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Cooperation between Learning Factories: Approach and Example

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Abstract

Learning factories can complement each other by training different competencies in the field of digitalisation and Industry 4.0. They depict diverse sections of the product development process and focus on various technologies. Within the framework of the International Association of Learning Factories (IALF), the operating organisations of learning factories exchange information on research, training and education. One of the aims is to develop joint projects. The article presents different concepts of cooperation between learning factories while focusing on the improvement of the development of learners competencies e.g. with a broader range of topics. A concept of a joint course between the learning factories in Bochum, Reutlingen and Darmstadt is explained in detail. The three learning factories will be examined with regard to their similarities and differences. The joint course focuses on the target group of students and the topic of digitalisation in the development and production of products. The course and its contents are explained in detail. The new learning approach is evaluated on the basis of feedback from the participants. Finally, challenges resulting from the cooperation between learning factories at different locations and with different operating models will be discussed.

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Keywords: Students; Education; Digitalization

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1. Introduction

Nowadays there are many different learning factories worldwide. Especially in the last 10 years, the amount of learning factories has increased rapidly favored by scientific publications and the founding of different networks. [1] All of these learning factories are dedicated to different topics. For example, over 80% of the learning factories address the issue of lean management and process optimization, almost half of them focus on production planning or quality management closely followed by topics such as business processes, assembly processes, digital factory or logistics [2].

This paper describes how three learning factories of the TU Darmstadt, the ESB Business School Reutlingen and the Ruhr-Universität Bochum work together across locations in different areas along the product life cycle in a lecture course, which is implemented in the respective curriculum. It reflects the global process flow of companies [3]. This assumption includes new competencies of students and future engineers as they are also going to work together with different departments and across various locations in their jobs [4]. After explaining the demand for the cooperation between different learning factories, the detailed approach of these three learning factories will be explained. The paper ends with an outlook about the further cooperation on an international level and about new topics and current trends.

The International Association on Learning Factories (IALF) initiated this approach. The IALF is a continuation of the Initiative on European Learning Factories (IELF), which was founded in 2011. Initially used as an European program the focus shifted towards international cooperation which initiated a change of the name to IALF in 2017. It is dedicated to international cooperation and development on the topic of learning factories. [5]

2. Approach to establish cooperation between learning factories

Learning factories are already cooperating with companies and university institutes in order to provide employees and students with an extended range of offers. Therefore, these cooperations usually arise from individual projects or through personal contacts. Examples are the summer and winter school within the joint NIL project (see [6]) or the establishment of a double degree master program “Digital Industrial Management Engineering” (Business School Reutlingen and Stellenbosch University). There is no approach that allows a systematic identification of learning factories for cooperation in order to provide customers (employees, students etc.) with the best possible offer. Therefore an approach was developed to support the identification of learning factories regarding specific topics and learning demands (see Fig. 1).

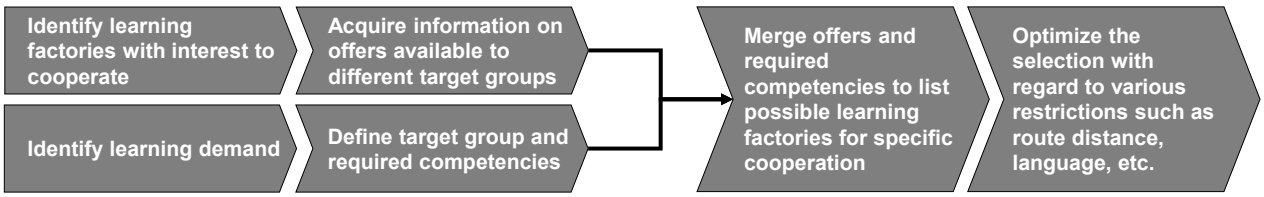

Fig. 1. Approach to establish cooperation between learning factories.

In a first step, learning factories with the intention to cooperate are identified. For example, one goal of the IALF is to cooperate in different fields of research and training. Next, information is acquired about the topics the learning factories address along the product life cycle and about the target group to which the offers are available. Surveys may be used to collect this information. These two steps define the possibilities for cooperation.

At the same time, the needs for cooperation must be defined. Therefore, the learning demands for a specific target group are identified. For many learning factories, the focus at the present time is to teach students topics in the field of digitalization. Subsequently, the competencies to be taught must be specified. Here the application of a learning

factory design on three design levels and the creation of competency transformation charts are recommended (for details see [6,7,8,9,10,11,12]). Examples of competencies in the field of digitalization include selecting assistance systems [13], implementing cyber physical systems [14] or realizing traceability [15].

In the next step, the offers of the different learning factories and the competencies are merged. The result is a list of learning factories, which have different offers regarding various target groups and are willing to cooperate. Ideally, the offers of one learning factory to another complement to close the competency gap. Now, restrictions regarding the selection have to be considered to make a final decision concerning the cooperation. Typical examples for restrictions are the offered languages, the length of trainings, available capacities or the distance between the learning factories. Especially the last one influences the costs of the trainings or learning modules. Furthermore, especially for students a short and therefore inexpensive journey is important. In order to select learning factories in terms of their distance from each other, algorithms can be used to solve the traveling salesman problem, for example. For a cooperation in the field of digitization for competency development for students, learning factories in Reutlingen, Bochum and Darmstadt were identified taking into account further restrictions, in particular language and distance.

3. Concept details

The joint course “Digitalization in Development and Production” has been conducted in the three learning factories of the Technical University of Darmstadt (TUDa), the Chair of Production Systems (LPS) at the Ruhr-University Bochum (RUB) and ESB Business School (ESB). Although these learning factories have some common topics, e.g. in the field of production and technical and informational assistance systems, the content of the joint course has been structured following the product creation process to minimize overlaps in course content (see Fig. 2). The target group of this course were graduate students coming from the different engineering and industrial engineering programs of the three universities. The major intended learning outcomes have been to improve the theoretical and practical knowledge in the field of digitalization in the development and production of products. Therefore, the addressed course contents have mostly been structured in a short theoretical lecture, discussions with the students and group works as well as hands-on exercises in the learning factories. For the group work and hands-on exercises, the groups were divided up so that the groups were mixed with students from different universities to foster the collaboration and exchange of knowledge between the universities and at the same time to address the aim of an improvement of the social skills of the students by working in interdisciplinary teams. The grading of the course have been done in line with study and examination regulations of the collaborating universities and included the grading of group and hands-on tasks as well as a written exam. Since the study and examination regulations at TUDa and RUB required a higher number of credits for this course compared to ESB, the students from TUDa and RUB had to hold an additional graded individual presentation at their home university.

Major topics of the course at the RUB were introduction to the overall course topic as well as workshops dealing with informative (e.g. data glasses) and technical assistant systems (collaborative robots) for assembly and maintenance including the identification and assessment of the required assistance levels for different applications. In addition, the students got in touch with the effects of assistance systems on industrial employment and employee participation from a company and trade union perspective.

The course at the learning factory at TUDa addressed the influence of Industrie 4.0 on lean production and shopfloor management as well as lectures and workshops on the digitalization of key performance indicators and different methods for systematic problem-solving and continuous improvement as Ishikawa-diagrams, Plan-Do-Check-Act and Gemba Walks. The learning objectives included answering the question of how digitalisation can be implementet beneficially in shopfloor management.

At ESB, a major focus has been set on the topics of smart logistics and intelligent logistical infrastructure as well as the seamless digital product and process engineering based on the 3DExperience business platform (Dassault systemes). Amongst others, short lectures and hands-on experiences about additive manufacturing and human-robot-

collaboration in production and logistics have been conducted. Since the students already got in touch with some collaborative robot systems for assembly applications during the course at RUB, the focus has been set on other collaborative robot models (such as Bosch APAS) and human-robot-collaboration applications in logistics. As an interdisciplinary workshop task, the students dealt with the product and project engineering for a new robot gripper to be used for automated material provision applications for the learning factory at ESB. After the students had finished the design and (additive) manufacturing of the gripper (each of the three groups for a different robot and application), they programmed their respective collaborative robot to test the gripper and presented their solution to the other groups. Finally, the students were involved in an idea competition to design a production network for a joint product of the learning factories in RUB, TUDa and ESB combining the major competence fields of these factory environments. This idea competition had been set up to generate ideas for a future production network of all involved learning factories based on a common product, to enable a holistic cross-learning factory course along the product creation process. For example, the product and process engineering for this common product might be done based on the 3DExperience business platform of ESB and the manufacturing of the product components might be distributed on the learning factories of RUB and TUDa. The assembly of the product can be done in more than just one learning factory to have a hands-on experience about different possibilities how to perform the intralogistics and assembly processes based on different technologies (e.g. Data glasses, automated guided vehicles, collaborative robots) which are available in the learning factories.

Although the major focus areas of the involved leaning factories is intended to stay the same, a continuous adjustment of course content to relevant topics in the field of digitalization of production is part of the course concept which is reviewed after each course cycle based on the received feedback and ongoing (research) projects.

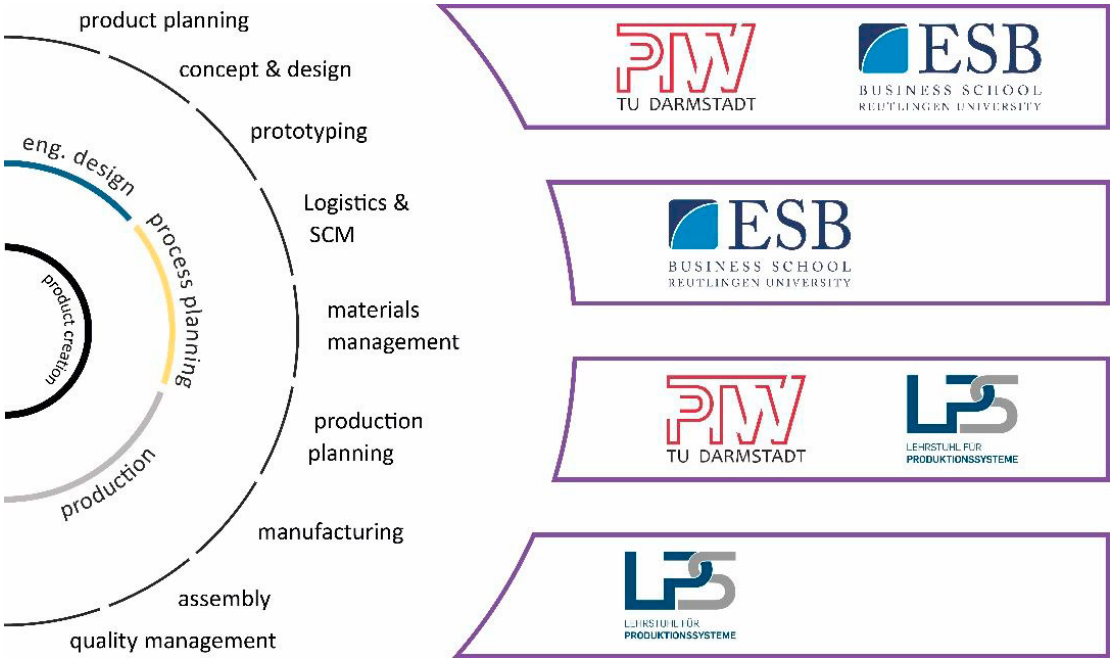

Fig. 2. Course structure following the product creation process.

In order to further improve the course, standardised evaluation questionnaires were answered by the students after the course units. In these questionnaires, the students were asked, for example, about their opinion regarding the content and structure of the respective course units, but also about concrete suggestions for improvement. Overall feedback of the participants was very positive with a wide range of innovative and interesting topics, which are

addressed from different points of view at the learning factories. Participants also liked the share of new and known content as well as getting to know other learning factories apart from their home university's learning factory. On the other hand, the students stated that the consistency and coordination of topics between the learning factories could be improved. In addition, the students remarked that due to the duration of the course, which lasted three days for each learning factory, there was a time overlap with other (compulsory) lectures. To cope with these points of criticism, measures as a transfer of the course into a holistic cross-learning factory product creation project have been considered. First ideas and concepts for this have already been generated during the idea competition at the ESB. This would result in a production network involving various learning factories. Alternatively, overlaps in content could be reduced by choosing learning factories with more diverse application fields.

4. Conclusion and outlook

Within the framework of the presented cooperation project on the basis of a university course for students an approach for the initiation of cooperation between learning factories is introduced. It was possible to demonstrate that a multitude of aspects like different organisational circumstances or limited capacities have to be considered in the run-up phase of a new cooperation. Clear differentiation of content and a solid preparation of the cooperation project can be critical for success. However, the fact that there are no databases for the thematic or competency-oriented selection of potential partner learning factories and that decision-relevant data must first be collected in the form of surveys is still a problem today.

First elements of the presented approach have already been applied in the development of the presented course. Especially in the area of the content conception of the course the participant´s feedback demonstrated that a structured approach and the avoidance of thematic overlaps is an important aspect perceived by the participants. It was also possible to show that although various organisational restrictions (e.g. other semester dates, etc.) had already been taken into account when setting the course dates, there was still further potential for improvement here as well.

Nonetheless, the course is a highly valuable form of collaboration between different learning factories and is particularly well received by students. For this reason, it is important to develop the course sustainably. During the implementation and evaluation of the event in the summer semester of 2019, it was criticised that digitalisation in some parts of the course was not being carried out properly and the theoretical part was too high. Based on this feedback, the adaptation of the contents and implementation of AI and machine learning as thematic components of the course is planned for the summer semester 2020 in order to take the feedback into account. In order to be able to identify feedback and the need for improvement even better in the future, work will continue on standardising the evaluation instruments. One of the biggest challenges for the course, apart from scheduling, was to achieve an overall package that was interesting for the students as well as coordinated and consistent in terms of content. This is also the biggest advantage of the cooperation, because the students were offered an exciting tutorial, which provided insight into different learning factories. This was confirmed by the students during the evaluation.

There is also a desire to internationalise the course in future years. One possible platform for this would be the EIT Lift program, but such internationalisation could also be achieved within the framework of the IALF. Nevertheless, internationalisation also poses new challenges for the conception of the tutorial. In addition to the enormous opportunities offered by the internationalisation of the format, the increased travel efforts for participants and the differences in semester organisation between different countries and international universities must also be taken into account.

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