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Study on action-oriented learning with a Learning Factory approach

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Abstract

An important prerequisite for prospective competitive factories is an effective and enduring development of production-related competencies in today's universities for manufacturing engineering. Learning Factories are an action-oriented approach for developing these competencies. They are highly authentic learning environments in which genuine products are manufactured in a simulated but life-like production setting. The study aims at investigating the learning success of engineering students in a Learning Factory. Results of a conducted experiment are presented and discussed giving proof to the hypotheses that students have a greater application-performance and a higher degree of action-substantiating knowledge after having attended an action-oriented learning event within the Learning Factory than after receiving a conventional treatment.

Keywords: Learning Factories; action orientation; competencies; manufacturing engineering

1. Introduction

In order to withstand international pressure of competition manufacturing companies must continuously develop their manufacturing processes, their production equipment as well as their operational and organizational processes. An equally important prerequisite for prospective competitive factories is an effective development of production-related competencies and the capability of adapting and evolving these competencies independently (Abele, Tenberg, Wennemer & Cachay, 2010). The exponential increase of production-oriented knowledge accompanied by shorter employees' dwell times in certain positions thus requires new effective production learning approaches. In addition, the ongoing effects of knowledge aging make a rethinking necessary (Abele & Reinhart, 2011).

These trends can only be countered by new learning approaches that contribute to the development of staff's competencies. It is beginning to show that the association with competencies of employees from all hierarchical levels is a key success factor for production engineering (Abele et. al., 2010). Often, the lack of staff's competencies complicates the implementation of sustainable productions that are able to react to unknown future developments.

In addition to a high knowledge degree, companies expect their employees therefore to utilize their knowledge but also to operationalize this knowledge in unimaginable situations (competency). Therefore, production-related academic education as well as advanced training requires new approaches that allow future and actual employees to act independently in real problem situations. The Learning Factory CiP (Center for industrial Productivity) maintained by

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the PTW at the TU Darmstadt could be considered as such an action-oriented learning approach. In the following, a scientific discourse on learning factories is documented. Additionally, an empirical test approach aiming at assessing action-oriented learning in the Learning Factory CiP and the discussion of the results are presented.

2. State of the art: competency development in manufacturing

2.1. Developing competencies for manufacturing engineering

Around the world, engineering education predominantly takes place in universities. In the wake of the European ‘Bologna Process’ first steps to competency-based studying have been initiated, but as yet it still has to be assumed that engineering study courses remain relatively science-oriented and highly abstract. This equally refers to contents as well as methods (Tenberg, 2011). The situation in the highly application-oriented German vocational training proves to be very different, as curricula with a consistent competency-orientation have been implemented. Here, educational objectives have been worded not in a knowledge-oriented but in an action-oriented manner.

2.1.1. Competency orientation

Erpenbeck and Rosenstiel (2007, p. XIX) define competencies briefly as ”dispositions to act independently” and in doing so refer to the linguistic approach of Chomsky (1962) and the psychological approach of White (1959). They are seen as context-specific cognitive dispositions that enable individual independent actions and are due considerably to knowledge (Klieme & Leutner, 2006; Weinert, 2001). The single action is referred to as ‘performance’ (Chomsky, 1962) and emphasizes the difference between what enables, presupposes and determines independent actions and the virtual action. This means that a single action cannot uncover all the underlying competencies. Several independent actions in a variety of situations are required (Tenberg, 2011). Erpenbeck and Rosenstiel’s (2007) approach distinguishes between two competency-classes and four competency-categories: Competency-classes describe two typical kinds of problem solving competencies which can be acquired by executing either ‘gradient strategies’ or ‘evolutionary strategies’. Gradient strategies, on the one hand, follow an algorithmic approach, evolutionary strategies, on the other hand, predominantly follow a heuristic approach. In daily work characterized by a small variety of working situations gradient strategies are applied. If different problem contexts or complex or new demanding situations occur usually evolutionary strategies are executed (Tenberg, 2011). Competency-categories describe four particular but systemic-linked competencies: personal, activity- and application-oriented, specialist and methodological, social-communicative (Erpenbeck & Rosenstiel, 2007).

In linking the gradient and evolutionary strategies with the four key competencies defined by E&R the competency model by Tenberg is derived (Figure 1). In order to perform successfully in unknown constellations (competencies) companies expect their employees to be able to apply certain knowledge (qualification). Thus, the key to competency development is the ability to master knowledge; this comprises cognition and comprehension of knowledge.

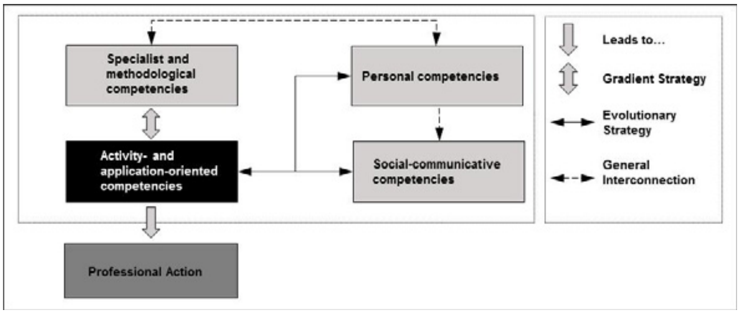

Figure 1. Competency model by Tenberg (on the basis of Tenberg, 2011)

2.1.2. Action-substantiating and action-independent knowledge

Due to their ambiguity and terminological fuzziness Tenberg (2011) published a theory about the relationship between competencies and knowledge avoiding the hitherto used terms of declarative knowledge and procedural knowledge. He restricted his basic model to three knowledge concepts: technical knowledge, process knowledge and conceptual knowledge.

In order to obtain flexibility of action, conceptual knowledge is needed in addition to technical and process knowledge. Conceptual knowledge can be subdivided into two distinct categories: ‘action-substantiating knowledge’ and an 'action-independent knowledge base'. Action-substantiating knowledge is generally required for the understanding of entities and their handling. Without this kind of knowledge, factors would unthinkingly be taken for granted and actions would be regarded as unalterable and definite. The understanding of knowledge is a central feature of expertise (Tenberg, 2011).

According to Ebner, Oertel and Schumm (2001), it is neither required nor possible to distinguish definitely between technical and process knowledge. So, in this model, it can be summarized as professional knowledge. Conceptual knowledge is linked with technical and process knowledge since it represents the referential background of each knowledge type. Solely, a person with conceptual knowledge has insight into the underlying causal coherences that can be made available in problem solving situations (Pittich, 2011). Not the more but the higher value (meaning action-relevant) conceptual knowledge enables the individual to determine a changed context adequately and to vary familiar actions in a reasonable way.

2.1.3. Theory of action-oriented learning

Academia and industry concur that by means of vocational education and competency development in universities comprehensive job-related competencies and thereby a capacity to act in terms of planning, implementing and evaluating must be generated (Dehnbostel, 2003). Action-oriented learning is a prerequisite for obtaining such a professional competency as it is always tied to specific working situations.

Therefore, an action-oriented learning process must be designed in a way that self-organizing competencies can be developed enabling learners to act independently, focused and performance-oriented. This means that students have to configure their own learning processes by handling complex problem statements as complete tasks. During these tasks they deliver independent judgments and make own decisions, thus, stimulating responsible actions. Teachers should stay in the background and rather assume a moderating role.

The teaching and learning settings must be modeled as closely as possible to the actual working context and process (Bader, 2003). Naturally, these must have to have a high degree of realism and clarity. Typical supporting media are computer simulations and role play, but also multimedia applications such as virtual reality (Weidenmann, 1993). However, this approach has not been pursued extensively at university level in the German engineering education. Although, in the meantime so-called learning factories have been used in this context.

2.2. Learning Factories as an approach for developing competencies

In research literature various definitions are provided for learning factories (Barton & Delbridge 2001; Pullin, 2009; Roth, Marucheck, Kemp, & Trimble, 1994, Siqueira, Barbarán & Becerra, 2008; Tian, 2011).

Usually, these approaches are to be found in the field of software development and are regarded as learning factories in German-speaking areas: an industrial environment that simulates realistic production processes while enabling practical training in various topics and at various professional levels. However, in terms of the product to be manufactured as well as the equipment- and organization-related environment a lot more objective approaches are required in production engineering. Therefore, modern learning factories represent one or more complete complex production lines in which far-reaching interventions into the manufacturing, assembly and logistics processes are possible for the trainees. However, as opposed to real production sites these interventions can be undertaken risk-free and without cost pressure (Cachay & Abele, 2012). As of today, mainly automobile-OEM operate learning factories in this sense (Reiner, 2009).

Furthermore, in the past learning factories have been established in varying extent, under different learning contexts (e.g. lean manufacturing, process optimization, energy efficiency) and with differing target groups (e.g. students, skilled workers, managers) at research institutions throughout German-speaking countries (Abele & Cachay, 2011). For a comparative investigation on existing learning Factories see Wagner (2012). A pioneer in this field is the existing Process Learning Factory CiP at the TU Darmstadt, inaugurated in 2007 (Lehm, 2011).

3. Research aim and methodology

3.1. Research aim

The study's research aim is to determine whether the action-oriented Learning Factory approach has advantages over conventional teaching methods. It is assumed that the Learning Factory as a teaching and learning approach enables manufacturing engineering students to cope better with real problem situations and to successfully apply learnt techniques. Consequently, it has to be reviewed by how much the Learning Factory approach exceeds the conveying potential of a conventional (not action-orientated) lecture. Thereby it has to be differed between the acting capacity of the learner and the corresponding knowledge. This means that the corresponding knowledge as well as th e students' capacity of acting in practical problem statements have to be determined. The research hypothesis is: Students have a greater application-performance and a higher degree of action-substantiating knowledge after having attended an action-oriented learning event within the Learning Factory than after receiving a conventional treatment.

3.2. Study design and structure

The experiment is based on methods of empirical social research with partially open proportions of non-participatory observation. This stu dy design allows t he testing of prefabricated hypotheses and the e xplorative exposure of structures in the research field itself at the sa me time. The study can be assigned to the field of real experimental designs and therefore offers a structured research field that allows comparisons between different cohorts as well as comparisons between investigative and comparison groups (Schnell, Hill, & Esser, 2008).

In order to verify the effectiveness of the action-learning approach in the Learning Factory in comparison to conventional learning methods two randomly composed groups of probands receive two different types of treatm ents dealing with the analysis of production processes. During the first day of the study the comparison group consisting of 9 students receives a conventional tuition. On the second day the 16 students accumulating the investigative group are trained by means of the new action-learning approach developed in the Learning Factory.

To begin with, both groups are subjected to take a sh ort preliminary test in order to d etermine their initial knowledge level on lean production in g eneral and process analysis at t he start of the study. The questions aim at addressing the probands' expertise and th ematic comprehension. These tests are im portant in order to pinpoint the exact individual learning progress e ffected by the res pective treatments. For t his purpose, the stude nts are aske d to give certain i nformation concerning their person so that indi viduals can be traced throughout the study (c ontrol variables).

Following the preliminary tests, both groups are prov ided with the same th eoretical knowledge concerning their task of analyzing a production process. During these circa 30 minutes of lecture the most important facts about process analysis (PA) and lean production in general are illustrated such as signification, purpose and procedure of PA. In the following 60 minutes the comparison group and the investigative group receive their respective treatments. The comparison group is instructed in form of a conventional teaching tuition in accordance with Schelten (2005).

The lean method of process analysis is thus demonstrated to the probands on the basis of an example. In this case, the process example is th e assembly of a sim ple shaft-hub joint. The complete lack of action-oriented learning methods is c haracteristic for this kind of treatment. Tuitions as a learning form have great resemblance with conventional learning methods at university.

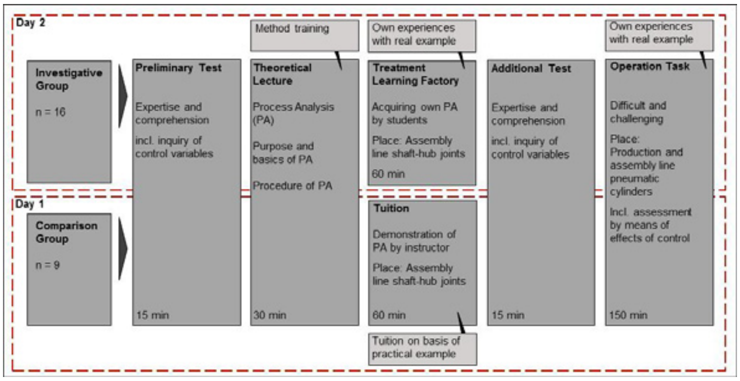

Figure 2. Overview over study on action-oriented learning in the Learning Factory CiP

The investigative group, on the other hand, is trained by an action-learning approach in the immediate vicinity of the Learning Factory. In the same 60 minutes these probands, divided into three groups, are able to experience the procedure of process analysis on the real shaft-hub joint example. They are allowed to make mistakes and experience the consequences. Very importantly, the supervisors accompanying the study do not interfere in the treatment enabling the probands to make their own experiences.

After their particular treatments the probands of both groups are ask ed to take a secon d additional test with th e exact same questions as in t he preliminary test. By comp aring the control variables the individual answers can be associated with the answers given in the first exam. But in order to really be able to evaluate the learning progress it is not sufficient to only test the accessory knowledge gained throughout the learning treatment. The action-learning approach additionally addresses comprehension and the ability to actually apply the learning content in a real problem situation.

Thus, as a last test both groups are asked to solve the same more realistic and more challenging task (operations task). The investigative group is divided into three groups, the comparison group into two groups. The corresponding processes are real assembly processes extracted from the assembly of pneumatic cylinders in the Learning Factory CiP. The degree of complexity is very high making the process analysis more complicated as in the shaft-hub joint example. Supervisors accompanying the groups during the period of 150 minutes qualitatively assess the probands' courses of action, their behavior and the results with the help of previously determined effects of control.

At the end of the study short interviews are conducted with the probands. The objective of these interviews is to find out how the probands have experienced their respective treatment and what suggestions for improvement they may have. The idea is to get an overall judgment of the learning approach.

3.3. Surveying method

3.3.1. Control variables

During the preliminary and additional tests variables of control are imposed. This has two major reasons: On the one hand, for the study to be valid it is important that the investigative and comparison groups are similar. This can be ascertained by imposed variables of control (personal information on the probands). It is important that overall all probands of both groups have had similar life experiences and have similar previous knowledge rates. On the other hand, in order to make a statement on the learning progress of every individual it is important to impose certain personal information so as to be able to keep trace of the probands throughout the study. This is not problematic as all results are kept anonymous.

3.3.2. Comprehension tests

13 questions are posed in the tests, 8 of which address theoretical knowledge. The remaining 5 questions can only be answered if the probands have the respective comprehensive knowledge. The goal is to see how much of the learning contents the students have really understood. Table 1 lists these 13 questions.

Table 1. Overview over theoretical and comprehensive questions in preliminary and additional tests

Theoretical Questions	Comprehensive Questions
What are the goals of Lean Production?	Why is a one-piece-flow production organization desirable?
What are the different types of waste in Lean Production?	Name the reasons why production figures alone do not suffice to judge an actual production state?
What are the steps of a process analysis?	Why is the customer takt time important?
How can the customer takt time be calculated?	For what is an A3-sheet used in the context of Lean Production?
What is meant by a cycle time?	What obstacles may arise in the procedure of process optimization?
What does the acronym PDCA mean?	
Name the steps involved in process improvement in Lean Production.	
What points are listed in an A3-sheet?	

Between 1 and 5 points are awarded depending on the amount of correct answers per question. If no answer or no correct answer is given 1 point is awarded. 2 points correspond with 'predominantly wrong', 3 points with 'partly correct', 4 points with 'predominantly correct' and 5 points with 'correct'. By using this scheme it is possible to evaluate the two tests within the scope of the study. Every proband achieves a certain score in the preliminary test and naturally a better score in the additional test. By comparing these two scores of all probands the respective learning progress of the investigative and the comparison group in respect of gained expertise can be accounted for.

3.3.3. Criteria of effect control

In the context of the operations task the groups are asked to carry out a process analysis on a complex assembly process. By observing their activities a qualitative assessment is possible. The five steps of the process analysis to be undertaken by the probands are:

- Determination of customer requirements such as customer takt time.
- Plotting of process steps: the assembly process consists of several executions known as process steps.
- Recording of inventory: all stocks directly related to the process are to be identified.
- Recording of information and material flow: material and information movements help understand the process.
- Recording of process data: the most important data is in this case the cycle time – the time necessary for assembling one workpiece.

Having a chronologic order, the evaluation sheet orientates on the respective steps of the process analysis. But also comprehensive effects of control can be found aiming at describing the overall behavior and achievements of the probands. Within the scope of this study it is notably important to evaluate the problem solving manner and the more or less structured modus operandi of the two groups.

In order to facilitate and standardize the qualitative assessment several effects of control are defined. Only by these means it is possible to characterize the probands' learning progress in terms of comprehension and applicability of learning contents. The effects of control constituting the evaluation sheet orientate on the steps of the PA:

1. Customer requirements have been determined (completely, partially, not at all): The groups are provided with information from which the customer requirements are to be derived. Main focus is on the customer takt time assuming the time in seconds that a customer demands a product.
2. Process steps have been plotted (completely, partially, not at all): In order to fully understand the process the proband has to analyze every process step. Every step has to be plotted visually to facilitate the exposure of optimization potential.
3. Inventories, material and information flows have been recorded (completely, partially, not at all): Before the actual analysis of the process can take place the process has to be described as a whole.
4. Process data, especially cycle times, have been recorded (completely, partially, not at all): A production process cannot be fully described without production figures. The most important figure is the cycle time. In this stage of the PA the probands have to use a stop watch and stop the times of several assembly cycles.
5. Realized analysis has been evaluated (completely, partially, not at all): The groups must show their ability to evaluate their hitherto work. Whether they have completely understood the process with all its strengths and weaknesses will show during the evaluation process of criterion 5.
6. Process analysis has been presented to and discussed with the group (completely, partially, not at all): In presenting and discussing their results the groups show their team working skills.
7. Further comments: This criterion enables the supervisors to mark any further points of interest that effect the evaluation of the probands in their respective groups. Mostly, comments on teamwork, general behavior and conduct, structured course of action as well as results are stated here.

4. Results

4.1. Study quality and validity

An important factor concerning the validity of a laboratory study is the composition of the two groups being analyzed. In this case, the probands of both groups should have an identical initial knowledge rate concerning the topic 'Lean Production'. As Table 2 shows, both groups are virtually identical in reference to the surveyed variables of control. Both control samples are large enough to enable a scientific predication. The average age and the female quotient are similar between the groups. The female quotient is a bit lower than the male quotient as the TU Darmstadt is a technical university and the female quotient is thus traditionally lower. All probands are students of either mechanical or industrial engineering having no vocational precognition. As both groups have similar average grades and consider themselves rather uninformed about lean production it can be expected that all probands have similar engineering skills. In summary, it can be determined that the investigative and the comparison groups are sufficiently similar and thus the validity of the study can be ascertained.

4.2. Results of the preliminary and additional tests

Tables 3, 4 and 5 show the results of the two tests conducted during the study. The preliminary test took place first thus giving an impression of every probands' degree of initial knowledge at the beginning of the study. The results show that the probands all have an identical initial situation. The comparison group was able to answer 32,0%, the investigative group 29,2% of the questions correctly. Concerning the knowledge and comprehension questions the allocation was similar.

Table 2. Composition of investigative and comparison groups (none = 1; middle = 2; high = 3).

Attribute	Investigative group	Comparison group
Number of	16	9
Average age	22,8	22,2
Share of womankind	31%	22%
Course of studies	engineer, industrial engineer	engineer, industrial engineer
Grade point average	2,0	2,1
Work experience	0	0
Assess their own knowledge	1,4	1,6

Table 3. Results of overall analysis.

Total analysis				
Comparison group				
Pretest	Posttest	Absolute increase	Relative increase	Absolute difference
32,0%	56,8%	24,8%	77,5%	
Investigative group				24,8%
Pretest	Posttest			
29,2%	59,1%	29,9%	102,3%	

Table 4. Results of the analysis on the action-independent knowledge.

Analysis of the action-independent knowledge				
Comparison group				
Pretest	Posttest	Absolute increase	Relative increase	Absolute difference
31,1%	54,7%	23,6%	75,9%	
Investigative group				27,5%
Pretest	Posttest			
28,0%	56,9%	28,9%	103,4%	

Table 5. Results of the analysis on the action-substantiating knowledge.

Analysis of the action-substantiating knowledge				
Comparison group				
Pretest	Posttest	Absolute increase	Relative increase	Absolute difference
33,3%	51,1%	17,8%	53,3%	
Investigative group				47,5%
Pretest	Posttest			
31,3%	62,8%	31,5%	100,8%	

The results concerning the additional test which occurred after the respective treatments show that the probands did have different learning progresses. Overall, the comparison group was able to ameliorate their score by 77,5% up to 56,8%. The investigative group on the other hand was able to more than double their score (+ 102,3%) reaching a score of 59,1%. In total, the resu lts of the in vestigative group improved by 24,8%-points in comparison to t he comparison group.

Although the investigative group did better concerning the knowledge questions (absolute increase to the amount of 28,9% versus 23,6%) their main gain versus the comparison group can be explained by the performance concerning the comprehension questions. The absolute increase was almost double as the investigative group relished an absolute increase to the amount of 31,5% versus 17,8%. The results of the investigative group improved by 47,5%-points in comparison to the comparison group.

4.3. Evaluation of the operations task

Overall, the emphasis of the evaluation of the operations task lies on two basic declarations. Firstly, the study allows comments on the effectiveness of the learning method 'Learning Factory' compared to traditional learning methods such as tuitions. The results of the comparison group can be compared directly with the results of the investigative group. Table 6 shows the different results of the two groups (the investigative group consisted of three smaller groups working on three assembly places, the comparison group was divided into two groups working on two respective assembly places) in respect to overall behavior, structured course of action and outcomes as described in the mentioned criteria catalog.

Table 6. Results of the operations task maintained by investigative and comparison groups

Criterion	Investigative Group	Comparison Group
Plotting of process steps	Plotting occurs successfully and completely – few minor questions	Plotting occurs merely partially – significant need of inquiries: Neither the process steps nor the symbolism seem to have been understood.
Recording of inventories, material and information flows	One group: complete recording, no problems The two other groups forgot to inscribe the names and amount of stock in their plots.	No recording of the information flow. Partial recording of the material flow in one group. Inventories are locally determined but only partially quantified.
Recording of process data	Complete recording in all groups	Cycle times have been recorded completely. Although no coordination or division of work distinguishable: Some probands are actually already working on subsequent steps.
Evaluation of realized process analysis (PA)	One group successfully and completely evaluates the analysis independently. The other two groups manage after a short inquiry about the next steps in the PA. Nonetheless, peaks in the cycle times are not in the center of interest, their causes are not investigated.	Realized analysis is only partially evaluated. Oscillations in the recorded cycle times are noticed, but the existence of different product variants is not recognized (no reflection). There is confusion and disorientation regarding the further course of action.
Presentation of process analysis	The PA is presented only in part because the evaluation results of the analysis are not used.	The PA is presented in part and only after repeated prompting. The evaluation results of the cycle times are not of key interest.
Further comments	Duration in one group: 10 minutes. Duration in the other two groups: less than 30 minutes	Instead of commencing with the PA the groups start optimizing the process without further reflection (not part of the task!). Duration: ca. 60 minutes

4.4. Interpretation of the results

All in all, both groups entered the study having an identical background and knowledge rate. Thus, it is not surprising that the results in the preliminary test differ merely by 3% (29,2% versus 32,0%). As expected, both groups were able to increase their knowledge and comprehension levels significantly after their respective treatments. But the investigative group's learning progress was significantly better than in the comparison group. The degree of amelioration in the investigative group is with 102,3% much stronger than the comparison group's 77,5%. As the learning progress remains similar on the knowledge basis the investigative group did much better in answering the comprehension questions (100,8% versus 53,3%). It is evident that the action-learning treatment in the Learning Factory CiP in contrast to the conventional treatment by tuition had a much greater impact on the investigative group's comprehension skills. Certainly, these conclusions still have to be acknowledged by a longitudinal study with statistical significance. Anyhow, the interpretation of the operations task's results affirms this conclusion as two basic theories can be upheld:

1. In the operations task the investigative group performed better than the comparison group.
2. The investigative group's learning progress was exceptional.

The investigative group did very well during the operations task showing a structured approach along the 5 steps of the process analysis. There were only minor points of criticism to be addressed and there was practically no need for supervisors to interfere. The comparison group, on the other hand, was only able to solve the task partially and many supervisor interferences were necessary to put them back on the right track. Neither the steps of the process analysis nor the symbolism seem to have been understood. A structured approach along the steps of the process analysis was not to be observed. The needed times for solving the task make this point very clear. One group amidst the investigative group required 10 minutes, the other two groups circa 30 minutes. The comparison group needed circa 60 minutes relying on considerable assistance from the supervisors along the way.

The investigative group's learning progress could be nicely observed by comparing their performance during the treatment with their performance in the operations task. As they were allowed to make mistakes and experience the consequences during their action-learning treatment they understood well why it is best to follow the steps of the process analysis in a very structured manner. The same mistakes were not repeated in the operations task.

These interpretations were underlined by the probands' statements made during the interviews conducted at the end of the study. The probands were asked to comment on four main topics: Reflection on the own learning progress, course structure, practical orientation and hints on how to deal with the learning approach. Table 7 shows some of the answers given by the students.

It is interesting that even the probands recognize that their learning progress augments when they themselves are allowed to try and solve the problem statement hands-on. Quite often during the study the probands of both groups spoke of light bulb moments when working hands-on. The results of the interviews allow several conclusions:

- Both the comparison and investigative groups expressed positive opinions towards the Learning Factory concept. Especially, the action-oriented learning approach with hands-on activities and the predominant practical orientation are emphasized.
- The proposals made by the comparison group concerning the course structure resemble the actual investigative group's Learning Factory treatment. Practical exercises would have been better than the tuition.
- Both groups rated the operations task as very positive. Although, one should keep in mind that the comparison group perceived the operations task as part of the training and not as it was intended as a test.

Table 7. Selected quotes from the interviews with the probands.

Investigative Group	Comparison Group
Reflection on own learning progress:	Reflection on own learning progress:
"Not until the first practical example I understood how important it is to comply with the order of the analysis process and how important a structured approach is for success."	"After the tuition I hadn't understood what the process analysis is about. This only became clear to me after having the opportunity to perform the task by myself. Only then did I understand what difficulties can arise in the course of the application."
Course structure:	Course structure:
"The mixture of theory and practice was very well-balanced." "The sequence from simple to complex examples made it very easy to understand the problem statement."	I liked the practical examples in the lecture." "Instead of a tuition the training should have been like the operations task."
Practical orientation:	Practical orientation:
"I thought that the practical orientation was great. I could really imagine how this problem statement can occur in real life."	"I found the tuition quite abstract. Therefore, I was happy to work on the realistic assembly working places during the operations task."
Hints on how to deal with the learning approach:	Hints on how to deal with the learning approach:
"You should provide this training for all students. The training principle should be adopted by other university departments."	"At the end of the operations task a best practice solution should be presented or handed out."

5. Conclusion

In this paper, a study is presented with the goal of verifying a certain hypothesis that students have a greater application-performance and a higher degree of action-substantiating knowledge after having attended an action-oriented learning event within the Learning Factory than after receiving a conventional treatment. At this, a comparison and an investigative group of probands received different treatments, subsequently having to solve an identical operations task independently. The former group was instructed by means of tuition, the latter group attended an action-oriented training in the Learning factory. Within the limits of the study, the hypothesis has been verified and confirmed comprehensively.

The results indicate that participants of action-oriented trainings in the Learning Factory have significant advantages over participants attending traditional schooling. This is the case because the former are much more capable of grasping problems and validating as well as implementing solution hypotheses so as to improve and stabilize the status quo of a production line. Without a doubt, it can be noted that the investigative group showed a better performance than the comparison group in the operations task. Moreover, the investigative group's learning progress was exceptional.

Due to practical implementation reasons the conducted experiment reverts to a relatively small cohort (n <20). Therefore, the generality of the results cannot be ascertained, however the results can be regarded as a first indication of the validity of the underlying basic assumptions.

In order to confirm these results, further identical studies are currently being carried out with different cohorts. In order to allow both regression analysis and variance explanations cross-sectional and longitudinal studies with cohorts larger than 150 probands will be conducted. The goal is not only to generally confirm the effectiveness of the approach but also to differentiate the causes and control variables contained in the studies.

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