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The Learning Factory – A New Stimulus to Enhance International Collaboration

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Abstract

The paper describes a new stimulus using learning factories and an academic research programme - an M.Sc. in Digital Industrial Management and Engineering (DIME) comprising a double degree - to enhance international collaboration between four partner universities. The programme will be structured in such a way as to maintain or improve the level of innovation at the learning factories of each partner. The partners agreed to use Learning Factory focus areas along with DIME learning modules to stimulate international collaboration. Furthermore, they identified several research areas within the framework of the DIME program to encourage horizontal and vertical collaboration. *Vertical* collaboration connects faculty expertise across the Learning Factory network to advance knowledge in one of the focus areas, while *Horizontal* collaboration connects knowledge and expertise across multiple focus areas. Together they offer a platform for students to develop disciplinary and cross-disciplinary applied research skills necessary for addressing the complex challenges faced by industry. Hence, the university partners have the opportunity to develop the learning factory capabilities in alignment with the smart manufacturing concept. The learning factory is thus an important pillar in this venture. While postgraduate students/researchers in the DIME program are the enablers to ensure the success of entire projects, the learning factory provides a learning environment which is entirely conducive to fostering these successful collaborations. Ultimately, the partners are focussed on utilising smart technologies in line with the digitalization of the production process.

Peer review under the responsibility of the scientific committee of the 9th Conference on Learning Factories.

Keywords: Learning Factory; International Collaboration; Star Network; Horizontal and Vertical Collaboration

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1. Introduction

It is normal practice for universities to conduct international collaborations through faculty exchanges, joint research work, publications, conferences, and student mobility programmes. With the advent of Industry Revolution 4.0, there is a now pressure on universities to collaborate to build their knowledge and technological capabilities with a focus on digitalization [1]. This paper addresses strategic moves made by four partner universities in order to sustain and enhance international collaboration so as to accelerate the development of academic and research programs associated with Industry 4.0. Hence this paper proposes a new initiative, namely to use the learning factory as a platform to enhance collaboration between the participating partners with an academic program as enabler to create research projects related to digitalization for the benefits of its members [2]. The paper discusses the special arrangement made between four participating universities, whereby they agreed to use their learning factories as a means to explore and enhance the university capabilities in relation to digitalization. Furthermore, it was also agreed that a master double degree programme called the Digitalization Industrial Management and Engineering (DIME) program should be offered with partner institutions to ensure the long term success of the new collaboration model, the Star Network (of which there is a detailed description in the third section) [3]. The model addresses success factors in research collaboration such as access to expertise [4] and to resources, the exchange of ideas [5] and other aspects which raise the potential for collaboration (see [6]). It proposes an extension of the existing morphology of learning factories introduced by Abele et.al. [2] and the systematic development of the learning factory content. In addition, the model addresses the problem of content improvement and examines how it can not only be propagated through individual commitment and one-off events such as a research projects or grants, but also by means of a systematic process – in this case the collaborative DIME study program.

The four participating universities in this study were Universiti Malaysia Pahang, Purdue University, and Stellenbosch and Reutlingen Universities from South Africa and Germany respectively. The learning factories of these institutions have developed a few thematic focus areas and each of them brings certain values to the network. This international collaboration has been made possible through the development of the Star Network headed by Reutlingen University which offers the DIME programme to its three participating partners. This has led to another level of collaboration being established between members via the concepts of horizontal and vertical cooperation. The paper is divided into five sections: the second discusses the collaboration model, the third describes the Star Network -, the fourth explains the collaboration outlook, while the fifth offers a conclusion.

2. Collaboration Model

The aim of this international collaboration is to enhance the technological capabilities of the partners' learning factories' in line with the requirements of digitalization or Industry 4.0 [7]. Currently, each of the learning factories utilises digitalization to a certain degree in their production process, supply chain and logistics, data management and other related systems. As shown in Figure 1, the ultimate goal of this collaboration is to increase the adoption of smart technologies by the learning factories the participating partners.

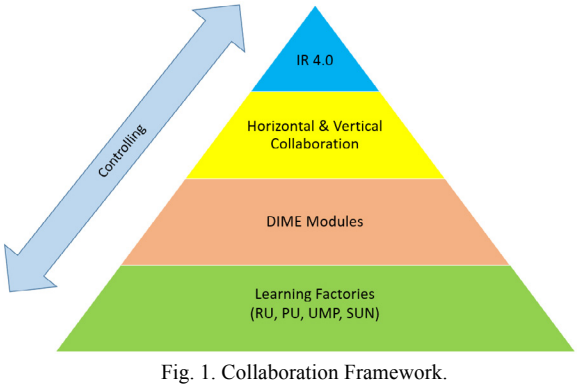

Fig. 1. Collaboration Framework.

The current partners in the network are the ESB Business School of Reutlingen University of Applied Science (RU), the Department of Industrial Engineering of Stellenbosch University (SUN), the Purdue Polytechnic Institute of Purdue University, and the Faculty of Industrial Management of Universiti Malaysia Pahang (UMP). Each participating institution focuses on certain thematic areas: the learning factory at RU is specialising in digital industrial engineering, SUN is investigating supply chain management and digital twins, Purdue is applying itself to robotics, sensors and smart automation, while UMP is spotlighting data analytics and distributed ledger technologies. Although the partners are specializing in somewhat different areas they all share a common objective, which is to offer a platform for students to develop disciplinary and cross-disciplinary knowledge and applied research skills necessary for addressing the complex challenges faced by industry.

Nevertheless, these differences have created a new opportunity for the sharing of knowledge through the DIME program wherein all partners are required to participate in a Star Network collaboration (detail description in the next section below). The DIME program enables each partner to offer a couple of modules from their area of expertise to postgraduate students within the Star Network.

As mentioned earlier, the postgraduate students in the DIME program act as enablers creating many research opportunities through horizontal and vertical collaboration. The following section will describe the details of Star Network and explain how horizontal and vertical collaboration is used to support learning factories in their quest to enhance their technological capabilities in line with Industry 4.0.

3. Enhancing International Collaboration

The aim of the Star Network is to establish horizontal research areas (horizontal cooperation) and to use the double-degree DIME program, (which as a Research Masters involves extensive research activities), as a driver for international collaboration [8] and of bilateral vertical research projects (vertical cooperation). It is intended that the horizontal research areas form a framework for future joint bilateral research activities between "ESB and partner university." Moreover, the DIME Research Masters will act as a mechanism through its annual research projects to further research sustainability and continuously develop the learning factories of each participating institution. At the same time, potential future experts are familiarized with important aspects of research and development such as scientific work, intellectual property, ethical aspects, interdisciplinary endeavours, work in international networks, various research and development methods as well as opportunities and challenges of digitization during their studies. It is thus through this program that the fundamental aspects of a successful career in research and development are inculcated.

To this end, it was necessary to establish thematic priorities from the research activities of the individual partners. The analysis was carried out in discussions with representatives of the partner universities and via on-site visits. Areas of thematic focus had to conform to the following criteria:

- To be of sufficient depth and focus to warrant inclusion as individual topics in the DIME study program
- To be of sufficient relevance to justify the further development of the learning factories at the individual locations
- To be of sufficient temporal scope and significance to generate research topics over a medium-term time horizon (> 5 years).
- To be of sufficient depth in terms of thematic focus to generate Master and PhD topics
- To be of sufficient interest to both partners to motivate them to maintain the thematic focus over a longer period of time
- To be of sufficient scientific novelty to be able to inspire new research-relevant topics
- To be of sufficient difference from the research topics of the partners to create distinguishing features in the bilateral cooperation.

The following main topics (thematic focus) with the above-mentioned properties were derived:

- ESB: Digital Industrial Engineering- SUN: Supply Chain Management / Digital Twin
- ESB: Digital Industrial Engineering - Purdue: Smart Automation / Sensors and Robotics
- ESB: Digital Industrial Engineering - UMP: Digital Analytics and Distributed Ledger Technologies

These topics are to be integrated into the "Regional Basket" of DIME in the form of two lecture modules (10 ECTS) to be run at each participating institution. Thus, students will be given the opportunity to choose their own areas of emphasis under the subject "Digitalization / Industry 4.0".

These topics form the areas of horizontal cooperation in the DIME study program as well as the framework for the vertical cooperation activities - the DIME research topics, which encountered by students in the course of their Master's studies (see Figure 2). The place of research or validation is the learning factory of each partner in the network. It is a requirement that the individual research topics of the students must lie within the thematic focus areas agreed in the bilateral cooperation. Both partners are to agree on the topic and jointly supervise the writing of the thesis. This will ensure that each individual thesis contributes to the further development of their respective learning factories. This will ensure a constant systematic process of further development at the content level.

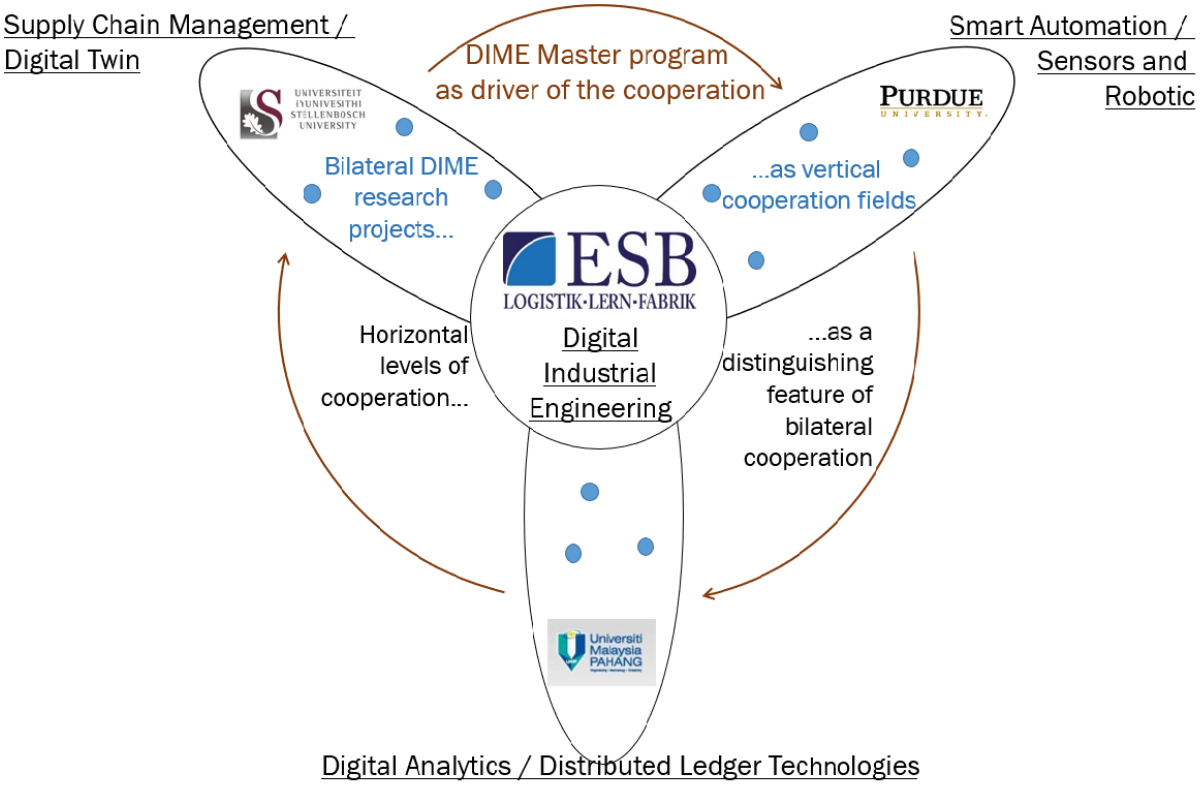

Fig. 2. Star Network Model.

4. Collaboration Outlook and Limitations

The collaboration of Star Network members can be considered a new initiative to accelerate learning and capacity building towards Industry 4.0. All available resources (knowledge, finances and technology) are to be used to synergize a range of disciplines across the network to explore and expand the fund of knowledge. In this way, partner institutions can link and leverage faculty and technology resources across the network to accelerate

development of their academic research related to Industry 4.0 while at the same time investing in their learning factories for the future.

From the focus group discussion among participating partners, it was evident that there is considerable interest in linking the DIME program directly to other member institutions besides Reutlingen University. Alternatively, there might be new institutions joining the network leading to the formation of new thematic focus areas. Hence, there is a great potential to develop the Star Network into a Fully Connected Network that will see other cluster areas emerging with students being able to obtain a double Masters degree from other institutions of their choice.

Nevertheless, there are a few potential constraints to this cooperation. The key issues are financial resources for student mobility, different educational systems and diversity in learning factory technology. The programme requires students to travel to partner institutions for at least one semester where they will take a couple of modules and undertake research work- at the learning factory. This will incur a substantial amount of travelling and living expenditures overseas; hence it is important for students to secure funding prior to joining the DIME study program. The second issue is lack of compatibility between the educational systems of the different universities/countries. Areas of discrepancy include, but are not limited to entry requirements, study duration, and study credit systems as well as the academic calendar. Consequently, the study programs can only be implemented if partner institutions manage to compromise over the differences. The third potential constraint is the different levels and systems of technology implemented at the various learning factories. Each of the four partners will inevitably develop their learning factories to their own specific system specifications. Eventually this could create potential challenges when a partner institution is interested in sharing their technology with other institutions with incompatible systems. Therefore, it may be necessary to modify or customise the technology at the partner institutions before transferring or utilizing the technology.

5. Expansion of the network by industrial partners

Research and development is not an aim in itself. The prosperity of a society is directly related to applied research and thus to the connection between universities and the industrial environment, regardless of the sector. Cooperation with industrial companies could be the next level in the expansion of the Star Network. Within the framework of collaborative research, two models could come into operation. In the first model, a partner of the Star Network would carry out coordinated projects with industrial partners so that the students could develop solutions with partners who are in practice. A second model could involve an international company working on research tasks with an internationally staffed research team as the core element. Young researchers would learn to conduct research in an international team at a very early stage. The learning factories, which are a feature of all partner institutions, would also be an ideal environment for researching, implementing and validating solutions and approaches before they transferring them to the industrial environment. With both models, students could be inspired very early on in their education to become engaged in research and development in an industrial environment. A positive side-effect of both models could be that the companies could contribute a small share of the financial expenses for the international stays at the respective universities, which are mandatory for the double degree. Before such an expansion of the network, the issues of intellectual property and different country-specific regulations must first be analysed and resolved.

6. Conclusion

In this paper we have presented the framework for a Master's double degree program that leverages learning factories at all partnering institutions to proliferate the dissemination of Industry 4.0 knowledge and research on a global scale. Collectively the horizontal and vertical collaboration models featured in this work will enable partner institutions to introduce and engage in Industry 4.0 research from the perspective of multiple institutions from across different nations, all engaged in related efforts. The advantage of this for students is that it will give them the opportunity to work on real research problems associated with Industry 4.0, keep on top of the latest research developments, have a highly rewarding intercultural experience, and develop the capability to work across cultures

in the field of science and engineering. For the institutions, the learning factory ecosystem offers an expanded research network, access to a broader range of expertise and specialized capabilities, a better global understanding of industry needs in relation to the Industry 4.0 research resulting from this collaboration.

In future research, we intend to introduce an example of a systematic process to improve and further develop the content of the system "learning factory" and we also propose to extent the morphology of learning factories introduced by Abele et.al. [2] in relation to the content-related development of a learning factory.

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