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Competency-oriented design of learning modules

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Abstract

The enhancement of job-related competencies is important for the competiveness of companies. For establishing these competencies, learning factories offer a basis for self-controlled and informal learning. Core elements of learning factories are learning modules with different foci. To develop the needed competencies a proper design of learning modules is fundamental. An instrument to systematically analyze and create learning modules is the competency transformation. The presented learning objective taxonomy supports the formulation of competencies for the transformation chart. Furthermore, it enables a comparison between actual and target states of learning modules. Thus, recommendations for improvements can be made.

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Keywords: competency transformation; learning objective taxonomy; learning factory; quality techniques of lean production; training development

1. Introduction

The rising complexity of today´s manufacturing environment is mainly induced by new technologies, highly customized products and shortened product life cycles [1]. In combination with an aging workforce and the claim for work task flexibility the quick and lasting buildup of job-related competencies becomes a critical success factor for manufacturing firms [2]. Competent and highly skilled employees are a vital component of continuous improvement processes and therefore contribute at a high extent to a company's competitiveness. Existing typical forms of further education and pure formal learning are subject of criticism concerning their ability to develop competencies [3]. Action-oriented forms such as learning factories, which promote informal and self-controlled learning, gain importance particularly in the field of lean production. A development of learning modules, which are core elements of leaning factories, is inevitable when new findings are raised in the field of didactics or regarding the topic.

For the competency-oriented design of learning modules, the instrument of the competency transformation was developed. It is integrated into a model for the design of learning factories [2]. Within the frame of the learning module, the developed competencies as well as the associated activities and conveyed aspects of knowledge are concretized in an actual state competency transformation chart. The preparation of the target concept is carried out based on findings of the actual state analysis and with respect to relevant literature.

A taxonomy is presented which supports the formulation of competencies and actions for the compilation of a competency transformation chart. The consistent application of this taxonomy for actual state as well as for target state transformation charts enables a comparison of competency transformation charts, by which general recommendations for the further development of the investigated learning module can be deducted. To visualize the application of the taxonomy, the learning module "Quality techniques of lean production", which forms part of the courses offered by the learning factory "Center for industrial Productivity" (CiP), is used. The paper is organized in the following sections: First of all, the term "competency" is defined and the development of competencies within a learning factory is displayed. Subsequently, the competency-oriented design of learning modules is presented by the learning module "Quality

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techniques of lean production". Here the methodology of competency transformation as well as the content of the learning module are discussed. The formulation and evaluation of competencies regarding the taxonomy represent the core of this paper.

2. Competency-oriented design of a learning module

The term competency generally describes the inner prerequisites of a person for self-organized acting, thus their willingness and ability. Contrary to the qualifications of a person, their competencies cannot be documented by certificates or specified by tests. Identifying or visualizing available competencies normally requires the execution of several actions in varying problem situations [3, 4]. The application of available knowledge to accurately perform actions in realistic and unknown problem situations forms the core element of competency development [5, 6].

Creation and development of competencies are effected by human learning and its reflection [7]. Every individual person learns in another way so that various different forms and methods of learning exist. In the present case, the focus lies on the development of technical and methodological competencies, which are necessary to creatively solve problems. Such problem situations are presented for example in a learning factory.

Learning factories are learning environments in which real production processes are simulated as realistic and authentically as possible [8]. Theoretical knowledge and methods are normally imparted in conventional courses and afterwards validated by the participants directly in the learning factory. During the practical stage, the participant has an active role and acts autonomously. The application of knowledge by actions and their reflection hereby facilitate the transfer of learned contents into practice at the participant´s company. In the CiP a variety of learning modules for different fields of lean production (e.g. quality techniques) are offered with the goal to develop the participants' competencies. The transfer of contents normally is carried out in the setting of one or two day workshops. The sequence of the workshops consists of a steady change between formal learning in training classrooms and informal, practical learning stages on the shop floor [8, 9].

2.1. Method of the competency transformation

The method of the competency transformation was developed during a research project at Technische Universität Darmstadt. The basic structure of actual and target states of the learning module "Quality techniques of lean production", whose content is presented in section 2.2, are analyzed with this method. The general framework is depicted in figure 1. The competency transformation chart of a learning module contains competencies of different levels of detail and associated actions and knowledge elements. A learning module enfolds a core competency and several levels of sub-competencies [2]. The number of sub-competency levels depends on the scope and complexity of the learning module. The approach of formulating these sub-competencies is described in section 2.3 in detail. Furthermore, Tisch et al. [2] assign associated knowledge elements to different categories: Technical and process knowledge as well as conceptual knowledge. In the case of thematically extensive learning modules, a division by contents via assignation of general topics to sub-competencies is suggested. On the one hand this improves the clarity of the transformation chart; on the other hand it facilitates the specific design of the learning module and the corresponding documentation after the creation of the competency transformation chart.

Pursuing the goal of complete collection of the actual state of the training course "Quality techniques of lean production", a design of the chart based on the actual imparted knowledge elements seems useful. The competency transformation chart is usually filled from right to left in order to identify the actually developed competencies. The current workshop documents serve in this connection as an information basis.

In the context of formulating a target concept and the corresponding optimization of the learning module regarding the targeted competencies, an inverse approach is chosen for the analyzed workshop. So the chart is filled from left to right. As the creation of a target concept aims at the development of intended competencies, their formulation should form a basis for that. The deduction of associated actions and knowledge elements based on targeted competencies assures that only relevant knowledge is integrated into the learning module. As mentioned above, the existing workshop documentation is used for the analysis of the actual state transformation chart. In contrary to this relevant literature in the topic of quality techniques and lean production as well as the actual state transformation chart are used as an information basis and foundation for the creation of the target concept.

Competency	Topic 1	Sub-competency 1	Corresponding action	Knowledge base
	Topic 2	Sub-competency 2.1	Corresponding action	Knowledge base
		Sub-competency 2.2	Corresponding action	Knowledge base
…	…	…	…	…
		…	…	…

Figure 1. Competency transformation chart [2]

2.2. Content of the learning module "Quality techniques of lean production"

The content of the analyzed workshop is based on the Toyota Production System, which fundamentally affected the concept of lean production. The goal of the Toyota Production System is the complete elimination of waste. Concerning quality, this means elimination and prevention of defects and rework, also known as "Jidoka" [10]. Within Toyota´s philosophy, Jidoka represents the central concept for the assurance of process quality from the beginning and the prevention of a transfer of defects to subsequent work stations. Jidoka comprises techniques which are applied for problem detection, alerting in occurrence of problems as well as problem solving [11, 12]. Due to its relevance for the implementation of lean production, the concept of Jidoka was the basis for creating the workshop "Quality techniques of lean production".

2.3. Formulation of competencies regarding the learning objective taxonomy

With regard to the competency-oriented design of learning modules, the formulation of competencies is a core element. Thereby they should be phrased in a way that they can be used as learning objectives within the learning context [13]. A learning objective characterizes the targeted learning result and the abilities and capabilities which a person should have obtained after the learning process (e.g. the workshop). Every learning objective generally consists of two parts: A content and a behavioral component. The content component comprises the functional content (knowledge), on which the learning process of the course participants is focused [14]. The behavioral component is expressed by a verb and describes the associated cognitive process, thus what the participant actually should do with the functional content (e.g. reflect, describe, apply).

In order to specify the particular learning objectives in detail, the underlying behavioral area can be distinguished in different levels. They are referred to as learning objective taxonomy [14]. Anderson and Krathwohl [15] developed such a classification of the cognitive behavioral areas. As shown in figure 2 the classification distinguishes six main categories: *Remember*, *understand*, *apply*, *analyze*, *evaluate* and *create*. The order of the categories arises from the cognitive complexity and the level of action-orientation, as the category *remember* puts the lowest and *create* puts the highest demands on the participant. The levels and key verbs serve as a support for the formulation of competencies. By the assigning of existing sub-competencies to the different categories, the demand level of a learning objective is pointed out. For example the sub-competency "Participants hold the ability to describe the sequence of the method ´systematic problem solving`" is assigned to the behavioral level *remember*, referring to the taxonomy. The verb *describe* refers in this case only to the repetition of imparted information.

Complexity and action-orientation	level	description	verbs	
↑	create	organization of single elements to an ensemble, development of approaches and solutions	develop, create, plan, elaborate, design, produce	Address conceptual knowledge
	evaluate	carry out evaluations based on criteria and standards	evaluate, check, discover, test	
	analyze	segmentation of an object into its elements and analysis of relations between the parts	distinguish, differentiate, select, structure, contrast	
	apply	application of methods and approaches in a given situation	carry out, utilize, implement	Address technical and process knowledge
	understand	establishing connections between old and new knowledge, explain circumstances and give examples, compare objects	depict, illustrate, translate, conclude, assign, compare, explain	
	remember	repetition of learned information (facts, definitions, etc.)	name, list, repeat, describe	

Figure 2. Learning objective taxonomy based on [15]

With the different levels of the taxonomy, various types of knowledge are taken into account. The levels *remember*, *understand* and *apply* address the technical and process knowledge, whereas the levels *analyze*, *evaluate* and *create* incorporate conceptual knowledge. Levels with higher complexity always contain the abilities of levels with lower complexity. Competencies are formulated with the support of the verbs of the learning objective taxonomy and thereby can be assigned to a specific complexity level. Therefore the goal is to develop competencies with a high level of complexity, as a competency can only be formed comprehensively, when all types of knowledge are present and used to perform actions.

The sub-competency "ability to name the different stages of quality assurance" only refers to professional knowledge and is part of the category *remember*. However, the sub-competency "ability to design possible poka yoke solutions regarding the product design (engineering) for identified problems" is part of the level *create* and contains features of technical, process and conceptual knowledge. By the application of the learning objective taxonomy therefore the realization of a comparison between actual and target state of the developed competency transformation charts is possible. Significant differences regarding the resulting ability of the participants to perform the required actions can be identified.

2.4. Classification of competencies by application of the learning objective taxonomy

The bar chart below (see figure 3) shows the assignation of the sub-competencies, which are formulated in the actual and target competency transformation chart, to the six categories of the learning objective taxonomy. In the analyzed workshop the total sum of sub-competencies differs from actual state to target state charts. The actual state includes competencies which do not have to be developed necessarily in the context of "Quality techniques of lean production". In addition to this, the target state transformation chart includes competencies which were not covered by the actual state. Therefore, only relative shares are displayed.

Significant differences exist regarding the complexity of actual and target state competencies. While in the actual state a percentage of 69% of 36 sub-competencies belongs to the lowest two categories *remember* and *understand*, in the target state only 39% of 28 formulated sub-competencies are present. Particularly the share of learning objectives, which bases merely on the repetition of learned information (*remember*), was reduced significantly in the developed target concept. The still very high percentage (32%) of learning objectives of the category *understand* results from the necessity to build a foundation of knowledge and comprehension for the application of lean quality techniques. The share of sub-competencies, which are only developed on the first two levels of the learning objective taxonomy (*remember* and *understand*), prevails in the actual state chart. This is caused by the too low quantity of suitable action tasks for the competency development in the process learning factory CiP. This fact is incorporated in the design of a target concept by the formulation of relevant actions.

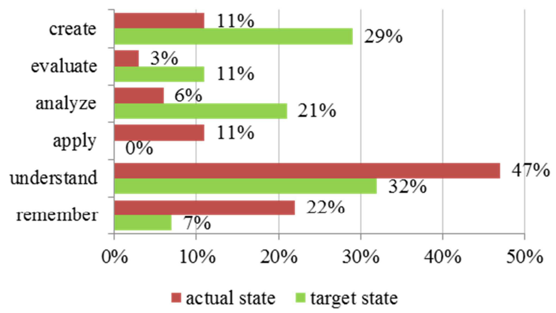

Figure 3. Comparison between actual and target state charts for the learning module "Quality techniques of lean production"

The developed target concept in contrast to the actual state of the learning module puts significantly higher demands on the participant. This is illustrated by the higher percentage of sub-competencies of the categories *analyze*, *evaluate* and *create*. In total, in the target state more than half of the sub-competencies (61%), are part of the highest three levels. In the actual state this applies to only 20% of the sub-competencies. Especially the increase in the categories *analyze* and *create* from 6% to 21% respectively from 11% to 29% is significant. This is caused by the optimization of actual developed competencies regarding their "range" during the creation of the target concept, as the categories *analyze, evaluate* and *create* put high demand on the participants. Thereby the goal is to expand the ability of the participants to perform the required actions by the independent use of knowledge in realistic situations and to improve this ability. Due to its proximity to reality and the practical relevance of subject matters, the process learning factory generally represents a suitable learning environment for the effective development of the intended competencies. In the target competency transformation chart extensive competencies are formulated which cover each type of knowledge and the related actions in separate sub-competencies. Thus, many levels of the learning objective taxonomy, especially the levels *evaluate* and *create*, are addressed.

But the comparison between the actual and the target state transformation chart is limited due to the fact that the sum of sub-competencies differs. The reasons are mentioned above. Therefore a more detailed classification of competencies was performed to consider also the content of both states. The goal is to prove that not only the competencies were developed to a level of higher complexity and action-orientation but also the right competencies were developed further.

Four different statements are possible about a sub-competency when actual and target state transformation charts are compared. First, sub-competencies can appear in the actual as well as in the target state. They are distinguished in sub-competencies, which remain on the same level of the learning objective taxonomy and those, which change the level. Furthermore, a sub-competency can be excluded from the target state, as it is not needed for the learning module "Quality techniques of lean production". In contrary, sub-competencies can be added which are necessary to develop.

Eleven sub-competencies persist on the same level in the actual state as well as in the target state. Nearly all levels of the taxonomy are represented. Figure 4 emphasizes the changes between the actual and the target state and therefore analyzes the last three statements specified above. Eight sub-competencies contain content that is not needed, all of them on the levels *remember, understand* and *apply*, which put a lower demand on the participants (figure 4 (a)). In the target state eight sub-competencies were added (figure 4 (b)). They are linked to the levels *understand*, *evaluate* and *create*. Five of the six sub-competencies on level *understand* are part of the topic "Basics of quality in lean production" indicating a deficient transfer of the needed knowledge in the actual state.

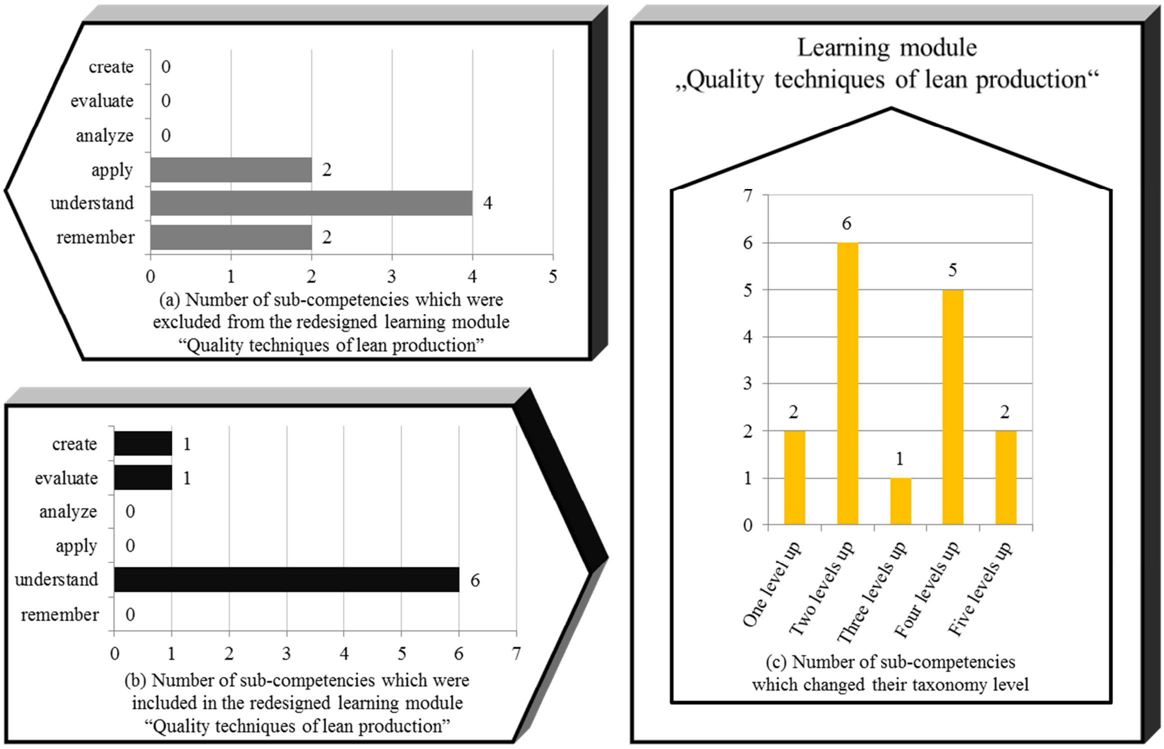

Figure 4. Changes between actual and target state transformation charts of the learning module "Quality techniques of lean production"

A goal of revision of a learning module is to develop the right competencies further. Moreover this paper argues that the target transformation chart covers more extensive sub-competencies with a higher level of complexity and action-orientation. Sixteen sub-competencies changed their level referring the taxonomy. Figure 4 (c) presents the number of sub-competencies which changed their taxonomy level. In the target state transformation chart half of them are linked to a level that is three or more levels higher than their level in the actual state transformation chart. This clearly evidences the development of more extensive sub-competencies from the actual to the target state. The development is shown exemplarily on the sub-competency: "Ability to name the essential contents of the step ´standardize` of the systematic problem solving process" (actual state), which is linked to the level *remember*. In the target state transformation chart these sub-competency was changed to: "The ability to elaborate improvements as standard and finish the systematic problem solving process", which is linked to the level *create*. To design a new standard in a specific situation, as intended in the target concept, additional knowledge is needed. This implies the knowledge of prerequisites to establish a new standard, the knowledge of typical steps like training of employees or design of audits and an understanding of the necessity to standardize the production processes. By referencing to a real problem situation the sub-competency is elevated from the level *remember* in the actual state to the level *create* in the target state. The analysis with regards to content shows, that during the redesign of the learning module "Quality techniques of lean production" the necessary competencies were developed further.

3. Conclusion

From the results of the realized actual state analysis and the actual state/ target state comparison general recommendations for the competency-oriented design of learning modules in learning factories can be deducted.

With the development of a stable target concept as an objective, primarily a formulation of the intended competencies should be carried out and based on this, associated actions and necessary knowledge elements should be identified (for further information on the development of a target concept see [13]). By this approach, intended competencies are in the focus from the beginning on. Actions and knowledge elements can be selected and formulated in a way that the development of the documented competencies can be assumed with the participation in the learning module. It should be considered that the formulated competencies can be used as learning objectives. The presented learning objective taxonomy including associated key verbs can be utilized as an aid for the knowledge-based formulation of competencies. However the ranking of the taxonomy levels and the related verbs are not always intuitively deducible.

Moreover, the assignment of sub-competencies to only one level could be complicated. The thematic flow and the planned order of teaching should be considered during the creation of the chart. Requirement for a complete creation, especially for the target state chart, is that all intended competencies must be known. This premise could be difficult to fulfill if competencies were not defined so far.

Furthermore, a learning module should not contain too many competencies as learning objectives. It could be difficult to develop each competency using a link to a suitable problem situation. If such a situation with practical relevance is missing, the ability of a participant to act self-organized is limited [2]. Instead of a development of the competency, only an impartation of theoretical knowledge elements would be carried out.

The knowledge, which is important for the development of intended competencies, has to be specified in the chart as well. It has to be assured that only knowledge elements are integrated, which are needed for the actions and the development of competencies. Redundant knowledge and knowledge elements without associated sub-competency are of no use and consequently waste. Necessary, but in the chart not existing knowledge elements entail a limitation of the ability to act and of the intended competency. The creation of the competency transformation chart is associated with high effort since all competencies, actions and knowledge have to be listed. But they indeed enable a systematic development of learning modules.

The learning objective taxonomy supports the formulation of competencies. By the combination of the different levels of the taxonomy and the categories of knowledge to sub-competencies, the chart is clearly arranged. It is comprehensible to which extend a competency is developed by the learning module in the actual state. Furthermore, it has to be considered that levels with higher complexity include those with lower complexity. Against this background also the comparison between actual and target concept should be evaluated. But is has to be considered that this comparison is limited in its significance, if it is performed without referring to the content of the learning module. As the analysis in section 2.4 shows, the presented approach is very helpful to formulate the sub-competencies in the transformation chart as long as the content of the learning module is also taken into account.

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