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A product selection method for the configuration of learning factories

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Abstract

A structured and systematic process plays an important role for the learning factory design. Especially the technical configuration of a learning factory determines its future application possibilities in research, training, and teaching. As part of the technical configuration, the selection of a product that best fits the set objectives is a challenge. This publication presents a method for the selection of products in learning factories. In the method, three successive phases are distinguished: in phase 1, the primary goals of a learning factory are defined and detailed into intended competencies and research targets. Next, in phase 2, the product and production requirements are derived, which are mutually dependent. A distinction is made between mandatory and optional requirements. While, the identified mandatory requirements allow a preselection of possible products, the optional requirements are used to evaluate these preselected products. Based on the preselection, in phase 3 the most suitable product can be identified that best meets the optional requirements.

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1. Introduction

As the number of companies and institutes operating learning factories (LF) increases worldwide, the systematic design approach plays an important role [1]. The technical configuration of a LF determines its possibilities in research, training, and teaching. In this context, a suitable product for the LF must be found. However, traditional factory planning approaches, such as the German standard VDI 5200 [2], do not provide any assistance in this regard. Despite the importance, previous approaches for LF design do not focus on the selection of the product for the LF. Therefore, the research objective of this publication is to develop a method for selecting products in LF based on the set objectives. The remainder of this paper is organized as follows: Chapter 2 describes the basics of designing LF. The focus is on previous procedures for product selection. Chapter 3 presents the developed method that is divided in three phases. This publication concludes with a short summary and an outlook in Chapter 4.

2. Basics on the design of learning factories

Various approaches exist for the LF design [3]. The most used approach is by Abele et al. [1,4], which is based on three design levels of the LF concept: the macro level (LF infrastructure and curriculum), the meso level (learning modules) and the micro level (learning situations) [5]. After determining the organizational environment, the organizational targets and the target groups, the intended competencies are derived. Subsequently, the infrastructure and the didactics are determined. The product is part of the socio-technical infrastructure on which the processes and factory elements are based. To design a LF, a morphology is used in the beginning that indicates

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the scope for the design [6]. The morphology is divided into the design dimensions of LF (e g. product). The design dimension "product" comprises different design elements with different characteristics.

In the design approach of Abele et al., the product is based on defined structural requirements [4], but no methods are given to select a product. The product selection is discussed in other design approaches: Wagner et al. [7,8] used a value-benefit analysis for this purpose. Küsters [9] describes a procedure in which a shortlist and the final product are derived from a longlist of products. Again, the selection process remains unclear.

3. Method for the selection of a suitable product

Based on the presented design approaches for LF, a product selection method was derived. The method is divided into the three successive phases “targets”, “requirements” and “design” (see Fig. 1).

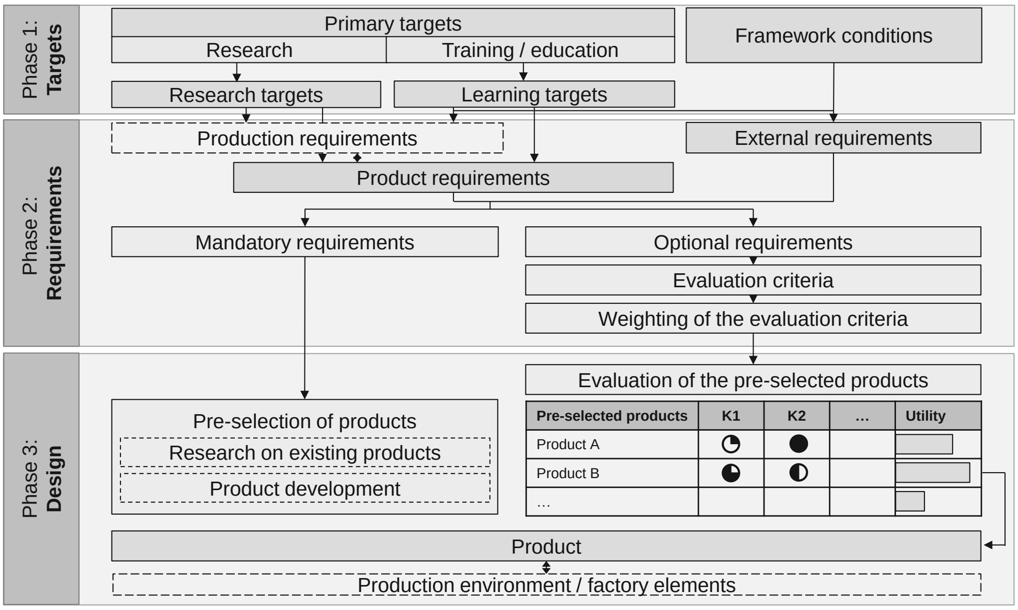

Fig. 1. Product selection method for LF.

In **phase 1**, specific targets are derived from the primary targets of research, training, and education [6]. Hence, the targets of this phase are research and learning goals. In addition, the framework conditions of the organizational environment should be examined in more detail (e. g. the industry to be mapped).

Subsequently, in **phase 2**, production und product requirements are derived from the targets and framework conditions. Additional external requirements are derived from the framework conditions. The requirements are mutually dependent. For example, some production requirements (e.g., demonstration of milling process) may cause product requirements (e. g. milled component) and vice versa. All requirements should be divided into mandatory and optional requirements depending on their priority because they are handled differently in the following steps: Evaluation criteria for the pre-selection of potential products are formed from the optional requirements. These evaluation criteria are to be weighted regarding their importance for the product used in the LF, e.g. by use of a pairwise comparison [10] or the Analytical Hierarchy Process [11]. For an objective and valid evaluation of the product each evaluation criterion must be operationalized.

The design of the product takes place in **phase 3**, in which a pre-selection of potential products should be conducted based on the mandatory requirements. If the LF is intended for a company, products that are manufactured in-house should be considered. If the LF is intended for a research institute, one can use existing products from other LF as a guide or use creativity techniques to create or select new products. A list of exemplary products used in LF can be found in [1]. If the mandatory requirements are not covered by any existing product, product development methods should be applied, e.g., in the VDI 2221 [12] or the Axiomatic Design [13]. Subsequently, the pre-selected products are evaluated with the simple additive weighting method [14] on the derived evaluation criteria. For this purpose, the sum product of the weighting and the evaluation factor are calculated to determine the utility value of all pre-selected products.

The selection of a product as well as the selection of processes and factory elements are interdependent and therefore either an iterative or a synchronous approach is possible (Fig. 2). In the iterative approach, the product or the factory elements are selected first. If the product is selected first (Fig. 2, 1a), the product with the highest utility value is selected at this point. Afterwards, the factory elements are determined based on the product. If the factory elements are chosen first (Fig. 2, 1b), the product is determined mainly by the production requirements. In the synchronous approach (Fig. 2, 2), the product and the factory elements of the LF are selected at the same time by determining a LF configuration for all pre-selected products. The synchronous approach can be used in combination with an optimization model for the configuration of LF. This optimization model is designed to find the best possible combination of factory elements regarding different restrictions (e.g., budget) [15]. Finally, the configuration with the highest overall utility value is selected. In the synchronous procedure, factory elements are researched and evaluated for each of the pre-selected product [16]. The effort required for the synchronous approach is therefore higher than for the iterative approach, but the global optimum for the LF is achieved.

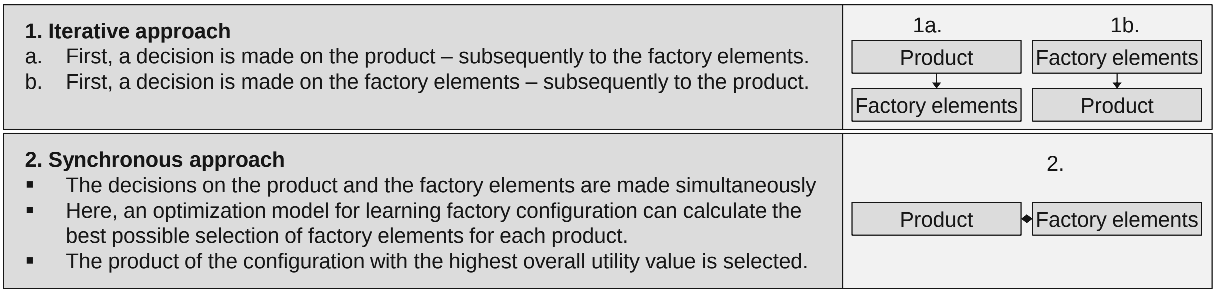

Fig. 2. Iterative and synchronous approach for Phase 3.

4. Conclusion and outlook

This publication presents a systematic method for selecting a suitable product in LF that complements the approach of [1]. The method is divided into three consecutive phases: First, the goals of the LF are determined and divided into research and learning goals and framework conditions. In the second step, requirements for the product, production and other external requirements are derived. With the help of the optional requirements, evaluation criteria can be determined and subsequently weighted. From the mandatory requirements, a pre-selection of products can be made, which are evaluated with the help of the evaluation criteria. This way, the product with the highest utility can be determined. Further quantitative validation is needed. Nevertheless, the presented approach assists the configuration of future LF, e.g., the third LF of PTW at the TU Darmstadt: the FlowFactory.

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