UNIVERSITÄT HOHENHEIM
LEHRSTUHL FÜR SOZIOLOGIE (550D)

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Beyond Routine: Assembly Work and the Role of Experience at the Dawn of Industry 4.0. Consequences for Vocational Training.

Dep. of Sociology – WP 01-2016

Impressum

Pfeiffer, Sabine (2016): Beyond Routine: Assembly Work and the Role of Experience at the Dawn of Industry 4.0. Consequences for Vocational Training. University of Hohenheim, Dep. of Sociology, Working Paper 01-2016. Internet: www.sabine-pfeiffer.de/files/downloads/2016-Pfeiffer-Assembly.pdf

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Content

1. Assembly work: just routine work?

This article deals with assembly work from the perspective of non-routine work. This may at first glance be surprising, since non-routine immediately suggests the idea of highly qualified digital work in software development or in innovative fields like collaborative engineering, or of interactive work in the caring sector on in consulting. But industrial assembly – the world of fitting, manipulating, and adjusting – in today's discourse overwhelmingly rates as routine work, and therefore highly susceptible by robotic technology or other digital technologies currently discussed. Not only the recent and highly acknowledged study of Frey and Osborne (2013) sees assembly on the top of susceptible tasks, the routine/non-routine distinction characteristic for labour market research for decades, always recurs to assembly work as major example for routine work (for a critical perspective on this approach see Pfeiffer/Suphan 2015).

It is not immediately obvious that non-routine work, of all things, should receive focus in the field of industrial assembly work. But this is precisely what this article will try: not just assume that assembly is "low-skilled" work only combining routine tasks, but instead investigated assembly work exploratively in all its dimensions and allowing non-routine capabilities to show, if there are any. Our[1] analytical findings show that it is not all that simple when it comes to the supposed simplicity and routine character of assembly work and, furthermore, that assembly work is also packed with different aspects of non-routine tasks and the capabilities to cope with them.

But, now on to a necessary digression into the lively ongoing debate about low-skilled work. For low-skilled work – assembly work included – currently is very much a subject of discussion. At first glance this is surprising, given that it was long assumed that low-skilled work was among modernization's losers in Germany (see Reinberg 2004, p. 61). Ever since the introduction of group work and "leaner" assembly plants there appeared as typical and predominant in industrial production and assembly in Germany the technician qualified in the dual system and with the job profile of the highly qualified problem solver (see Baethge-Kinsky/Tullius 2006; Jürgens 2006, p. 15; Kern/Schumann 1984; Schumann et al. 1994; Springer 2005, p. 15). Contradicting this assessment, already in the 1980s there were the first empirical indications that a complete utilization of available qualification potentials was just as unfeasible as a dynamic expansion of qualifications (see David 1996, p. 13 f.). And even today, the preponderant part of the approximately one million assembly workers in the metal and electronics industries are classified as semi-skilled (Feldmann et al. 2003, p. 1 f.; Kuhlmann 2004, p. 178 ff.). Current labour market research statistics show that employees in "low-skill jobs" or the "less-qualified" make up 30% of the workforce and of employable individuals in Germany as well as the EU (see Clement 2006; Dostal/

[1] "Our" addresses the entire team at ISF Munich that contributed the basic empirical analyses; Tobias Ritter, Stefan Sauer, Eric Treske and Daniela Wühr.

Reinberg 1999; Tessaring 2005). We are seeing forecasts that in 2010 approximately one million jobs in Germany will have to be categorized as low-skill – so it seems that low-skill work contrary to expectations will not be on the way out (Zeller et al. 2004c) – Low-skill work is of quantitatively significant magnitude in retail trade, service industries and capital goods and it is characteristic for many fields of industrial assembly work (Bellmann/Stegmaier 2007; Kupka 2005, p. 12).

From the quantitative angle, therefore, low-skill work although diminishing over the decades still remained a relevant subject in Germany, particularly in assembly work. But, as pointed out by a whole series of current studies, the qualitative demands on what is termed low-skill work are changing. Today it is increasingly taken for granted, on the one hand, that socially-driven "widespread basic qualifications" generally are stressed more than they used to be as given (Zeller et al. 2004b, p. 21) and, on the other hand, that on the "secondary labour market" (Weinkopf 2007, p. 25) more is demanded even of people without formal qualifications than used to be the case. Also, and especially, for the semi-skilled there is talk of a "qualification shift" (Zeller 2005, p. 58) and of substantial changes in requirements structures (Baethge-Kinsky/Tullius 2006, p. 114). For semi- and unskilled workers the substantive requirements are shifting: increasingly, they need both technical as well as process expertise (Zeller et al. 2004, p. 51), even if the technical knowledge required of the semi-skilled is "basically structured more simply" and "in practice is highly specific to operational processes" (ibid., p. 54). An appropriate classification of the varied, in part contradictory, findings re the changed requirements for low-skilled labour calls for a clear differentiation between the formal qualifications and the actual qualification profile or job content of the specific position (Bellmann/Stegmaier 2007, p. 10) or differentiating between formal qualification and effective competence (Erpenbeck 2004, p. 82). Many workers doing assembly work may be formally low-skilled, but, after handling complex products and in moderately to highly automated work surroundings, in the course of their often long employment they have become highly competent. In that case they should be included among the "low-qualified highly competent" according to Erpenbeck. The less knowledge and skill is unilaterally equated with formal and theory-based forms of knowledge in such a classification, the more the indispensable and special competence of assembly workers comes into sharper relief. Especially the concept of experience seems to be essential for really grasping the demands on assembly jobs (and their changes). Current studies at least suggest this: Thus, Zeller et al. emphasize that is practical knowledge that enables the semi-skilled to act adequately and as demanded by the situation, to grasp the big picture better, to cope with breakdowns, to perform quality controls more effectively, and to better integrate and associate information based on its relevance (2004, p. 54), Buck (2003, p. 22) points to the importance of experiential knowledge in a framework of competitive decentralized assembly systems and reduces it to the requirements formula: "experiential knowledge + engagement + expertise." But what does not emerge clearly from such insights is what experience actually is, how it is obtained, how it "functions" and why it seems to play such a big role, along with technical knowledge and standardized handling, in the industrial context in particular. In

Freimuth et al. (2002, p. 14) we encounter first hints as to what the quality of experience in assembly work might consist of: The talk there is of expertise and know-how that are "as if physically and mentally" connected, of sensing changes in materials, of the ability to "smell" problems before they manifest themselves, of knowing from experience "roughly how far to exceed tolerances without risk, or load materials without destroying them" plays just as big a role as "rough rules of thumb" that are "organized along fuzzy logic lines."

We will present the condensed key findings of our studies in what follows. To do so, we will give a rough outline of the analytical concept: Experiential knowledge and labour capacity as a specific view on informal expertise and "tacit knowledge." This perspective brings into focus aspects such as feel for material, intuition, a flair for plant and equipment and the like (*chapter 2*).

In our studies of assembly work we were interested in looking more closely at this "other" side of work: Is there any non-routine to be found in assembly work today? What exactly is experience about in assembly work? How does it find expression? And above all: How important is it currently and in the future in the flexible assembly systems context? To this end, we conducted a total of 62 qualitative interviews in five assembly companies, *chapter 3* gives an overview on the methodological research design and the sampling strategies.

In the next step – and this is the major part of the article – we will present detailed key findings from the empirical analysis, starting with an overall view and condensed insight into our key findings (*chapter 4*). If we look at assembly work from a holistic perspective, we discover that it is anything but "low-skill" and mere routine and thus easily replaced work. The detailed research results are presented in three parts: *Chapter 5* covers the role of non-routine tasks in assembly, startup and malfunction, concentrating on the core tasks of assembly like handling the material, that is, parts, products, equipment, and machinery. *Chapter 6* reveals interactive capabilities that play an increasing role in assembly work but are mostly overseen in the view of conventional distinctions of routine/non-routine tasks: We will show how much interactivity is needed not only in between the working group, but also for ensuring high performance and quality and even a smooth material flow despite observed flaws of the assembly related ICT systems. In *chapter 7* we describe the usually neglected role of assembly workers in processes of innovation and organizational learning.

To sharpen our empirical driven argumentation we then contrast different types of assembly and ask if there are substantial differences between our four case studies of mass assembly and the one contrasting case of more qualified workshop assembly (*chapter 8*). We conclude with a discussion of our findings in light of current educational policy debates in Germany (*chapter 9*) as Germany's system of vocational training is not only quite unique, but also gets increasing international awareness in the ongoing discussion about Industry 4.0 or the industrial internet.

2. A theoretical framework for non-routine

When they design technology and/or the organization of work, when they conceptualize the learning and continuing education modules in enterprises – then the design principles and training methods mostly orient themselves to technical knowledge, material logic and the feasibility of plannable action. Moreover, in judging performance, experience-based abilities seldom play a role. However, everyone knows who the experienced co-workers, the "old hands," are. What they are really able to do, knowing what the name of the game really is, this is the edge they have over the rookies in their work place – these are all factors that are seldom visible from the outside. This also stems from the fact that experience is personal and always comprises informal, implicit, individually distinct knowledge and action. These qualities are difficult to "pin down"; they cannot be loaded into databases or conveyed as theoretical knowledge. The importance of experience is noticed for the most part when it is lacking: when the work station has already been moved or the co-worker has already retired. In this article we focus on the nexus of knowledge, work, and experience, as clearly captured in the sesquipedalian "experience-based knowledge work." Knowledge, work, and experience – these are three concepts that normally are not thought of in the same breath necessarily. To think about them and study them as one, we had recourse in the project to two concepts from industrial and labour sociology: the concept of subjectifying work action (Böhle/Milkau 1988; Böhle/Rose 1992; Böhle et al. 2002) and, connected with it, *labouring capacity* (Pfeiffer 2014). And, although everyone is talking about experience but no one really seems able to verbalize just exactly what experience is, let us begin by elaborating on the conceptual bases of our investigations. We have a fairly clear idea of what work is on the task and activity level. Or, to put it more precisely: We have an image of the manner in which we act and think while working – we all like to see ourselves as objective and logical, as knowing exactly what we are engaged in. It is possible to summarize this idea of doing work as follows:

- Our eyes perceive explicit data and "send" them to our brain. We have a clear objective in mind and work toward it on the principle of: think first, then act.

- All that we do is based on our logical thought processes and the theoretical knowledge we possess.

Machines are inert objects; we relate to them in a purely functional way. According to this idea, this is how we "function": Our eyes act as optical sensors that report data. Environmental stimuli enter our brain and are "processed" there. All this happens based on logical assumptions and theoretically-based knowledge. It is as if we were bipedal, breathing computers. The world around us is perceived as object and that is also how we deal with it: factually, value-neutrally, and objectively. Hence. we also call this action mode "objectifying." Unquestionably, people can act this way. And there are indeed many daily work situations in which this is the best way of proceeding.

Above all, it is whenever we know exactly what lies ahead, when it is clear what the next step should be, when the circumstances surrounding our action can be planned and figured out. However, we also know simultaneously that there is another side to the world and to us as well. The world of work is less and less amenable to being planned out. In many workplaces, the unpredictable has become the new normal. Everything is moving faster and is more complex, so that, at times, no one can say with certainty what is the right thing to do in a live situation. Still, a decision has to be made regardless and often without enough time for thinking through all the theoretical possibilities "like a chess player." But, even the chess grand masters value both situational awareness and intuition most highly because there comes a point when computation no longer gets them anywhere. Furthermore, this is a case where the possibilities are even circumscribed by a clear set of rules. In operational reality, in contrast, something is always bound to happen that no one anticipated. There is always a first time, always a situation that never happened before, and in which the cookie-cutter approach will not do. This type of situation calls for changing roles: the logical-analytical "computer" turns into the improvising musician who masters his instrument with virtuosity and from the gut. This way of acting is also work, and it is constantly increasing in importance. Mostly, it is the experienced workers are the ones who can cope with the unexpected. Work also requires – experience.

Humans approach work with all their senses. Wits and logic alone cannot help us make the right decision in critical situations – intuition, gut feel, and emotion can also furnish useful inputs. We are not just head but also heart. And. it is the body that knows and senses, notices and feels its way, remembers sequences. These capabilities often take time to develop, hence they are above all encountered in experienced workers. Theoretical subject matter knowledge and standardized processes help meet stable, recurring demands. But it is experience that provides us with the chance to also manage the (as yet) unknown, which permits dealing confidently with imponderables. This is because experience is more than just a static ensemble of routines. Experience also signifies a special way of dealing with things, people, and situations at work. The most important traits of this type of acting and knowing that we term "subjectifying" are:

- A holistic awareness: we hear, see, feel, smell simultaneously – everything may be important, nothing is conclusive.

- An explorative, dialogical process: we feel our way, step-wise. We wait for the reaction, we change our behaviour from moment to moment as the situation demands.

- Intuition and feel: often there is no time to think everything through ahead of time. Then we need to have an intuitive sense of the correct thing to do.

- An empathetic relationship: machines may be inanimate objects, but you need to get to know their quirks in the way you get to know a person. And you need and have a good feel for how to interact with them.

What we normally understand as work and what role experience plays are two sides of the same coin. It is not a matter of either-or, but of both-and – of work in the sense of rational planning *coupled with* experience, even, and especially, in assembly work. It is this quality of human ways of working that will keep the human from ever being completely replaceable in complex work environments: the capacity for acting rationally *and* emotionally, analytically *and* intuitively, planned *and* improvisational, as well as by thinking *and* doing; and, beyond that, knowing what type of situation calls for what way of acting and what knowledge. In juxtaposing subjectifying and objectifying work action, we capture not just two key elements of the "experience-based knowledge work," i.e., work and experience, but now also a third one: knowledge. For, in the so-named subjectifying mode, knowledge is always an integral component of acting already and hence of work. Work without knowledge is simply not conceivable; work was always also knowledge work, not just since the knowledge society was proclaimed. Admittedly, while in objectifying work activity the theoretical and formalized (technical) knowledge is consulted before the respective action, (experiential) knowledge and action are inseparably intertwined in the subjectifying modus. A rough overview of both modes is found in *Table 1*.

Usual conceptions of work … „objectifying“	**DIMENSIONS**	**… and the role of experience „subjectifying“**
data registering planned out	PERCEPTION PROCESS	holistic-sensory dialogic and explorative
logical and analytical theory-based objective and rational	THINKING KNOWLEDGE RELATION	sensing and assoziative experience-based empathetic

Table 1: Dimensions of objectifying and objectifying work action

These fundamental dimensions of experience – and their particular importance in complex and highly automated or computerized work environments – are not new insights in labour and industrial sociology. Already, in the late 1980s, the role of experience in "subjectifying" work action was uncovered, first in the study of work in the transition from conventional to CNC-controlled machine tools (Böhle/Milkau 1988) in the processing industry (Bauer et al. 2006; Böhle/Rose 1992) and later among others also in the area of collaboration and interaction work (Bolte 2006; Bolte et al. 2008), and of information work (Pfeiffer 1999 und 2014). This revelation did not languish in academic niches but quickly became relevant in practice: in designing production technology (see Martin 1995; Schulze et al. 2001) and IT systems (Pfeiffer et al. 2008), in the area of vocational training (see Bauer et al. 2006; Schemme 2006, p. 148 f.; Sevsay-Tegethoff 2007) and

in organizational development (Böhle et al. 2004; Böhle et al. 2008). Subjectifying work action, however, is not just an innate ability that individuals "bring with them," so to speak, to work; on the contrary, to be trained, subjectifying abilities in a sense require an opposite number. That which we in everyday language call experience is always something specific. There is no such thing as the assembly experience, rather the special experience in XY assembly work at company Z. Depending on which technology and products are involved, which process steps are typical, and which organizational form is characteristic, it is differentiated by everything that makes the individual workplace specifically what it is, gathered into the special experiential knowledge and action that is required just in this workplace. And it is only there that it can come into being.[2]

After what now has been nearly 20 years of research and implementation experience on the topic of "subjectifying work action and experience" we can make two summarizing observations *First*, these qualities of work action are to be found in all areas studied to date, and, beyond that, they are at least as essential for successful work action as their counterpart, the objectifying abilities. *Second*, of all the empirical fields investigated from the research perspective of the subjectifying work action or labouring capacity, it is particularly in complex work situations that the special importance of these action and knowledge qualities shows up – making experience, in a way, the "core competence" for dealing with the unexpected and therefore is also a guarantor of performance, especially in production (see Böhle et al. 2004). It is therefore hardly surprising that experiential knowledge (whether parsed as "tacit knowledge" or implicit knowledge) in recent years has experienced a renaissance in many areas of society, but above all in the areas of work, vocational training, and technology design, and has found a previously unheard of degree of acceptance (see Böhle et al. 2002). However, it remains that the broad acceptance that is still gathering steam in everyday operations is frequently confronted by a downplaying of, to some extent even discrimination against, the quality of experience. There are many obvious reasons for this having to do with the nature of experience, for example:

- Experience cannot be "seen." As long as everything is apparently running smoothly as seen from the outside, its importance simply does not register. Experience is knowledge that has become "second nature," which makes experience so hard to "pin down" – for instance, by stashing it in databases. And that is also why it is often forgotten to mention or notice it: in breaking in coworkers, in peering over someone's shoulder, during maintenance, etc.

- Experience is something personal; it differs from person to person because everyone has different experiences. This is what makes talking about one's own experiences and exchanging it so important; on the other hand, this is exactly why this unfortunately happens so infrequently.

[2] In order to capture this "opposite number" of work means, work objects, and work organisation, the study was done with the analytical concept of *living labouring capacity* (see Pfeiffer 2014) which positions the material and social givens of work means, work objects, and work organisation as equals alongside the physical and person-specific subjectifying work action.

- It is skilled workers of all stripes especially that regard experience as an almost self-evident element in their skill set that needs no verbalizing. The semi-skilled, for their part, assume that precisely their experience is irrelevant – and this impression is also often conveyed in enterprises.

- Experience is of dynamic quality and therefore it could be seen as the substantial opposite of mere routine. While experiential action interacts within given situations and tackles complexity and unforeseen circumstances, just routine would fail to cope with anything that is or seems slightly out of the ordinary.

There are yet two more reasons for the disregard or disrespect for experience: One is the misperception, rife in the literature as well as in practice, which equates an "experience trove" with hardened routines that blind and stultify in dealing with the new and the unexpected. But the understanding of experience that we have developed of it here as subjectifying action and knowledge qualities means exactly the opposite, namely: experience as a method for doing, as the ability to have (and want to have) new experiences and to apply previous experiences in new ways in coping with unforeseen challenges. The second is that the valuing of experience ultimately is hampered by our industrial history: For many decades, tayloristic forms of organizing work (and, closely tied with it, also the relevant design principles for production technologies) understood experience not as an instance for managing under uncertainty but rather as a source of unpredictability. The objective was to filter experience as an imponderable element out of the production process as much as possible through formalization and standardization or, better yet, to eliminate it entirely. Interchangeable workers reacting identically by the book every time to invariably recurring, unchanging requirements need anything but individually distinct experience that developed in line with personal experiences. This perspective on experience as nuisance factor, pointedly formulated as a veritable "enemy" of standardized processes and formalized procedures, still exerts its influence as cultural background on our world and (not just) the (industrial) world of work. As much as this way of seeing stubbornly hands on, particularly on the decision making level in enterprises, just as little does it fit modern production requirements. It is in complex, partly highly automated processes that the experience of co-workers facilitates forward-looking detection of looming malfunctions and their eventual impacts – all the way to a complete standstill of work processes – and prevention through early intervention. Along with the ever rising variety of versions and ever more dynamically changing market demands, assembly work with standardized, even robust, processes is no longer immune to the unexpected – to cope successfully ad hoc and situationally with these calls for an experience-based effort. And handling the unexpected is only one facet – experience in flexible assembly systems is above all also needed if meaningful standardizations and process improvements are to be pursued in the first place.

Hence, only by acknowledging the special qualities of experience and promoting them can use be made of their vital complementary functioning. It therefore makes sense to take a close look at the expressions of the non-routine parts in assembly work and to highlight something that normally takes place in obscurity and unnoticed. In the next chapters, first we present the methodological approach followed by a detailed insight into the material findings from our studies.

3. Method and sampling strategy

Following the multiple company case study (Yin 2008), our findings derive from 62 qualitative interviews in the automotive sector and in the machinery manufacturing branch. These interviews lasting from 45 to 90 minutes each were complemented by group discussions with employees, management and field experts, and some shift-long working place observations (for an overview of conducted interviews, group discussions and workplace observations per case see *table 2*).

	AUS1	AUS2	AUS3	WSA	EPM
Interviews with…	21	8	8	8	17
…assembly workers	13	6	5	6	8
…group leaders	6	1	3	1	3
…administration	2	1		1	5
…work council					1
workplace observations	6	2	1	2	3
group discussions	5	2	1	2	3

Table 2: Overview of empirical basis

The branch focus of our research projects was put on the automotive and the machinery manufacturing industry in Germany considering their importance to what is recently discussed in Germany under the term Industry 4.0 (Kagermann et al. 2013). The company sample in the automotive industry consists of four suppliers and represents the typical structures of German assembly locations in regards to employee count, product and process complexity or work organisation. For details see *table 3*.

Company characteristics	AUS1	AUS2	AUS3	WSA	EPM
Revenue in Mio EUR	25-50	25-50	> 110	5-15	25-50
Global workforce	1.000 to 2.500	5.000 bis 10.000	2.500 to 5.000	100 to 250	500 to 1.000
Workforce German site	250 to 500	250 to 500	2.500 to 5.000	50 to 150	150 to 250
Share of personell costs	22%	24%	22%	25%	20%
Assembly characteristics					
Product complexity	simple to medium	medium	high	medium to high	medium, to high
Series volume	40 to > 1 Mio.	10 to > 10.000	50 to > 1.000	1 to 10	1 to > 10.000
Assembly system	Single & Flow	Single & Flow	Flow & U-form	Workshop	Single & Flow
Level of automation	medium	medium	high	low	medium
Teamwork since	2000	1998	1995	1990	1994
Team size	10	15	5 – 15	1 – 10	8 – 15
Assembly workforce					
Overall	150 to 200	50 to 100	1.000 to 1.250	< 25	50 to 100
vocational trained/skilled	10%	39%	45%	100%	22%
unksilled/semi-skilled	90%	50%	45%	–	78%
Female worker	21%	–	5%	–	22%
Migrant worker	40%	44%	20%	–	8%
Aged under 30 years	8%	28%	14%	27%	8%
Aged over 50 years	36%	28%	25%	40%	24%

Table 3: Company and workforce characteristics of case studies

Though the initial interviews were conducted in 2006, and the last workplace observations and further group discussions around 2008, the case studies still represent typical German assembly in said branches today regarding the automation level, the dominant forms of assembly and the skill variety oft he workforce. Three companies represent mechanic or electro-mechanical products and are suppliers solely fort he automotive industry (AUS1 – AUS3), one company produces electronic parts for the automotive as well as for other industries (EPM). In the machinery manufacturing branch we observed one enterprise with a total employee count of under 100 (WSA), producing complex and unique machinery via workshop assembly. This company was chosen as a contrast case as this kind of assembly mostly is seen as highly qualified and considered as less routine work than the mass assembly in the automotive sector.

Beyond *theoretical sampling* techniques according to the Grounded Theory (Glaser 1992) and in line with our research interest, one crucial criterion for selecting adequate interview partners in the five chosen companies was their variety of characteristic assembly work (e.g. the automation level, the complexity of parts and oft he assembly process). All gathered and completely transcribed materials underwent an in-depth qualitative content analysis (Mayring 2000) combined with theoretical sensitive coding suggested by Grounded Theory, choosing emergence over forcing empirical data (see Kelle 2005).

4. Assembly work beyond routine – an overall look at our empirical findings

The assembly-experience matrix shown below (see *table 4*) presents a condensed depiction of the results of all of our interviews, workplace observations, and group discussions or workshops in the five businesses surveyed. It shows which dimensions of an experience-based knowledge and action (table columns) are used for which requirements during assembly (table rows) and how important each of them is. Our key objective for the empirical work was to determine the expression and importance of specific work capacity of experienced assembly worker, as well to capture the situations or dimensions in which experience has an important to vital importance. In the interviews, we tried to elicit verbal descriptions from the everyday work activities in which phenomena of subjectifying work action played an especially central role. These are found aggregated in the columns headed holistic awareness, dialogic approach, associative thinking inclusive of hunch and feel and, finally, empathetic relationship.

Assembly overall	Holistic awareness	Dialogic approach	Association and feel	Empathetic relationship	Cumulative significance
Assembly					
Running	■	◎	◎	◉	◉■
Start up	◉	■	◉	■	◉◉■■
Problem Avoidance	■	◎	■	■	■■■
Problem Resolution	◉	◉	◎	◉	◉◉◉
Disposition/organisation					
Group/team	◎	◉	◉	■	◉◉■
Performance	■	◉	◎	■	◉■■
Quality assurance	■	■	■	■	■■■■
Material flow	■	◉	◎	■	◉■■
Innovation					
Set up/optimising	■	■	◉	◉	◉◉■■
Learn	■	■	◎	■	■■■
Experience swap	◉	◉	◉	■	◉◉◉■

◎ plays a role ◉ important ■ vital

Table 4: The overall assembly – experience matrix

This assembly-experience matrix in a compressed format shows clearly that experience qualities play a role in all areas pertaining to assembly work. In addition, we can also distinctly pick out the areas in which they are of special or even vital importance: namely during startup, in quality control, and in set-up and optimization of assembly systems and processes – in other words, in the areas that are addressed particularly by the more flexible assembly work design that integrated production systems strive for.

Before we detail our findings along the individual requirement dimensions in assembly work, here are two major results of our inquiry: First, even repetitive work is not all that unskilled, provided one makes the effort to observe it in detail and on the level of work action. For handling technology, work routine, product, and breakdowns, experience remains a relevant factor – even when it involves seemingly "simple" work. Second, the competency demands relative to disposition and organisation are escalating even for so-called unskilled jobs. But these also have an experience aspect: Quality controls, unimpeded material flow, coordinated group action and performance do not only result from standards, but above all also from the workers' subjectifying workarounds. Finally, it quickly became apparent during the survey process, that experience not only plays a significant role in learning, in knowledge exchange, as well as in setting up and optimizing processes, but also that the "unskilled" assembly workers often are more conscious of this role than, for example, their group coaches and supervisors. Despite all the pruning that necessarily goes with a tabular compaction of 62 qualitative interviews from five different companies, the matrix does show that especially the capacity for holistic sensory awareness and an empathetic relationship with equipment, products, and processes is of striking importance. Our analyses above all show the holistic quality of these skills: It may be possible to classify the whole range of experience and human capacity for work in each specific dimensions of assembly work, but, in daily work, performance without quality is unthinkable just as a smoothly running assembly operation is inconceivable without anticipatory fault avoidance, and so forth. Many of the passages[3] in the interviews we conducted thus can also be assigned to at least one other dimension. This points up the special quality of experience: At all times and in all places it bears on every action and it is only on paper that it can be deprived of this holistic quality.

[3] For reasons of space, we do not replicate interview excerpts in this article. They are available in their entirety in the comprehensive version of the study (Pfeiffer 2007).

5. The role of non-routine tasks in assembly, startup and malfunction

The center of assembly activity is occupied by “actual assembly work”: fitting, handling, inserting, and adjusting – seemingly monotonous, undemanding activities. Assembly in its uninterrupted normal operation in a sense represents the implicit paradigm of “unskilled work” that glimmers through the debates on this subject we referred to in the introduction. And in the interviews on the supervisorial level we often encounter the view that precisely in this context no elaborate experiential knowledge is needed. However, if we look in a differentiated manner at the demands that are givens in the daily work of a trouble-free assembly operation – and not just in startup or in recognition, avoidance, and remedying of malfunctions – then the profound importance of experience for such seemingly “simple” work emerges clearly.

5.1 Undisturbed assembly

For it is all about just-in-time assembly of what may be highly complicated products in the shortest cycle times with the highest quality. Here work cannot be reduced to a single hand movement – even in the smoothly running assembly operation experienced workers do much more: They perceive the entire process with all their senses (products, parts, machinery, group…). Bodies adjust not only to cycle times, but synchronize with the entire process and the rhythms of coworkers (for instance, on a U-shaped production line). No matter how monotonous the sequence of steps may be, experienced workers remain on the alert for the unexpected. They regard the whole as “their” work; every departure from normal is significant. Part of this, for example, is the ability to keep track of the whole environment with peripheral vision, so to speak out of the corner of the eye, while the inexperienced concentrate more or less exclusively on what they are doing.

In sensory awareness, hearing plays a very special role: Even the smallest change in the background noise – despite the prevailing immense ambient noise – registers with experienced workers and is gauged accurately. With the ability to perceive changes in sound early on and interpret them accurately, the transitions from the (still!) undisturbed assembly operation to prevent malfunctions are fluent. Many changes of sound can be assigned easily and unequivocally to individual processing events, but most often the required perceptual ability is tuned to significantly subtler variations. Hearing is interwoven with a feel for something like a normal or changed texture of the entire noise carpet: The experienced assembler does not hear clearly identifiable tones that point to the cause of a technical defect, but instead knows that the machine has a “belly ache.” Something that could at first glance be put down to imprecision or vagueness is precisely the strength of this perceptual ability: Precisely because a fuzzy awareness is possible, any

change – even one never before experienced, still unfamiliar – can register very early on. Those with experience start listening (up) already when approaching the machine or when crossing through the shop floor, so that the perceptual ability is not only or first turned on during the actual assembly hand maneuver. What separates the experienced from the inexperienced assembly worker is, among others, the former's sensitivity to the change in sound relating to their own process or machine heard over the ambient noise. Decisive in this is the ability not only to perceive the changes but also to classify and integrate them while they are happening. It is not a matter here of an intentional, targeted listening but instead, analogous to the peripheral vision out of the corners of the eye, it requires listening to the whole noise carpet and changes in it as if through "the corners of the ears." Given the short cycle times that are normal in series assembly today, it is not just precision that is called for in handling but also speed.

Speed *and* precision, volume *and* quality are linked by the experienced worker in a kind of unique overall handling dexterity, not just in the speed of a single hand movement. This type of dexterity, which has a strong physically related component, is much more than dull routine. It is really a very sensing type of action (even when handling component groups, some of which may weigh several kilos) that keeps open all sensory channels for unexpected changes. It is precisely this dexterity, the body-memorized feel for handling and processing, that also facilitates that every hand maneuver, every haptic contact in an individual assembly hand movement and comprehensive quality control (of own activity, of upstream processes, of materials used, of process steps, etc.) are all rolled into one. What shapes the total process even more robustly and effectively can nevertheless be felt as stress-related demands by the individual. Still, because this staying clocked in does make functional sense on the material-corporeal level, it gets done; the body can (and "wants to," so to speak) escape the material requirements only conditionally.

Nothing is ever the same. The experienced worker also takes this into account even when the assembly of one and the same part has been running flawlessly for some time. It is always also not just about reacting to potential changes, but about anticipating them: Not only does this apply to inter-company upstream processing steps, but even in the event of a tool change on the supplier's side. What passes in assembly work as uninterrupted normal operation frequently would not be that if experienced assembly workers could not continually master, almost in an offhand way, the minutest actions geared to avoiding and remedying malfunctions that they integrate into their supposedly "repetitive" hand movements. Frequently, this is not even noticed in companies, because, as a consequence of the preemptive handling of malfunctions, they do not "register" as downtime. Let the individual assembly steps, looked at superficially from outside, appear to be repetitive and unskilled: thanks to their abilities, the experienced workers not only master the running assembly, but they also see to it that the assembly line keeps running optimally. They themselves are absolutely aware of the special quality of these experience-based

abilities, and they also apply them to new challenges – even when the business environment does not provide sufficient framework parameters, up to and including unpaid time even.

5.2 Startup and handling changes

With startup, it becomes obvious with particular frequency that the assembly workers' experience compensates for standards that are either not set or not likely to be set, for example, because the specifications for adjusting the processes and machines are not clear enough or are missing altogether. In part, the parameters are not adapted for the changes in parts or tools, because there is no standard for regularly updating values once they are set; in part, the processes themselves are so fluid (e.g., through waste, quality fluctuations of raw and other materials and sometimes because of machines that are over 30 years old) that pre-set parameter settings can only serve for gross orientation and tending to them permanently does not make technical sense either. Be the reason what it may: If adjustment parameters are not available or not sufficient, the adjustment at startup has to rely on the experience of the workforce. Generally, many adjustments during parts changes or startup call for a careful feeling your way, in which sensory awareness as well as handling feels play a special role. Depending on the internal division of labour, complicated adjustment processes will come within the purview of the adjusters and/or group leaders. But groups in which the experience of several workers makes possible, for example, the parallel adjustment of several work stations during a refitting, naturally reduce set-up times and so boost the overall productivity. This is why, wherever feasible, the "unskilled" workers take the adjustment process in hand themselves. As such, experienced workers and group leaders know exactly which adjustment and refit operations require what level of experience. When this is not given its due, things go wrong.

Seasoned workers master conversion to similar or familiar parts effortlessly; this is normal for them. They know the devil is in the details – an omitted end stop can ruin everything. And even the basically familiar series part can differ tomorrow because there have been design changes. The veterans are ready for anything. Particularly in adjusting parameters, when completely new parts are to be worked on, assembly workers and set-up people work together closely. Let their collective practical knowledge be applied to parameter setting, and this shared relationship with the adjustment process will prove especially effective result-wise. Another decisive advantage of experience takes effect in the startup of new and unfamiliar, possibly even technically more difficult, parts (as distinct from changeovers to familiar parts): Experienced assembly workers do not know fear, but they have respect. They size up the challenge and see their qualitative differences. And their experience lends them the necessary aplomb for confronting the challenge.

5.3 Anticipating and coping malfunction

Uninterrupted normal operation is anything but pervasive normality; it is more like a fragile state that can be disturbed any time and without notice by imponderables. This often has to do with the (mostly creeping) wear and tear of the equipment, the handling contrivances, as well as molds and tools used. But the unforeseen also arises from variations in materials and the quality of assembly parts, whether they come from downstream processes or from suppliers. Automation can also produce unexpected problems; especially in the relatively tightly chained assembly areas or the so-called bottleneck processes. Particularly in the highly automated volume assembly, the smallest flaws can have far-reaching and above all costly consequences: a wrongly-interpreted sensor reading, an initiator that will not switch on, or a relatively minor programming error after releasing a software upgrade, and it is all over. Early recognition of impending malfunctions is one of the most important skills of experienced assembly workers. It is only with experience that varied and unexpected causes of trouble can be recognized by the smallest telltale signs that an outsider would scarcely notice. Key here is also knowing that malfunctions can have the most varied causes: equipment wear and tear and changed materials, supplier parts, or handling-automation, etc. The variety of problems can never be completely intercepted with technology – that much sensing technology would make no sense and would not be necessary in any case. Experienced workers know, for example, what the total noise background sounds like from a particular workstation – they not only catch the slightest deviation, but they can also gauge its relevance.

There is a common notion that with added control technology and more sensors in the machines and logistics facilities disruption avoidance could, in a sense, be taken away from the operators and delegated to technology. But not all breakdowns can be captured in a timely, unambiguous manner and reported by technology. Even in the case of disruptions that can register with ICT support, experience-guided awareness of malfunctions is often quicker and more effective. For that matter, control and measurement technology can itself be a source of malfunctions, something that experienced workers know. A persistent unchanged measurement reading, for instance, arouses suspicions and they have ways and means for quickly checking if the indicated reading and reality are one and the same. Experienced workers thus not only understand the language of the material processes, but also the language of erroneous control signals – they know how to interpret both and to relate them to each other in order to forestall malfunctions before they happen. What “runs along” subliminally as an early indicator of impending disruptions in ongoing assembly work shows up as a key element in problem prevention: Holistic sensory awareness puts the experienced worker in a position of recognizing any sort of possible problem indicators so quickly that an actual dysfunction can often be avoided by a preventive action. Especially, being sensitive to noise often helps to detect machine wear and tear at such an early stage that an unplanned shutdown can be completely forestalled. It is not only machines and tools that are under “observation” by seasoned assembly workers as potential disruptive factors, but also

intake, transport, and handling technology, for they are often the cause of entire processes grinding to a halt. The experienced, however, do not just keep an eye on the main press or on the process bottleneck, but also, for example, on the seemingly irrelevant conveyor belts. But not only noises are attentively listened for in order to register machine wear and tear in time. Where noises cannot help, the whole range of sensory perception takes over in order to recognize any sort of problem already by first signs and take it seriously. Included here is the look and feel during handling, as well as closer observation of machine or process behaviour. Should small or larger problems surface, it is not just the practical knowledge of the maintenance person that is in demand, but also the assembly worker's experience. The latter takes care of many small details while a process is running – for example, the repeatedly needed resetting of end stops. Experienced workers not only master the small intervention, they are also aware of the limits of their experience. They do not experiment blindly with the equipment and control technology, but can judge when keeping something in working condition is called for. Larger breakdowns can be handled most effectively when maintenance and assembly workers mutually recognize each other's pertinent, specific experiential knowledge and – especially in searching for causes – jointly implement it. Time permitting, the experienced assembly worker profits from the repairs done by maintenance personnel to gain additional practical knowledge of the machines and facilities. Small, seemingly ordinary interventions, e.g., sign off, are normal practice and are hardly thought of as troubleshooting by the workers. And yet, they also are only possible when grounded in long years of experience, for it is equally wrong to sign off prematurely as it is not to have enough confidence to sign off (instead calling in the group leader in every single instance, for example). Whether the defect report on the equipment should be taken seriously or can be ignored without compromising quality or the upstream process calls for split-second decisions, which is exactly why they can only be made effectively by someone with experience. The notion is often encountered that especially highly-automated facilities can purposely be staffed with the less experienced, since these facilities generate error message on their own in case of process and quality deviations. But interpreting these error messages is not that simple. Reconciling their real significance is successful only the basis of grounded experience. Indeed, experienced workers in assembly regard the necessity to intervene as an integral element in their work, as a "minor detail" of which nothing much is made. That does not change the fact that these steady interventions are what keeps larger disruptions from happening in the first place.

The numerous, seemingly simple, standard errors that are experienced as normal and that can be easily fixed must not blind to the unforeseen errors. Experienced workers are aware that their standard fix does not always do the trick and that a same phenomenon may hide totally different remediation requirements. This ability to differentiate, this knowledge of the variability of what causes defects, and hence also the variation in remedial measures, only accumulates over time – it simply is a matter of experience. Just as relevant as a timely recognition of malfunction about to happen is choosing the right time to intervene. Especially with wear- and process-related dis-

ruptions a timely intervention can prevent serious, costly repercussions. The “low-skilled” assembly workers sometimes know more tweaks and more effective ones, based on their specific experience with normally operating equipment and processes, than the fitters or the group leaders. And they absolutely think in a cost-conscious manner in these situations – a skill that supervisors often deny in “their” assembly people.

6. Assembly embedded interactive tasks: disposition und organisation

Besides the actual assembly work, the “extraneous” plays an ever more important role especially in the case of modern, flexible assembly processes. Our inquiries show that experience is significant not just in working with technology, machinery, and products, but also, and increasingly so, in relation to the group and group action, performance, quality assurance and materials flow. Disposition and organisation in recent years have clearly grown as requirement dimensions and belonging to them is not only a new canon of technical knowledge but also specific manifestations of experience. Experience matters in work life not just in relation to dealing with technical things; the corporate social environment is also the source of experience as well as an area for its application.

6.1 Non-routine and interactivity in group or team

In assembly group work, experience relates not only to the use of so-called “social skills.” Certainly, it is important to be team-capable, to act in a collegial manner, resolve conflicts objectively, listen actively, etc. Of course, experience plays a role in these forms of social coexistence as well. However, an assembly team is not only about social cohesion. It is also and especially a work connection. To perceive with all the senses is an important dimension of experience-based action. It is meaningful not only in relation to early problem prevention, but also when it comes to group relationships among colleagues. Sensing in timely fashion who needs help, or seeing with your peripheral vision that a new colleague’s workstation is too elaborately arranged ergonomically – that, too, is a question of experience. In certain types of assembly work, such as on U-type assembly lines, it is all about cycling smoothly into the technical processes and into the group. That is achieved only with a highly developed holistic awareness. Experienced individuals move as a group in synch with short cycle times, often in a confined space like a practiced soccer team. Only when a player is substituted and the rhythm is lost does the extent become apparent to which a collective body sense and coordination capability are in play here. Experiential knowledge is always individual – not everyone in a group can have accumulated the same experience.

This diversity turns into strength when all are aware of their own experience and that of the others, but also of everyone's limits. This is a particular challenge for an experienced group leader. In a successful shared group experience, not only do quality and piece counts click, the entire group's experiential knowledge also grows. In this context, the ability to relate in a shared experiential manner to the work object is often more important than "just" the social level of collective skill. With this clocking in with technical processes and the group not only is the work process mastered, but planning errors or shortfalls in fine-tuning are compensated for. Organizing the rotation within the group is therefore not only question of a fair distribution of the workload, but also depends on gauging individual skill and experiences. An experienced group will factor both criteria into how it organizes its rotation.

Productivity does not just result from efficient flows, standardized processes, and fully developed technology. Piece counts and cycle times demanded by today's market pressures, are not achievable without the experienced assembly worker. Whenever the question of skill requirements in assembly work is the subject – the issues of performance and productivity are seldom part of the discussion. Performance and productivity are seen as basic and self-evident framework conditions and as resulting from the most optimal work possible in engineering and construction, in job planning and production control. According to this view, assembly as supposedly unskilled and monotonous routine work in the end is only the executing organ whose actors are interchangeable at will. Even when the decision makers in an enterprise are aware of the potential impacts of shifting or temp work and that experience also is a significant element in performance, they are often downplayed. The workers on the assembly line, however, know that whoever is the most experienced on a workstation guarantees not only the best quality on it but also the highest piece counts. The supervisory level frequently underestimates the engagement of the "unskilled" assembly workers. Especially the group leaders or team leaders know quite precisely from experience which seats can be assigned to the less experienced and on which stations highly developed experience is indispensable. A job rotation that would not work in practice often has to do with knowing that the group's overall productivity and/or quality would suffer in the short run if a change were made. Seasoned workers apply their skill and knowledge in every situation and thereby ensure quality and productivity. These are not just "afterthoughts" of technical-organisational flows but also flexible guarantors of the efficiency of the whole.

6.2 Non-routine capabilities ensuring performance and quality

The overall equipment effectiveness (OEE), is calculated from key performance indicators like machine availability, machine performance level, etc. But a key factor in a high OEE stems from something that is so difficult to put a number on and cannot in the least be captured in key performance indicators – worker experience. Absent experience that is permanently fed into ongoing assembly as well as start up, the cycle times and piece counts demanded today are not

achievable in the long run. Without the ability to make the right move in case of impending malfunctions – even under time pressure! – high productivity is not sustainable. This experience is also indispensable when it comes to performance. This does not just apply to piece counts; experience is also a material performance factor in specialty mechanical engineering. What matters there is meeting deadlines and as rapid an implementation as possible, capabilities that are tightly coupled with the experience backing them up. One reasons that experience and performance are tightly interlaced resides in the speed and sleepwalker-like facility in performing the individual hand movements. This is an ability that seasoned workers will always possess over new hires or the less experienced.

The experienced, however, are simultaneously adept at not sacrificing quality on the piece count altar. Speed does not become a fetish, but instead, when changing starting conditions bring with them differentiated and, especially, action sequences of varying durations, these will be executed with the necessary caution. Experienced workers pull off this permanent, situationally conditioned balancing act because they not only can perform the individual hand maneuver quickly and precisely, but also because a hand movement is not just a hand movement. It is also always a subliminal quality control that often involves sufficient and simultaneous problem preventing micro-moves “at the margin” or, better said, “on the fly.”

Complex products, like those produced in assembly location Germany, are quality products; demands for quality will only keep increasing. The global competitive situation shows that, today and in the future, it is not just about competing on costs, it is also about competing on quality. Quality is crucially determined on the worker level and connected with their skills, an insight that has not been challenged for many years. This is why many quality control measures, such as static process control (SPC), self-checking by craftsmen, quality circles, and quality management, go hand in glove with worker training methods. But quality cannot be assured only by methods or by conveying theoretical knowledge. Quality is the dimension in assembly work in which all kinds of experience-based knowledge and action have an indispensable role. A holistic awareness, a dialogic dealing with product and process, a feel for material and flows, as well as a real relationship to handling things are all necessary for guaranteeing high quality in lasting fashion. Quality production thus is not only important on the level of what is an almost “ordained” quality assurance.

The experienced pick up possible errors with all their senses, literally with every fiber of their bodies. Reaching into the Kanban basket, loading the machine – every haptic contact, every glance out of the corner of the eye is ongoing quality control. Here a changed metal surface attracts attention, there a problem burr is noticed or a drill hole is seen to be missing. All this happens practically in the blink of an eye, almost unconsciously, with every move of the hand, day in day out – and all of it is possible only against a background of highly developed experience. Only someone through whose hands much quality has flowed, only someone who has already experi-

enced the most varied defective parts has accumulated the experience for this kind of holistic quality control. Not only does this prevent own mistakes, but it also catches errors from preceding processing steps and intuits potential mistakes by the colleague in the next seat. Add to this something akin to a collegial quality understanding, for example, by handing off the parts in such a manner that the left-handed colleague in the next station gets at them better. To take responsibility for overall quality in this sense comprises much more than what can be depicted by quality KPIs. But if there is a shortage of this kind of experience in assembly, today's minimum parts-per-minute rates are not achievable. There is no such thing as a zero-defect car without a maximum of experience on the employee level.

6.3 Mastering the material flow and compensating ICT-flaws

Integrated production systems aim not only at optimizing assembly processes per se; the continual improvement with the objective of an unimpeded material flow is just as crucial. Highly variegated solutions have been found, depending on the type of product and assembly technique. There are Kanban systems that even tie in the suppliers. Then there are the so-called milk runners, individuals tasked with cyclical material provisioning and which therefore relieve the groups of that burden. In high volume production, the internal business logistics in part are even outsourced to external service providers.

In one-of-a-kind ("one-off") and batch production assembly, in turn, it is not only the material flow, but even material procurement that assembly workers are responsible for. While in the course of semi-autonomous group work and lean production the responsibility for material flow was very firmly shifted to the group, now the tendency is to relieve the group of it. In addition, ICT systems for production planning and control hold out the promise of real-time and precise monitoring of material flows and warehouses, implying that no order will be released unless all necessary parts are readily available. Were all these logistical, organisational, and ICT measures to function smoothly and interact seamlessly with one another, if all actors worked together well, from suppliers to the logistics provider to the milk runner and the employee in procurement – who ultimately enters the basic data relevant to material flow in the ICT systems – then the demands on the assembler relative to material flow would be vanishingly small.

However, the industrial reality looks different. The supplier parts may be in house, but not in sufficient quantity at the right time in the right place. Milk runners may give it their best, but then they can't be there at the decisive moment since their "functioning" depends on too many external conditions. The difference between the PPS (Production Planning System) readout and the real material situation unfortunately empirically is not an exception but a daily fact in many enterprises, as is also the often time-intensive search for the missing parts that ensues. Those with experience know all about this "completely normal insanity." Their holistic awareness relates not

to assembly itself but the whole ball of wax. A Kanban basket that for too long has not been replenished, a harried milk runner, intuition in looking for missing parts: seasoned assembly workers conceive of it all as an obvious part of their work.

It is simply true that assembly work can only run undisturbed when no imponderables arise from incongruous real and computerized processes, or if the resulting uncertainty does not impact the flow of production. Exactly this kind of imponderable is on the rise: time and again, experienced workers have to improvise on the level of the real process. An example that repeatedly crops up empirically are deficits in capacity and product planning that, when they manifest themselves, must be improvised for situationally and ad hoc by experienced workers. In the rarest cases do these deficits result from incorrect planning on the part of employees in production planning. Instead, what happens here is that the basic, materially determined parameters, which are indispensable for meaningful planning, are not entered into the planning system as actual data – leading repeatedly to many cases where the times stored in electronic production plans for individual work runs do not agree with actually required times. This then coincides – frequently with cumulative effect – with requirements that are not capable of being integrated in a timely manner with capacity planning and that simply cannot be compensated for in terms of substance (e.g., problems with individual equipment, delays, sub-par supplier parts, and the like).

Typically, to top it all off, there is the search for what could be called computer-generated missing parts, to coin a phrase. This refers to parts which, according to the PP&C or ERP systems, should be available in sufficient piece count and even at the right time at the right place for a pending order – at least that is what the display says. But too often the displayed normal status does not really exist. The parts are neither to be found on the spot or in the indicated storage location. Should the planning horizons generated by the sales logic then remain in the systems as constructs that are difficult to work around, the forecasts suggested via ERP and PPS then tend to turn into barriers to real, functioning plans. What planning could not manage can only be compensated for by experience in the work process.

7. Innovation and organisational learning

Assembly work even plays a role in innovative processes, and assembly workers are involved in optimizing and organisational learning measures. Their experience is needed in configuring and ramp-up of new assembly lines, they are inclined to continually optimize the assembly process, and last but not least they play an important role in transferring their non-routine capabilities and the related so called tacit knowledge towards other workers e.g. in assembly sites offshored to

low-cost countries, to assembly line planners and to experts for automatization – even at the cost of losing their own jobs.

7.1 Configuring, optimizing, and learning

Constantly configuring and optimizing processes is unthinkable absent the specific experiential knowledge of the individual assembly worker. Many companies have realized this and involve the employees earlier than ever in process configuration and optimization. Even when it comes to conceptualizing facilities and shifting workstations their experiential knowledge is purposely brought in and used, in a way it never used to be. And finally: Whether it is Kaizen and CIP (continual improvement process) or a company-wide employee suggestion program, all these systems thrive on assembly workers' inputs of practical knowledge. And this they provide indeed. Seasoned workers know not only about the relevance of their experiential knowledge applied to configuration, they volunteer it. They regard configuration and optimization not as special tasks but as integral elements of daily work, not only in the operational "small potatoes" at their own workstation, but also by taking part in overarching optimization processes or by pushing for them. A natural optimization strategy relates to the level of the item count. Experienced assembly employees also take care of that, even if they raise their own time pressure and that of their colleagues in doing so. Seasoned workers not only bring their experience to bear on configuring individual hand movements in their workplace in its narrowest sense, but also they eye entire processes when it comes to optimization. Often the configuration and optimization activities of experienced assembly workers compensate for design flaws in equipment or instruments, and in specialty mechanical engineering area even for design flaws in the products themselves. What matters most is that experienced individuals not only have the ability to configure and optimize processes but also want to exercise that ability. Empirically, we found many indications of the kind of self-starter engagement with, and enthusiasm for, what might be called "grass-roots" optimization – a potential that should not be stifled by too much top-down standardization.

7.2 Learning and being able to gather experience

Experience is not simply switched on or off. It is not only the spontaneous consequence of putting in many years at one and the same place of work. Experience is also a question of attitude and a method of doing. The experienced are not only sure of how important their experience is to the work process, they also develop a feel for the paths to learning, a highly individual way of "picking up" experience. It is learning by doing and experienced workers organize their doing, they seek out opportunities for new experiences instead of avoiding them. In this way, any work situation can turn into a learning situation; for example, maintenance repairs on your own workstation. An experienced assembly worker knows that she can experience her machine in a totally different way than while it is running. Or, when a colleague is doing rework, she pitches in

and, by doing so, takes the initiative in looking at the upstream process. The seasoned understand the significance of such situations and take advantage of them – if allowed to. Regrettably, the piece count pressure is often so great that such valuable situations of learning by experience cannot be exploited sufficiently. Also, many in-company continuing education activities are oriented toward formal teaching of theoretical knowledge and too seldom to criteria for an experience-guided learning. In contrast, there is no need to explain to assembly workers how learning from experience differs from other learning techniques. They have a very well developed sense that gathering experience and learning during the work process are two sides of the same coin. Experienced employees doing assembly also know that experiential learning can already start when watching others at work. The key element in experience learning, however, is and will remain hands-on doing: the haptic handling of work objects, the deploying of sensory awareness, gaining body intelligence and a feel for materiality during the work process. Many interview excerpts illustrate that assembly workers are very much in the know about this access to learning and also apply this knowledge purposefully. In learning and experience-accumulating, the important thing is to confront things, to get into them, experience them hands-on. Many interview passages show that assembly employees often know more about successful mechanisms and feasible ways of experiential learning than many vocational trainers.

Combined with this attitude of being open to experience comes being conscious that what is learned by hands-on doing is retained best – it imparts certainty and authority in dealing with the unforeseen. They treasure experience and therefore seek out learning situations that make it possible for them to experience new products or equipment, for example, from the ground up. Ultimately, learning from experience also means learning from problems that have been solved. While on the discourse level inside enterprises an ever more strongly expressed discrimination of the word “problem” seems to be being formulated, experienced assembly workers recognize the value of problems for gathering experience. Not just the actual cause of the problem can be of significance here – experiential learning also feeds on the large and small problems that paved the way to a solution.

7.3 Sharing experience and collective learning

Exchanging experiences is also part of experiential learning. Fundamental here is being aware of how special and important one’s own experiential knowledge is – and not just your own but also the experiential knowledge of others. Readiness to share this knowledge does not first have to be awakened in the experienced for they know that everyone has their share of it. If this readiness is lacking, it is usually operationally conditioned, for instance, due to a group leader that does not nurture but monopolizes everything herself, a group climate based on competition, or piece counts and cycle time pressures that crowd out everything else.

It happens that passing on experiential knowledge occurs best in a concrete situation and by direct showing, by mimicking and by shared hands-on doing. That takes time and opportunity. The situational passing on of experiential knowledge during the work process is the most effective way of collective learning: no continuing education module, no group discussion, no written best practice can take its place. As part of a successful exchange of experience you have to approach more experienced colleagues to share theirs. That in itself calls for experience – knowing who has the deepest and the most helpful store of experiences. And this experience then is called on situationally when it is needed. Of course, it is not just relevant to gather experience from the right source, that is, from the colleague who has pertinent experience with the problem at hand. It always takes two (at least) for an exchange of experience.

That means there has to be the right attitude on the other side, that of the experienced person. Employees must not only want to pass on their experience, but they must be able to judge who is less experienced and what experience the other person lacks. Being prepared to exchange information does not stop at the group boundary or at the end of a shift. Among the employees, this willingness includes a great deal, such as experiences with the equipment manufacturer, sharing about shift and group boundaries, all the way into time after work. A typical example of sharing experience at shift change shows that, besides the entries into the shift log, those hard-to-formulate experiences with the process-related state are passed on. Exchanges of experience gained are regarded as completely normal elements of work activity; and, where necessary, even to the point of "hot wiring." Experience exchange functions not only verbally, but is often coupled with a demonstration on the object and with mimicry. Wherever possible, experience exchanges interlace with shared hands-on doing.

8. One-off and workshop assembly: a special case?

High volume assembly, one-off assembly in specialty engineering shops, line or U-shape assembly, highly automated or manually intensive: assembly work covers a wide spectrum. The differences are immense and vary not only by assembly type, but at least as markedly by automation level, batch sizes, product complexity, technologies deployed, forms of group work, etc. As commonly-held as it is wrong is the notion that the skilled worker in specialty engineering is, and needs to be, more experienced than the unskilled assembler in line production. Our studies show that all dimensions of experience are encountered in every kind of assembly work, and thus assembly work should not be labeled as routine work only. The way experience is expressed clearly

can differ significantly. But for these differences the type of assembly is no more important than, for example, the product complexity or the degree of automation.

Nonetheless, there are differences. Unlike volume assembly, in specialty assembly the separation between continuous assembly and startup tends to blur, especially in one-off assembly where "continuous startup" could be said to prevail. Moreover, compared to line assembly, the "group" topic recedes into the background. Instead, because of the high degree of task integration, the subject of disposition/organisation assumes greater importance, involving as it does requirements for closer coordination with construction, work scheduling, supplier businesses and processes and even with customers on the application side. And, without question, assembly workers in workshops for the most part have a more integrated work environment, and they are granted greater autonomy in their work activities.

Experience, in a manner of speaking, grows as their tasks grow, a truism that not only the empirical findings from our study confirm. Still, employees in workshop assembly manage these tasks with the same facets of experiential knowledge as those in seemingly unskilled volume assembly. In both types of assembly, the features of experience are expressed in the same dimensions: holistic awareness, dialogic approach, association/feel and empathetic relationship. Time pressure is less pronounced in workshop assembly and there is less standardization of work processes, and this also means that errors do not necessarily entail immediate consequences for costs. A great deal can be straightened out in workshop assembly by improvising or spontaneous changes in work sequence and the like, a freedom that is absent on assembly lines. Here experience has to function "on the spot."

All things considered, however, the comparative look at both types of assembly work shows that the differences between workshop and line assembly are not as large as they are usually made out to be. This does not devalue the common image of the experienced workshop assembler in specialty mechanical engineering, which coincides largely with that of the skilled technician; however, it is high time that experience in the "unskilled" work on the assembly line is accorded recognition that measures up to its importance and overcomes the long hold routine/non-routine distinction.

So much for the experience perspective. If we look at it instead from the formal qualification side, it becomes apparent that relevant technical training is indispensable for demanding assembly in workshops – but the same holds just as true for exacting volume assembly. The skill-level gap, and therefore also the outside recognition gap, that three years of technical training account for, incidentally does not just reside in the elaborated theoretical technical knowledge and a plus of skilled craftsmanship and processes, but also provides a head start on experience: three years of training also happen to be three years of experience gathering, which, for the most part, takes place during an early vocational and work-biographical socialization phase and during which a

foundational experience repertoire that can be built on is acquired. To that extent, the experiential edge gained during vocational training is a better diagnostic criterion for differentiating skill levels than a comparison of different kinds of assembly work.

9. Assembly, non-routine and vocational training

In the (vocational) training policy debate swirling around unskilled work at present "nearly irreconcilable" perspectives clash, which, "on the one hand, postulate the abolition of skilled work and basic vocational training and, on the other hand, a tough defense of the status quo (Lacher 2006a, p. 89). The contradictions already start with the initial diagnoses. Much seems to speak for an expansion of the qualitative demands of assembly work. This is equally the diagnosis for learning, thinking, responsibility, cooperation and completeness (Bullinger 1993, p. 163) as it is for the expansion of purely technical knowledge and industrial skills in process, context, and dependency knowledge (Freimuth et al. 2002, p. 13). Apparent is an increasing requirement for process skills that would also equip skilled and unskilled employees to "expend their technical skills to fit the situation" (Zeller et al. 2004), and an increased significance of integration knowledge in the sense of an ability to apply knowledge of procedures in other process steps in the concrete case (Berger et al. 2005, p. 49). Finally, assembly employees need "sufficient social and qualificatory resources [...] for dealing with novelty, uncertainty, complexity and conflicts" (Buck/Reif 2003, p. 36 f.). Even the concept of "helper activities" needs new definition in view of these phenomena (Zeller et al. 2004a, p. 31). Driving definitions in this case is no longer the description of the workplace, but rather the work environment, that is increasingly marked by complexity, dynamism, and non-transparency (ibid., p. 35-49). And lastly, even when it comes to planning assembly systems, bringing the know-how of colleagues engaged in value creation to bear is seen as indispensable (see Kluge et al. 2007). Looking at these assertions, the answer to the question of skill and qualification requirements in assembly work is clear: Various kinds of changes in assembly work are accompanied by increasing demands on the abilities of employees and an expansion of the knowledge needed to cope with daily work. That said, the natural outgrowth of an increase in training and qualification is subject to controversy and discussion in new education policy tones.

In connection with increase in manual activities, Lacher (2005, p. 62 und 2006) sees even in the standardized automobile assembly production systems a new worker type, the "qualified routine worker." The latter sees herself confronted by increasingly ambiguous operational requirements: between the poles of complete operational tasks and repetitive piece work, between teamwork

and individual routine tasks, between continual improvement and work based on standards, and finally between business process orientation and sub activities.

At this new interface between unskilled work and skilled work, a segmentation is occurring both of the skilled as well as the unskilled "handyman activities." Activities emerge that presuppose more complex abilities and expanded knowledge and along with them awaken the need for two-year vocational training courses for assembly and fabrication work; in other words, for an education below the level of the skilled worker (Zeller 2006). This demand is increasingly encountered in the current discussion: so, for example, also Springer (2005a, p. 24), alongside the multi-year basic technical education of technical problem solvers calls for the introduction of a short basic qualification for routine work with the option of systematic ongoing qualification in the direction of problem solving. Lacher (2005, p. 63) goes so far as to take the conflicting demands between routine and flexibilization as a reason for demanding "the abolition of the three-and-a-half year rigid time formula for initial vocational training." And from the employer side comes a similar determination: In the area of manual line assembly, as a rule no skilled worker qualifications are necessary and there exists all the way up into the processing functions a high degree of misallocation of qualifications; instead, the hallmark of efficient work organisations is the integration of low-skilled and skilled activities (Gryglewski 2005, p. 5 f.). With that, the initial education as "qualifications and flexibility reserve" loses importance in comparison with work-task related qualification, hence employability is laid at the feet of the employee. (ibid., p. 8). And so a discussion that still has legs starts up again: Already in the 1980 and 1990s, studies of assembly work prognosticated that, at most, a near skilled-worker qualification level would suffice to achieve a "partial professionalization" based on occupational experience and adequate semiskilled qualification (Seitz 1992, p. 174).

However, the prevalence and loudness of voices that went so far as to advocate abolishing three-year vocational training have diminished. Lacher (2006a, p. 87), for example, stresses that the classic skilled worker is by no means obsolete. That is why, on the one hand, training for skilled work must continue; on the other hand, vocational training also is called for to meet the demand for qualified routine work (ibid., p. 90). The approaches that are being offered or discussed at the moment as potential solutions differ: Besides approaches relying on enterprise-specific solution, the (e.g., Glander 2006, p. 183 f.) career education debate focuses on possible options in the context of the national qualification framework (see Clement 2006, p. 100 ff. und 2007). Others right away cast an eye on a whole bundle of otherwise non-specific measures, for example, Weinkopf (2007, p. 30) in calling for improving the documentation of experience and (partial) qualifications below a completed vocational education, but, on the other hand, also for making in-company continuing education mandatory, and, furthermore, also calling on education policy to create more opportunities for upward occupational mobility. This is exactly how possible models must let themselves be measured: In the final analysis, it is not only about entry level oppor-

tunities for the barely qualified to obtain qualification, but, above all, also about options that pick up there to offer further upward mobilization (so-called “mobility chains”; Reinberg 2004, p. 74). The permeability of educational systems, that is so happily conjured up in the Lisbon and Copenhagen processes, also has to apply to any eventual, newly-created two-year training course in assembly work. The key here is a genuine permeability that is regulated by a genuine social partnership. Yet it remains that not only those employees doing qualified routine work, but also skilled workers are being insufficiently prepared during initial vocational education for the new demands posed (in particular, by complementary tasks) by integrated production systems.

Clement und Lacher (2006, p. 10) regard especially the occupationalism of training in the dual system as the cause of this. But in this regard, from the perspective of experience and work capacity, it should be noted that vocational socialization, facilitated by a three-year training program in the dual system, is not only characterized by the integrated mediation of theoretical expert knowledge and practical skills – but it is also the three-year option (and one that, in our view, it is ultimately not replaceable by anything like it) suited for gathering not only basic occupational but also employment-related experiences and, for that matter, for providing training in the skill of experience-making on the job as a fundamental work capacity. The demands on initial vocational education that indisputably have been changed by comprehensive production systems (CPS) in no way put in question the concept of vocationalism. Kaizen processes as part of a flexible standardization are inconceivable without sustained participation by employees. This is demonstrated not only by current studies by Toyota in Europe (Pardi 2005 und 2007), but even the above cited employer positions do not gainsay it. This is why a rejection of a three-year initial education in the dual system makes no sense – even not by the “guided group work” logic championed by Gryglewski, because the increasing technical and other responsibilities at the group leader level in that case more than ever require high-level training. As understandable as clinging to a three-year training system that has no alternative would be from the labour union side, it ignores the realities of assembly work and ultimately the labour market in society as a whole. There will still be large numbers of the less qualified in assembly work in the future. Precisely from the perspective of work capacity it makes no sense to deploy well-trained skilled workers to overwhelmingly repetitive workplaces where there is danger that their training-specific work capacity would erode over time. Such a misuse of work capacity is the real problem – not the cost argument cited by Gryglewski that skilled work in assembly is too expensive. The other problem with this argument is that it does not have traction factually insofar as it is not the entry qualifications that are relevant for the pay grade but rather the activity performed (see Lacher 2006a, p. 89). And for employee groupings that are structurally disadvantaged on the labour market, i.e. the less qualified, whether from migration background or not, assembly work remains one of the more crucial occupational areas. That they require substantial knowledge and skill in their line of work we were able to demonstrate earlier with our empirical findings. Inter-company recognized and certificated qualification modules could represent an important component in sustaining and

increasing the value of the working power on the labour market of this worker category that is especially threatened by job losses. That would make a factual debate by the social partners for creating such supplementary qualification structures substantially more meaningful than the currently existing, purely company-specific training module. But here the stress is on the world "supplementary," because it cannot be a matter of an alternative to the three-year training program. Anyone who, like the employer side, at this time is calling for a more adequate qualifications allocation, does not just need a more adequate variability of qualification offerings and levels, but also the possibility of making them comparable between companies And, on the union side, whoever wants to overcome the historically growing focus on the skilled worker level for organizing potential in the metal and automobile industry ought to be able to discern the need – absolutely existential given the state of the labour market –for a higher-value labour market profile of the employee pool for assembly work that is typically constituted of low-qualified workers, as an important interest representation endeavor.

The education policy debate shows that employees in assembly work see themselves faced with conflicting demands. The talk is of qualified routine work and new segmentations between unskilled and skilled work, but also of increasingly in-demand process and relationship knowledge, integration and context knowledge. All the discussion participants seem to agree that in assembly work it is increasingly a matter of skills for Keeping "the whole" in view (i.e., the process and not just the individual workstation) Dealing flexibly with the unexpected.

Neither of these is learned from textbooks but in the course of practical work – by experience. Assembly work is anything but "just" unskilled work. It is on the level of the day-to-day, experience-based work action that first emerges what specifically hides behind the new requirements. To date, the experience of employees in assembly work has been the guarantor that they would be able, time and again, to cope with the new demands, and do so, often enough, without formal qualification or sufficient in-company continuing education. But experience cannot substitute for qualification! The increased demands of assembly work call for new qualification endeavors, both in the three-year training program as well eventually in yet-to-be created, low-threshold supplementary offerings. But, more than ever, these must be designed to be "experience conducive." Examples that have proved successful in practice, such as the dual initial training in the commercial area that can be changed and supplemented to such an extent, do exist (see Bauer et al. 2006 for chemistry technicians. The principles of experience-based learning (see Bauer/Munz 2004) are particularly suited, not only for supporting the "the hidden side of professional handling" but above all for developing "hidden abilities of the less-qualified and the disadvantaged" (see Böhle 2004). This holds all the more true for in-company continuing education: Where, as in the companies we studied, the employees doing assembly work manifest language, reading, and writing difficulties, it is the experience-guided methods of instruction that are especially well suited for making complex relationships come alive and for being experienced.

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Citation

Pfeiffer, Sabine (2016): Beyond Routine: Assembly Work and the Role of Experience at the Dawn of Industry 4.0. C
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