Developing Competencies for Continuous Improvement Processes on the Shop Floor through Learning Factories – Conceptual Design and Empirical Validation

J. Cachay*, E. Abele

Technische Universität Darmstadt, Institute of Production Management, Technology and Machine Tools (PTW), Petersenstr. 30, 64287 Darmstadt, Germany

* Corresponding author. Tel.: +49-6151-16-6551; fax: +49-6151-16-3356. E-mail address: cachay@ptw.tu-darmstadt.de

Abstract

Developing employees’ competencies in order for them to be able to solve problems quickly is an essential feature of future-oriented production. The object of research and practice in this field is to develop action-oriented approaches implemented through learning factories. So far, however, these approaches have not taken sufficient account of production workers, even though the development of their competencies is necessary for a broadly based and continuous improvement process. An integrative approach is presented. It enables the development of problem-solving competencies among shop-floor workers during a target-oriented continuous improvement (CI) process with the use of learning cells.

© 2012 The Authors. Published by Elsevier B.V. Selection and/or peer-review under responsibility of Professor D. Mourtzis and Professor G. Chryssolouris. Open access under CC BY-NC-ND license.

Keywords: Competency Development; Learning Factory; Continuous Improvement (CI)

1. Introduction

The challenges of the market, such as shorter product life cycles, greater numbers of product variants and growing economic volatility, require that, in order to sustain their competitiveness, companies must be able to quickly adapt their production methods to changing market conditions [1,2]. Companies must therefore be capable of continuously improving their production processes and also of developing them further. This means that the extent to which the actors in an organization are able to implement the necessary changes is becoming an increasingly important question [3,4]. This makes the ability of all employees to contribute to improvements a key success factor for the operative excellence of production processes.

The paper introduces a novel and empirically validated qualifying approach, which is part of the research agenda for competency development in the learning factory CiP [5-7].

2. Competency development for continuous improvement

2.1. Competency as a basis for action orientation

Numerous studies emphasize the significance of knowledge for the future viability of modern industrial locations [1, 8, 9]. Knowledge alone, however, is not sufficient; for means of production that are versatile and adaptable, it is necessary to ensure that employees are able to implement new techniques, thus making it possible to work successfully in conditions that are today unforeseeable.

The abilities required for this can be described as competencies, designating the ‘capacity for acting independently’ [10]. Besides knowledge and expertise, they imply the ability to organize their actions themselves. Competencies are thus the ‘demands made of individuals to adapt to new conditions and to modify..."
and put into practice their own strategies for acting in concrete situations’ [11].

Empirical studies reveal that the disparity between mere knowledge and this kind of competency is smallest when learning environments are designed in a constructivist manner, i.e. when the learners are given opportunities of experiencing and interpreting, thus enabling them to link up new insights with an already existing corpus of knowledge [12]. Learning factories represent a coherent approach for broadening competency in the optimization of production processes.

2.2. Qualifying by the use of learning factories

Learning factories pursue an action-oriented approach in which employees are able to develop competencies for improving production methods from the perspective of lean production. This is done in a highly realistic learning environment in which genuine products are manufactured in a simulated but life-like production setting [13].

It is important to emphasize that the focus of attention here is based on real problems which occur in the running of the learning factory (problem pull) and not theoretical content, for the understanding of which practical examples are merely used when appropriate (problem push).

Developing competency in the methods of production optimization should as far as possible be coordinated among the different functions and hierarchies of a company’s personnel. In the CIP learning factory, training curricula are currently available for the graduate training courses in production technology as well as for courses at the management and master craftsman levels. The approach has also proved to be successful at both the skilled worker level as well as at the engineer level [14]. Up to present, however, training has been provided above all for engineers working directly in production areas and auxiliary planning areas as well as for senior personnel ranging from master craftsmen to group leaders and plant managers. By contrast, scarcely any personnel working directly on the shop floor have so far undergone the time-consuming training of the learning factory.

2.3. Action-oriented learning in production practice

For a kind of production that is expected to react swiftly to new demands, a permanent focus on the groups of personnel trained so far would appear insufficient. What must be achieved instead is to establish technical as well as methodological competency on the shop floor of the primary organization in small steps in order to solve problems and develop production further, so that improvement processes can be achieved successfully in day-to-day operations.

Such continuous improvement (CI) processes, however, require that competency development takes place as widely as possible at the level of shop-floor workers. This can seldom be done by means of time-consuming training courses with extensive curricula. Rather, it must be adapted to the specific qualification needs of the employees and be of limited scope. Among other reasons, this is necessary because empirical studies have pointed out that shop-floor workers have difficulty applying what they have learned within everyday CI practice [15]. Therefore, these kinds of competencies for improving production can only be generated and made available beforehand to a limited extent [16, 17]. Instead, learning processes must be established as part of the improvement strategy which further the required technical and methodological competencies.

What is needed here is a clearly structured form of CI which corresponds to the competency development that is intended and which has an underlying curriculum to support it. This approach, in turn, enables problem-oriented learning (problem pull).

3. Competency development along guided improvement processes

Based on empirical findings, a form of CI was designed [18] which meets the requirements of lean production systems: continuity, a high degree of participation, playing a role as an integral part of daily work and being a target-oriented approach [19–21]. To this end, CI contains not only ‘top-down’ elements, which are the responsibility of the shop-floor manager, but also ‘bottom-up’ elements contributed by the shop-floor workers.

The CI is supervised by the first line manager, who is in charge of all three forms of control in accordance with [20] with regard to process, goal and contents. The CI procedures, as well as the participants and timeframe, are determined through the steering of the process. This also gives rise to an institutionalization through a daily recurring routine in everyday working practice. CI can be integrated into daily performance meetings or shift handovers as part of shop-floor management procedures through which the continual improvement process runs in defined routines.

On the basis of the state of production to be achieved in future the line manager lays down specific targets; this results in the improvement process shifting from a hitherto more reactive orientation at the shop-floor level (reacting to deviations from the target figures) to a proactive orientation (moving towards the future state of production) [22]. A CI based on this kind of target orientation is, moreover, the key characteristic of a
mature CI in the evolutionary step model in accordance with [19]. A steering of the process by way of the contents of the CI takes place indirectly insomuch as only those methods are selected and approved which allow the process to move towards the targeted state of production. The methods required are only taught in concrete situations and applied directly in actual practice.

4. Methods of goal identification in CI with accompanying competency development

At the PTW Institute a method has been developed for this form of CI with accompanying competency development which enables a CI process to be established in an industrial setting and target-oriented improvements to be carried out, accompanied by competency building among shop-floor personnel, see Fig. 1.

4.1. Method design

The method comprises elements of the planning and action levels, which take place once for the initialization of a pro-active personnel CI, and elements which take place repeatedly in the operational phase of the actual CI. In the initial phase, the method comprises the elements of organizational analysis, the creation of a general vision statement and the creation of an overall process target.

4.1.1. Organizational analysis

First of all, the current state of the improvement processes taking place in the production is established and, with the help of a self-assessment questionnaire, those steps are identified which must be taken to set up the intended CI in the primary organization. For this purpose, a cyclic phase model was developed in order to enable a top-down/bottom-up CI to be introduced regardless of the current state of the improvement processes [18].

4.1.2. Creation of general vision statement

This element focuses on setting targets from the perspective of lean production which are as tangible as possible. Here, care must be taken that the general vision statement conforms to the principles of lean production. The function of the abstract basic principles laid down in the statement is not only to motivate but also to provide legitimization and, in particular, orientation [23]. Accordingly, a vision statement is not a goal but a guideline along which the improvement activities can proceed [24].

4.1.3. Creation of the overall process target

In drawing up the overall process target a remote but hypothetically achievable target state of production is decided upon. For this purpose, the value stream design method is used in which targets can be laid down and visualized from one overall value stream by way of various sub-streams right down to the immediate work process. The actual current state of production, the status quo, is taken as the starting point. The vision statement serves as the upper limit. The overall process target thus established can now serve generally as an orientation in determining concrete working-process targets for the shop-floor operators’ CI.

4.1.4. Qualification analysis

On the basis of the targets set, the shop-floor operators involved in the continuous improvement process, must be capable of identifying obstacles which prevent the targets from being reached. On the top of that they need to draw up hypotheses on how to remove these obstacles and carry out appropriate experiments in order to validate these hypotheses. This means that the targets pursued in the improvement process must be in keeping with competencies which the shop-floor operators have at their disposal. Consequently, before working process targets are determined, an analysis of the qualifications of the personnel taking part must be made. This marks the beginning of the operational phase of the CI. On practical grounds, their actual current qualifications are first of all established, based on the knowledge of the line manager. To this end, methods of production optimization which are to be found in a qualification matrix, correspond to individual competencies in the form of taxonomic levels. If, in the course of the continuous improvement process, an increase is observable in the performance of the personnel with regard to the individual skills they have learned, the corresponding competency is added to the matrix.

4.1.5. Target setting

When setting the working-process targets, those targets are chosen which can be achieved by the shop-floor operators at the working-process level. This means that an assessment is made by the line management of the competencies which the operators have at their disposal in order to judge whether certain targets appear at all realistic in the light of the competencies available.

If necessary, the target must be adjusted. No training takes place at this point. This is intentional since the principle of a ‘problem pull’ is followed, and it is the appearance of a real problem during the course of the improvement routine that determines the point when training begins.
4.1.6. Target description

Targets for the working-process level are meant to give shop-floor operators an orientation for their actions in the continuous improvement of their own sphere of the production process. Therefore, the target state of the working process is described by the line manager together with the operators in an interactive process. Studies demonstrate that 75% of the overall take-up of information takes place through the sense of vision [25]. Thus, the description is visualized by quantifying the target with as few generally understandable key figures as possible and supplementing these with graphic elements.

4.1.7. Improvement Process

This is followed by the top-down/bottom-up CI, where shop-floor operators, under the guidance of their line managers, try to achieve the target described in short PDCA cycles. Only when here an actual problem occurs, which the operators cannot solve, does a short situational training session take place in the production setting on the basis of a comparison of the actual and the target situation. This procedure, by analogy with the learning factory approach, enables competency development based on actual problem statements.

4.2. Learning cell approach

Learning cells are short modular curricula which consist of illustrative elements such as posters or short videos and in most cases of an educational simulation game in the form of a model capable of animation with haptic elements (demonstrator). The contents of the learning cells are methods of lean production pertaining to analysis, assessment and design, as well as its underlying principles.

The purpose of learning cells is to carry out accompanying brief training sessions in the immediate production setting. Once the need for training among shop-floor operators is identified, brief teaching sessions take place on the basis of learning cells. These are particularly suited to immediate use in the actual production setting because of their simple structure and the limited space they require.

The aim of the learning cell approach is to enable shop-floor operators to analyze, assess, plan, implement and validate working-process targets in their own sphere of action with a large measure of independence. Here, too, emphasis is placed on developing competencies.

In contrast to the pure learning factory approach, in which quasi-real problems are simulated, actual problems occur in the learning cell approach in the immediate sphere of action of the shop-floor operators. The learning cells are developed for specific target groups within the production workforce and adapted accordingly.

Furthermore, it must also be taken into consideration that line managers do not usually have any special pedagogical training. Therefore, the whole underlying curriculum must be structured in such a way that it can actually be taught by this kind of personnel. The training materials for the shop-floor management are therefore provided with instructions for use which give a more detailed description of the contents and the sequence in which the theoretical methods are to be introduced. In addition, these materials contain the whys and hows underlying each of the competencies, which allows shop-floor managers to quickly check the theoretical knowledge of the workers before using the materials.

4.3. Method training in the learning factory

The method is trained in the learning factory CiP and focuses on experts of production optimization and the lower production management level as participants. The aim is to develop the necessary technical and training competency of the managers within the frame of the learning factory curriculum. Besides the training modules based on the principles and methods of lean production, two further modules exist whose aim is to train line managers in carrying out the CI:

- management system CI,
- method training competencies for lean multipliers.

The first of these two modules focuses on training the method of identifying targets in the CI with
accompanying competency building, along with the underlying CI.

In the second module the basic didactic tools required by line managers for situational competency development are trained in the learning factory. The contents of this qualification module consist of procedures for shaping learning processes in the area of production, as well as methods for conveying contents. The two modules presented, in conjunction with the training modules on the principles and methods of lean production, qualify the line manager to carry out the CI described, together with the related competency development, with the help of the so-called learning cells.

5. Research aim and methodology

The research aim is to validate and adapt the method for target-oriented improvement processes with accompanying competency development as well as the underlying improvement process. To this end, a two-step qualitatively empirical approach is used which consists of expert interviews and direct observations [26].

Firstly, as part of a laboratory study in the learning factory CiP, it is examined whether – with the underlying improvement process – the desired effects, i.e. target-oriented improvements, can be achieved with shop-floor operators. The extent to which the two training modules contribute to this is likewise examined.

In a study undertaken beforehand, the curriculum is worked through with students of engineering, after which the method for target-oriented improvement processes with accompanying competency development is put into practice. This is followed by a study with shop-floor personnel, where the suitability of the learning cells developed for the target group of production workers is put to the test in a realistic training setting.

In the second part of the study the method is validated in manufacturing companies. First of all, target-oriented improvement processes are established. If brief training sessions are necessary those are initially carried out by the researchers themselves. This is done in order to separate the aspect of competency development through the line manager from the activities of the shop-floor workforce. The aim of this is, in particular, to gain an insight into how the capacity of the operators to act in real situations can be increased by applying the method.

In the second part of the study the line manager takes over the task of situational training. Here, the purpose is above all to gain an insight into the success of the training when carried out by the line manager. In all phases of the study the results are documented using criteria of effect control.

6. Results

Preliminary studies with students in the learning factory demonstrate that, for this target group, competency development for the intended CI leads to a significant improvement in the results of the tasks set. After only a short time already, first-year students were capable of applying simple methods of production optimization successfully [27]. In contrast to the comparison group, whose activities have not been accompanied by the presented method for identifying goals in CI with accompanying competency development, the test group had the ability to carry out goal-oriented improvements of a clearly superior quality, in a more structured way and within a shorter time. As a performance indicator cycle times, reached through process improvements at individual workstations, had been used. These were measured to be up to 20% below the comparison group.

In a second study the two training modules were carried out with 40 employees of manufacturing companies. Here, it was shown that, through the structured design of the method with the insertion of brief, situational training sessions made up of learning cells, the employees were significantly better able to identify problems, validate solution hypotheses by means of small experiments and subsequently put them into practice. The two training modules thus proved constructive with regard to both test groups. In addition, it can be noted that, because of their restriction to the bare essentials, the learning cells can be used as an efficient means of introducing theoretical contents quickly and briefly into a new subject area of lean production.

Studies carried out in manufacturing companies show, moreover, that the form of the continuous improvement process described above enables target-oriented improvements to be made by shop-floor workers in their day-to-day operations [18] but that, since the employees’ methodological competency is not yet sufficient, these improvements sometimes have distinct limitations. Thus, the method with situational qualification elements through learning cells is currently being tested and studied in further companies. As far as can be seen at the moment, one of the main difficulties lies in the precise identification of the problem and a clearly understandable visualization of the targets by the management. For, learning processes can only be adequately furthered when an appropriate degree of difficulty is chosen, when the target setting is simple and imaginable and when at the same time an actual improvement of the production processes is observable. One component which would appear especially promising in this respect is the method value stream design. As a target cascading procedure for improvement
processes at the working-process level, it has proved easily learnable and understandable for everyone involved; since, starting off from an overall value stream by way of various sub-value streams right down to the working process, targets can be made concrete and represented in visual form. With this, a CI at shop-floor level can be oriented to overarching targets. Furthermore, the results of the expert interviews carried out so far show that this situational and ‘tailor-made’ training concept, in part because of its efficient use of resources, meets with a high degree of acceptance in practice. Especially for the level of shop-floor operators the method is assessed as a useful addition or even as an practice. Especially for the level of shop-floor operators training concept, in part because of its efficient use of resources, meets with a high degree of acceptance in practice. Especially for the level of shop-floor operators the method is assessed as a useful addition or even as an alternative for the pure learning factory approach. However, it also shows that due to highly varying cycle-time commitments and various formal qualifications (craftsman and unskilled production assistant) of the examined shop floor operators in the production types (single-part production and multiple-part production) the interviewed experts come to different conclusions whether possible contributions to process improvements exist. In the case of multiple-part productions an adaption for the level of the foreman and the master craftsman levels will be made.

7. Conclusion

The approach presented is an integrative strategy which enables competency development among shop-floor operators in dealing with problems during a target-oriented improvement process and includes the use of learning cells. The research results so far obtained suggest that the application of the developed method should be studied further in an industrial setting. To this end, longer-term studies should be undertaken in order to obtain further differentiated results. Therefore, different groups from the production types, single-part production and multiple-part production, will be separately explored in depth.

A further research aim would be to discover which targets can be reasonably addressed with actual shop-floor personnel and which targets should only be dealt with by experts in order to determine a criterion for breaking off the method. It may be assumed that improvements at the level of the overall value stream require a great deal of knowledge about potential solutions on account of the changing material flows and steering concepts. For this reason these targets would appear less suitable to be dealt with by shop-floor operators.

References