplinary problems by logically applying various concepts learnt in their modules and outside the module as they would have researched [12]. It should be noted that the methodology used to solve the problem is not merely an experimental approach under normal laboratory conditions, but rather at a higher level, in which a logical, systematic and integrative approach is applied in solving a real-world complex problem [9].

4 CONCLUSIONS

In conclusion, a learning factory is an environment in which students are exposed to a real-world or simulated environment in which they tackle real-life problems which might be multi-directional and interdisciplinary in nature so that they develop industry-required competences by experientially exploring solutions. From the CIRP Learning Factory's workshop inputs, Stellenbosch University Learning Factory would provide a similar environment so that its engineering graduates would acquire competencies to design and develop solutions for complex engineering problems as well as to manage complex engineering activities. By offering tailor-made learning modules, delivered by a learning factory approach, the competence gap between student capabilities and the industry's as well as ECSA's expectations in a South African context can be mitigated.

5 REFERENCES

[1] Abele, E., Cachay, J., 2012 "Kompetenzentwicklung durch Lernfabriken: Lehrplan für Shopfloor-Mitarbeiter bei proaktiven Verbesserungsprozessen," wt *Werkstattstechnik online, Volume 102 (2012)*, Issue 3, p. 88-93.

[2] Bauernhansl, T., Dinkelmann, M., Siegert, J., 2012, "Lernfabrik advanced Industrial Engineering – Teil 1: Lernkonzepte und Struktur," wt *Werkstattstechnik online, Volume 102 (2012)*, Issue 3, p. 80-83.

[3] Plorin, D., Poller, R., Müller, E., 2013, "advanced Learning Factory (aLF) – Integratives Lernfabrikkonzept zur praxisnahen Kompetenzentwicklung am Beispiel der Energieeffizienz," wt *Werkstattstechnik online, Volume 103 (2013)*, Issue 3, S. 226-232.

[4] Tietze, F., Czumanski, T., Braasch, M., Lödding, H., 2013, "Problembasiertes Lernen in Lernfabriken – Ingenieursausbildung und Weiterbildung im Bereich der schlanken Produktion," wt *Werkstattstechnik online, Volume 103 (2013),* Issue 3, p. 246-251.

[5] Gerst, D., 2007, “Humanressourcen” appears in: Arnold, D.; Isermann, H. et al. (Ed.): Handbuch Logistik. *Springer-Verlag*, Berlin.

[6] Ott, B., 2011, “Grundlagen des beruflichen Lernens und Lehrens – Ganzheitliches Lernen in der beruflichen Bildung,” 4. Edition, *Cornelsen*, Berlin.

[7] Steffen, M., Frye, S., Deuse, J., 2013, “Vielfalt Lernfabrik – Morphologie zu Betreibern, Zielgruppen und Ausstattungen von Lernfabriken im Industrial Engineering,” wt *Werkstattstechnik online, Volume 103 (2013)*, Issue 3, p. 233-239.

[8] Cachay, J., Wennemer, J., Abele, E., Tenberg, R., 2012, “Study on action-oriented learning with a Learning Factory approach,” *3rd international Conference on New Horizons in Education (INTE),* June 5th – 7th 2012, Prague

[9] Abele, E., Metternich, J., Tisch, M., Chryssolouris, G., Sihn, W., ElMaraghy, H., Hummel, V., Ranz, F., 2015, Learning Factories for research, education, and training, *The 5th Conference on Learning Factories 20, Procedia CIRP 32*, pp.1 – 6.

[10] Rentzos, L., Mavrikios, D., Chryssolouris, G., 2015, A Two-way Knowledge Interaction in Manufacturing Education: The Teaching Factory, *The 5th Conference on Learning Factories* , *Procedia CIRP 32*, pp. 31-35.

[11] Brown K. L., 2003, From teacher-centered to learner-centered curriculum: Improving learning in diverse classrooms *Education;* Fall 2003; 124, 1; ProQuest Education Journals pg. 49-54

[12] Nöhring, F., Rieger, M., Erohin, O., Deuse, J., Kuhlenkötter, B., 2015, An Interdisciplinary and Hands-on Learning Approach for Industrial Assembly Systems, *The 5th Conference on Learning Factories 2015, Procedia CIRP 32*, pp. 109-114.

[13] ECSA EXIT LEVEL OUTCOMES, Extract from EXCSA Document PE-61/E-02-PE Rev-2 26 July 2004 http://www.up.ac.za/media/shared/Legacy/sitefiles/file/44/1026/2063/2012ecsaexitleveloutcomes_ownextractfrome02_.pdf, Accessed on 30/09/2015

[14] Guide to the Competency Standards for Registration as a Professional Engineer, Engineering Council of South Africa (ECSA), Document: R-08-PE, Rev 1.0, Approved by ECSA on 12 January 2012, pp 1-17. https://www.ecsa.co.za/ECSADocuments/ECSA%20Documents/Documents/R-08-PE.pdf, Accessed on 30/09/2015

[15] Tisch M., Ranz F., Abele E., Metternuch J., Hummel V., 2015, Learning Factory Morphology – Study Of Form And Structure Of An Innovative Learning Approach In The Manufacturing Domain. *Turkish Online Journal of Educational Technology 08/2015*; Special Issue (2):356-363.

6 BIOGRAPHY

Andre F. Van der Merwe is an Associate Professor in the Department of Industrial Engineering at Stellenbosch University. He holds a PhD in engineering obtained at Stellenbosch University. His research interests are in advanced manufacturing, resource efficient production engineering and learning factories.

Vera Hummel, Prof. Dr.-Ing., has been a professor at the ESB Business School, Reutlingen University since 2010. Before she was working from 1994 to 2008 for the Fraunhofer IPA and the IFF Universität Stuttgart. She is the initiator of the ESB Logistics-Learning Factory at Reutlingen University. Currently she is leading the Education and Research Centre “Logistik- und Wertschöpfungssysteme” at Reutlingen University. Her research, consulting and trainings topics cover industrial engineering, logistics management, quality management and business excellence.

Stephen Matope is a Senior Lecturer in the Department of Industrial Engineering at Stellenbosch University since 2012. He holds an MSc (Manufacturing Systems and Operations Management) UZ and a PhD (Industrial Engineering) obtained at Stellenbosch University as well as a Diploma in Education (Technical and Vocational). His research interests are in manufacturing engineering and learning factories.