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Digitalised work-integrated microlearning: Enabling continuous vocational education and training in highly automated work invironments

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Digitalised work-integrated microlearning: Enabling continuous vocational education and training in highly automated work environments

ITB Research Report No. 70

Results from the consortium project:
Vocational professionalism in the manufacturing industry (BROFESSIO)

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Zusammenfassung

Den Anwendungskontext bildet eine hochautomatisierte Arbeitsumgebung eines Automobilzulieferers, die wir aufgrund ihres restriktiven Arbeitscharakters als lernfeindliche Arbeitsumgebung bezeichnen (u.a. isolierte Teilaufgaben, wenig sozialer Austausch, unklares Feedback aus der Arbeit – insbesondere bei Störungen). Auf der Grundlage eines designbasierten Forschungsansatzes untersuchen wir, ob und wie in solchen Arbeitsumgebungen digitalisierte Lernangebote ermöglicht werden können, um eine berufliche Weiterbildung zu fördern. Im vorliegenden Beitrag analysieren wir zunächst drei Leitmotive des Diskurses über Arbeit und Lernen in Deutschland: Humanisierung, Kompetenzorientierung und Digitalisierung. Anschließend systematisieren wir Formen des arbeitsintegrierten Lernens und Kriterien lernförderlicher und lernfeindlicher Arbeitsumgebungen. Diese Formen und Kriterien bilden die Grundlage für unseren didaktischen Ansatz des digitalisierten Mikrolernens, den wir in der o.g. hoch automatisierten Arbeitsumgebung erprobt haben. Der Artikel schließt mit einer reflexiven Analyse und einem Ausblick. Einerseits führte unser Ansatz zum gewünschten Ergebnis: arbeitsprozessintegriertes Lernen wurde ermöglicht. Auf der anderen Seite ist die Entwicklung und Implementierung von digitalisiertem arbeitsintegriertem Mikrolernen in einer hochautomatisierten Arbeitsumgebung sehr voraussetzungsvoll und aufwendig.

Abstract

The context of operation is a highly automated work environment of an automotive supplier, which we call a learning-hostile work environment due to their restrictive work conditions (e.g. isolated subtasks, little social exchange, unclear feedback of the work–here: unclear feedback of the automated production system in the case of malfunctions). Grounded on a design-based research approach, we investigate whether and how digitalised learning opportunities can be enabled in such work environments to promote continuous vocational education and training. In this paper, we first analyse three themes of the discourses about work and learning in Germany: humanisation, competence orientation, and digitalisation. Subsequently, we systematise forms of work-integrated learning and criteria of work environments that are conducive and hostile to learning. These forms and criteria form the basis for our didactic approach of digitalised microlearning which we have tested in a highly automated work environment. The article concludes with a reflexive analysis and outlook. On the one hand, our approach led to the desired result: work-integrated learning was made possible. On the other hand, the development and implementation of digitalised work-integrated microlearning in a highly automated working environment is very demanding and effortful.

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Preface

With regard to the new work processes resulting from digitalisation and the associated competence requirements for employees, the statements of the Industry 4.0 discourse remain on the one hand rather vague. The catchwords 'Industry 4.0' and 'Work 4.0' arouse as many promises as fears. Hopes are directed towards more humane working conditions, for example, through the use of soft robotics, as well as towards new possibilities for reconciling work and private life. On the other hand, there are fears about the replacement of skilled workers by ever more intelligent technology, and concerns about the establishment of the 'glass employee' due to digital (performance) monitoring technologies. A study conducted by the Fraunhofer Institute for Industrial Engineering (IAO) on the manufacturing industry underlines the importance of qualification and competence development in the introduction of Industry 4.0 but remains quite general in the discussion or explanation of qualification requirements. It addresses the need for lifelong learning, stronger interdisciplinary thinking, and IT competence (Schlund et al., 2014). The conclusions of the Industry-Science Research Union (Forschungsunion Wirtschaft-Wissenschaft), which accompanies the Federal Government's High-Tech Strategy, are similar. In their implementation recommendations for the 'Future Project Industry 4.0', the authors predict that employees will be required to have a very high degree of self-directed action, as well as communication and organisational skills. They also predict that the subjective skills and potential of employees will be even more strongly in the future. However, it is still uncertain whether the associated hope for "qualitative enrichment, interesting work contexts, increasing personal responsibility, and self-development" (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft-Wissenschaft, 2012, 51) will be fulfilled. Although the final report of Industry 4.0 Working Group states that people will be at the centre of future intelligent production process (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft-Wissenschaft, 2013, p. 99), such findings remain vague. Overall, the picture of future working environments is not uniform. Ittermann et al. (2015, p. 35) note that idealised visions of the future of industrial work contrast with rather pessimistic trend statements. However, automation alone is not a sufficient condition for concluding that activities will be devalued or upgraded (Hirsch-Kreinsen, 2015). It is, therefore, an empirical question, determining which new demands are made on employees.

New challenges with regard to the realisation of work process-oriented learning are arising in light of continuing digitalisation and changing working environments for continuing vocational education and training in enterprises. How work and learning can be linked for in-company continuous vocational education and training was the question in the joint project 'Vocational Professionalism in the Manufacturing Industry' (in German: 'Berufliche Professionalität im produzierenden Gewerbe (BROFESSIO)'). Our consortium project explores how work and learning can be linked, how the working environment can be used as a learning opportunity, and which learning formats foster work-integrated competence development. The core of this approach is that the learning processes start where they have the greatest relevance and urgency for skilled workers and management: in the work process. Our initial assumption is that work process knowledge cannot simply be derived from explicit knowledge structures and job descriptions, but rather arises in concrete task processing and the solution of (complex) challenges in everyday work.

Partners of the Consortium Project

Two universities, one non-profit association, two companies, and the trade union of metal works, IG Metall, were represented in the consortium project. This network was coordinated by the University of Bremen, Institute Technology and Education.

The Institute of Technology and Education (Institut Technik und Bildung, ITB), founded in 1986, is a central research unit of the University of Bremen. The research work of the ITB is devoted to vocational education and training research at the national and international levels under the guiding principle of shaping the relations between work, technology, and education.

The Beuth University of Applied Sciences for Technology Berlin (Beuth Hochschule für Technik Berlin) offers the largest range of engineering courses in Berlin and Brandenburg (currently over 70 courses). In terms of student numbers, Beuth Hochschule is one of the ten largest universities in Germany.

SUSTAINUM, Institut for Sustainable Management (Institut für zukunftsfähiges Wirtschaften Berlin e.V.) is a non-profit association that focuses on education, science, and research in the field of sustainability. SUSTAINUM designs the associated innovation, organization, and communication processes both nationally and internationally and accompanies social, political, and economic actors on their way to sustainability-oriented action.

With more than two million members, IG Metall is the largest single trade union in Germany and the world's largest organised employee representation association.

HELLA Fahrzeugkomponenten GmbH (HFK) has been operating in the Hanseatic city of Bremen since 1961. HFK develops and manufactures electromechanical and electronic components for motor vehicles in Bremen. The HELLA's site in Bremen specialises in sensors (sun sensors, temperature sensors, rain and light sensors, oil level sensors, microsystems) and actuators (central locking and climate control).

The Bayer Pharmaceutical Division is the pharmaceutical section of Bayer AG. The main locations for research and development in Germany are Berlin (cooperation partner) and Wuppertal (also in the USA, Japan, and China). The Berlin work portfolio ranges from product development to supply chain management, and from strategic marketing to various administrative functions.

The consortium project BROFESSIO was funded by the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) within the funding programme 'Future of Work: Innovations for the Work of Tomorrow'. The funding priority 'Operational Competence Management in Demographic Change' is concretised by three research and development areas:

- Work process-integrated competence development for the economy of the future.
- Competence management for longer employability.
- Concepts of company-specific competence management.

The consortium project BROFESSIO was part of the research and development area 'Work Process-integrated Competence Development for the Economy of the Future'.

Continuous vocational education and training aimed at helping individuals after initial vocational education and training or after entry into working live to 'improve or update their knowledge and/or skills, acquire new skills for a career move or retraining, continue their personal or professional development.' (Cedefop, 2014, p. 51). BROFESSIO (2018) addresses two central objectives of continuous vocational education and training: The development of competences to continue the professional development. In the following research report we present not the whole project, but rather findings from our approach to develop, test, and enable work-integrated digitalised microlearning in highly automated work environments to promote continuous vocational education and training. We applied our approach in the work environment of HELLA.[1]

[1] We would like to sincerely thank the following people for their continued support and contribution: Tilman Dombrowski, Torsten Grantz, Holger Heinze, Benjamin Höhne, Bernd Kaßebaum, Sandra Kroll, Jörg Longmuß and Christian Staden.

1 Work and Learning in the Context of Change[2]

Change in the world of work is a reliable constant, but the contemporary changes are already associated with a 'revolutionary upheaval'. So far, however, the 'revolutionary' upheavals brought about by 'Industry 4.0' and 'Work 4.0' have often remained on the semantic level. In her discourse analysis, Sabine Pfeiffer (2015) debunks the frequently cited belief that Industry 4.0 is causing revolutionary upheavals and emphasizes that 'the' Industry 4.0 does not exist. Rather than technical potential, it is questions of economic efficiency, product complexity, the value creation chain, and already existing production technologies that are the central factors that guide the operational implementation of new technologies. Thus, the inflating spread of the term Industry 4.0 by no means corresponds to a technological status quo. On the contrary, it is rather a matter of 'professional agenda building' (Pfeiffer, 2015, p. 20)[3]. The World Economic Forum (WEF), which at its meeting in January 2011 founded a task force on the topics of 'Future of Manufacturing' and 'Global Agenda Council on Advanced Manufacturing', had a decisive influence on the dissemination of the term. Such bodies act primarily as intermediaries between political and economic decision-makers and support the media presence of the Industry 4.0 debate. In her discourse analytical review, Pfeiffer (2015) draws the sobering conclusion that it is not primarily technical feasibility that has set industry 4.0 debate in motion, but rather the economic necessities identified as relevant by economic elites. In Germany, the debate on Industry 4.0 has met with fertile ground, especially from the mechanical and plant engineering sector since it was and still is important to raise awareness of Germany as a leading market for innovative solutions in the field of Industry 4.0. A study by the German Association for Information Technology, Telecommunications and New Media (BITKOM) calculates the economic growth generated by Industry 4.0 in Germany is to reach EUR 78 billion by 2025 (Baethge et al., 2003), with particularly high growth rates expected for certain sectors, such as mechanical and plant engineering, transport, and logistics.

Only a few months after the WEF meeting, the topic 'Industry 4.0' was presented for the first time in Germany at the Hanover Fair in spring 2011 by the 'Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft' of the Federal Government as a project for the future. In the same year, the Federal Ministry of Education and Research (BMBF) founded the Industry 4.0 working group, which presented its results at the Hannover Fair 2013 under the title 'Implementation recommendations for the Industry 4.0 Future Project'. A primary consolidation of the various players involved in these discussions initiated the founding of 'Platform Industry 4.0'[4]. The central players at the beginning were BITKOM, the German Machinery and Equipment Constructors (VDMA), and the German Electrical and Electronic Manufacturers' Association (ZVEI). At the beginning of 2015, the platform was restructured in favour of a stronger involvement of trade unions (IG Metall) and science (Fraunhofer Gesellschaft). The expansion of the platform signals that the topic of Industry 4.0 and Work 4.0 is to be understood as a social phenomenon and that it unfolds structural effects from the semantic level. In addition to the increasing

2 The analysis presented in this section is described in detail in Ahrens & Gessler (2018).

3 https://www.weforum.org/system-initiatives

4 https://www.plattform-i40.de

number of platforms and state portals in the individual 'Länder' (the 16 federal states in Germany), these include, for example, the initiation of new research priorities and special programmes which, under the heading 'Vocational Education and Training 4.0', are devoted to reviewing existing occupational profiles at the regulatory level and focusing on the potential of digitalisation for shaping the future of the world of work.

In April 2015, the Federal Ministry of Labour and Social Affairs published its Green Paper 'Arbeiten 4.0' (Working 4.0) for a discussion of the essential developments and fields of action in tomorrow's working society. The socio-political opening of the discourse, which in the beginning was primarily shaped by economic and innovation policy, reveals that beyond questions about the potentialities of cyber-physical systems, questions about changing forms, the contents and organisation of work are gaining importance. Already in its final report, 'Implementation Recommendations for the Future Project Industry 4.0', the Industry 4.0 working group discusses 'new social infrastructures of work' (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft, 2012, p. 11), which are accompanied by comprehensive qualification and training measures as well as the design of new organisational models of work. It is noticeable that, in comparison to the debate on Computer Integrated Manufacturing (CIM), the discussion on Industry 4.0 makes questions of initial and continuing training and work organisation explicit (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft 2013, p. 59). In their implementation recommendations for the 'Future Project Industry 4.0', the authors forecast that employees will be required to have a very high degree of self-directed action, communication and organisational skills, and that the subjective skills and potential of employees will be even more strongly challenged than they are today. However, it is still completely uncertain whether the associated hope for 'qualitative enrichment, interesting work contexts, increasing personal responsibility, and self-development' (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft 2013, p. 57) will materialise. Overall, the picture of future working environments is mixed. Ittermann et al. (2015, p. 35) state that idealised visions of the future of industrial work contrast with rather pessimistic trend statements.

It is undisputed that the discourse on Work 4.0 does not remain without effects on competence development and the relationship between work and learning, but the nature and intensity of these effects is an open question. Following Hartmann (2015), three stages of the relationship between work and learning can be traced. It becomes clear that the question of a work design that is conducive to learning is by no means new, but that new answers and demands are being formulated through changing legitimising frameworks. In his review of the research and practice of work structuring in Germany over the last 50 years, Hartmann (2015) distinguishes between three phases with regard to the relationship between work and learning. The first phase occurred between 1974 and 1989 and was characterised in particular by the research programme 'Humanisation of Working Life'. The second phase followed between 1990 and the beginning of the 21st century, which was characterised by the research programme 'Learning Culture, Competence Development and Innovative Work Structuring'. In contrast to Hartmann's diagnosis of interpreting the third current phase as an 'innovation policy phase', the relationship between work and learning is considered under the heading of digitalisation, because in the course of digitalisation we are not only experiencing a structural change in work, but also new opportunities for learning. It becomes apparent that competence development and learning formats are closely linked to social change, and that the current renaissance of the discussion about work and learning is by no means 'old wine in new bottles', but rather a mode of processing structural changes. A review of previous central research programmes on competence development allows a more precise assessment of the challenges that employees and companies alike are facing today when it comes to the demands of the future world of work. Based on the assumption that competence development in companies takes place in the interplay between the operational, social, and technical levels, the different legitimation frameworks can be used to illustrate the effectiveness of competence development depending on how the three levels are brought into relation to each other on the basis of the respective legitimation context. In the course of progressive digitalisation, the question of whether and how competence development can take place if the working environment is anything but competence-activating and learning-promoting due to automation or if our 'positive prejudice against forms of learning close to work' (Gonon 2005, p. 134) is not met.

In the next section we analyse three themes of the discourses about work and learning in Germany: humanisation, competence orientation, and digitalisation.

1.1 Humanisation

About 40 years ago, the social-liberal government programme launched the research programme 'Humanisation of Work (HdA)' (Humanisierung der Arbeit – HdA, 1974–1989) in 1974. This was the first national research and development programme for work design and was a response to the finding that technological progress does not automatically lead to improved working conditions. Questions of work participation and the humane design of workplaces formed a major focus of the programme, which is marked as a 'turning-point in labour policy' (Sauer, 2011, p. 18). Issues of co-determination and democratisation discussed at the societal level were brought to the world of work. While Taylorist work organisation was strongly characterised by the separation of manual and mental work, the approaches of the HdA programme aimed at improving working conditions by enhancing the recognition of work performance, participation, and self-development in the workplace. At that time, the move away from technology-deterministic approaches and the associated claim to shaping the interaction between people, technology, and organisation were essential for the development of competences in companies. The question of work design was discussed under the probe of the concept of the socio-technical system that had already been developed at the Tavistock Institute in the 1950s. This approach focuses, firstly, on the assumption that the organisation as a social structure and a technical system can only ever be designed in mutual relation. Secondly, the work task is understood as a central mediator between technology and organization. Instead of supposed technical constraints, the focus is on socio-technical system design. The concept is based on the assumption that people, technology, and organisation are to be reflected in their mutual dependence and interaction and that the way in which the work task is designed is central to competence development. The focus of interest is therefore on work design that promotes learning and competence and the formulation of criteria to describe learning and learning opportunities in the world of work. In the context of the HdA programme, the criterion of complete action (inform, decide, plan, evaluate, improve) gained importance. This refers to actions which, in terms of project orientation, encompass individual work tasks–preparation, planning, implementation, monitoring, evaluation, reflection–as completely as possible.

Although the practical relevance of this concept for workplace competence development is undisputed, Hartmann (2015) notes that the idea of socio-technical design has not yet been able to establish itself sustainably. Nonetheless, it has not lost any of its importance when it comes to the question of shaping future working environments. The current debate on Work 4.0 also refers to the idea of the socio-technical design approach:

> It is not technology or technical constraints that determine the quality of the work, but scientists and managers who model and implement the Smart Factory. What is needed in this context is a socio-technical design perspective in which work organisation, further training activities, and technical and software architectures are developed in close mutual coordination, from a single mould, with the focus on enabling intelligent, cooperative, self-organised interactions between employees and/or technical operating systems along the entire value chain (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft*,* 2013, p. 57).

In retrospect, two central aspects of the HdA programme for workplace competence development can be identified: the socio-technical design criterion and the criterion of complete action. Due to the socio-political legitimation framework, however, the HdA programme often remained unclear in its relationship to the respective company strategies and company organisational concepts due to its normative orientation. Nevertheless, it is apparent that the normative demand for 'humane' work is regaining momentum in the discussion on 'good work', albeit with a shift in emphasis in favour of the progressive subjectivation of work. It is no longer the demand 'only work matter' that characterises current labour policy discussions, but the question of 'quality of work'. In contrast to the initiatives aimed at improving poor working conditions, reducing environmental pollution, and removing the negative impacts of restrictive monotonous work in the 1970s and 1980s, the term 'good work' emphasizes the individual and his or her status in the world of work rather than the workforce as a whole. The question of 'how' and the criteria for quality of work is the guiding principle. This can be understood as a continuation of the socio-political humanisation programme in the context of demographic development and digitalisation.

1.2 Competence Orientation

Whereas in the 1970s and 1980s the legitimation context of continuing vocational training in enterprises was primarily based on working conditions and work organisation, in the early 1990s the focus shifted to the subject and on new learning formats beyond institutional structures. The so-called 'competence-oriented turnaround' (Arnold & Steinbach, 1998) in the 1990s was characteristic of this. In contrast to the concept of qualification, the competence approach emphasises the learner's ability and responsibility and focuses on the subject in its entirety. The concept of competence is based on the actual requirements in practice and the question of individual dispositions for action. The turn towards the concept of competence was partly of a political-strategic nature in the course of the reunification in which the socialist German Democratic Republic became five (eastern) states within the

Federal Republic of Germany. The process of reunification initiated the 'Qualification Offensive (East)' in the 1990s. For the participants, the new term was intended to signal 'that competence development is not a matter of classical further training courses in the traditional form, but rather to try to integrate work and learning in connection with the activities considered necessary changes in value patterns and attitudes' (Vonken, 2001, p. 513). With the change of perspective to the concrete relevance and practicability of the learned knowledge, the acting subject and its (learning) environment become the focus of competence development. In this phase, questions of the effectiveness of competence development are primarily directed at individual learning processes and the design of learning processes. The changed demands and expectations of in-company competence development since the mid-1990s are expressed in the fact that they refer not only to the necessity–instead of the (institutional) creation of opportunities–of individual learning ('lifelong learning'), but also to the importance of incidental, informal learning. Whereas in the 1970s the focus of continuing vocational training in enterprises was on work organisation under socio-political guidelines, in the 1990s the emphasis shifted to the individual worker and learning in the process of work.

In 1991, a series of model experiments (1991–1996) on the subject of 'decentralised learning' (Dehnbostel, 1993) was started to develop and test new forms of workplace learning, new combinations of learning locations, and new didactic-methodological approaches, in particular, new didactic concepts for learning stations and learning islands. As a counter-project to vocational training in central institutionalised training facilities, the pilot projects concentrated on four main areas: organisational forms of workplace-based learning and new combinations of learning locations; function, cooperation, and qualification of training personnel in regard to learning at the workplace; quality of the learning location workplace, learning efficiency and quality criteria as well as didactic-methodological approaches with regard to learning at the workplace (Dehnbostel, 1993). Initially the projects focused on training, and in the second phase, on continuing vocational training. The claim of decentralised learning did not only refer to the spatial dimension of the learning locations, but also to the role and significance of the subject. The strengthening of self-organisation as well as the consideration of individual learning biographies were and still are central ideas in the implementation of continuing vocational training.

As early as the end of the 1990s, there was talk of 'new forms of learning', and a 'new learning culture' (Kraft, 2000). The support programmes launched by the Association for Research in Continuing Vocational Training (Arbeitsgemeinschaft betrieblicher Weiterbildungsforschung, ABWF) in the 1990s were ground-breaking in this respect. In contrast to institutionalised continuing training, the focus was on 'learning in the process of work'. In this context, the Federal Ministry of Education and Research initiated the research and development programme 'Learning Culture Competence Development' lasting from 2001 to 2007 with the focus on 'Learning in Continuing Education and Training Institutions' (Lernen in Weiterbildungseinrichtungen, LiWE), 'Learning in the Work Process' (Lernen im Prozess der Arbeit, LiPA), and 'Learning in Social Environments' (Lernen im sozialen Umfeld, LisU). This complex programme architecture was implemented by ABWF within the project 'Skills Development Management' (Qualifikations-Entwicklungs-Management, QUEM).

The research programme reacted to the transfer problem of formal continuing training formats – the problem of transferring acquired knowledge into knowledge in action – and the paradigm shift from continuing education to competence development with the change to informal, action-integrated learning and the educational policy postulate of lifelong learning. The background to the programme was mainly educational policy demands rather than socio-political demands. At the programmatic level, the main actors in this research programme were concerned with 'new values, new modes of behaviour, and new ways of building experience' (Erpenbeck & Sauer 2000, p. 292), whereby the focus was not exclusively on work but also on activities (learning in a social environment). The central keywords of the education policy guidelines were competence, self-organisation, differentiation, and individualisation of learning, which were certainly also understood as a departure from the vocational qualification and labour market orientation of previous institutionalised continuing vocational and education training (CVET). In perspective, this period was concerned with a 'new type of CVET' (Baethge et al., 2003), which moves away from learning as a 'store of knowledge' and concentrates on the generation of learning content and incentives from the respective work processes. The new type of continuing training was a reaction to the increasing criticism of the lack of practical relevance of institutionalised, demand-oriented continuing training and the structural change in companies in favour of process orientation. While the prerequisites for the effectiveness of formalised continuing vocational training practice lay not least in the predictability of occupational requirements, the increasing knowledge base of work and new production concepts make these forecasts more difficult, particularly at the occupation-specific level. The contours of post-Tayloristic work organisation were accompanied by the question of the extent to which professionally organised work is being eroded in favour of formal competence profiles. These were and still are interdisciplinary competencies of problem solving, flexibility, independence, self-organisation, coordination, and communication skills.

The effectiveness of in-company competence development was primarily directed towards the development of general methods for competence development and competence assessment as well as the upgrading and opening up of informal learning. However, with the concentration on research and advancement of instruments for competence development and measurement, the concrete operational application side, the actual operational design, and implementation of competence-oriented work at the workplace that promotes learning, has been leading a shadowy existence. Companies were involved primarily through their personnel and further training departments, while the shop floor level was largely ignored and only few empirical findings on the connection between process-oriented work organisation and competence development became available. In 2014, Johannes Sauer, former head of the Vocational Skills Development unit at the Federal Ministry of Education and Research, soberly formulated the following in retrospect on some 20 years of research on continuing vocational training: 'The crucial issue in companies is learning in the process of work. The ability of work to foster learning is the decisive design task. However, companies and personnel development departments are not well prepared for this' (Sauer, 2014, p. 5).

The implementation of work organisation that promotes learning is becoming increasingly topical due to the digitalisation of the world of work. While organisational and subject-related approaches dominated until the end of the 1990s and critically dealt with technology-deterministic approaches, questions of how to deal with the ambivalences of subject-orientation–learning as an opportunity, excessive demands or unreasonable demand –are just as much an integral part of the discussion as the ambivalences of digitalised working environments.

1.3 Digitalisation

The research findings of the 'Learning Culture Competence Development' programme were incorporated into the 'Work – Learn – Develop Competences: Innovative Ability in a Modern Working Environment' programme, launched in 2006. After the Federal Government had declared 2014 to be the focus of the annual 'Year of Science' under the heading 'The Digital Society', the programme launched in 2006 was replaced in 2014 by another: 'Future of Work: Innovations for the work of tomorrow' (BMBF, 2016). At the research policy level, five thematic fields were identified which require empirical and theoretical findings:

- Obstacles in the innovation process and ways to overcome these obstacles.
- Competences and instruments that are necessary to make obstacles to innovation transparent and those that are necessary to balance out the contradictions in the innovation process.
- Interactions between the four aspects 'organisation', 'technology', 'health' and 'competence development' of a holistic approach to innovation related to the world of work.
- Forms of technology deployment that specifically increase the innovative capacity of individual players and companies.
- Changes in the world of work that are necessary to ensure equal opportunities.

In terms of content, the thematic fields are linked to the objectives of the Federal High-Tech Strategy and are to be achieved through the following five research priorities:

- Balance of flexibility and stability in a changing world of work.
- Innovative ability in demographic change.
- Operational competence management in demographic change.
- New approaches to prevention.
- Work design approaches within the future project 'Industry 4.0'.

The third focal point 'operational competence management in demographic change', in which the consortium project BROFESSIO is also located[5], is concretized by three research and development areas:

- Work process-integrated competence development for the economy of the future.
- Competence management for longer employability.
- Concepts of company-specific competence management.

[5] https://www.bmbf.de/foerderungen/bekanntmachung.php?B=784

In comparison to the previous legitimation framework of operational competence development, this phase differs in two respects: firstly, an integrative approach to competence development is favoured, which equally addresses the levels of people, technology, and organisation. On the one hand, it is about the participatory design of work processes and on the other hand, it is about a form of inclusion of technology beyond the purpose-means scheme. Economic rationalisation calculations expect a lot from the possibilities of digitalisation, but underestimate the structure-forming interrelations between technology, forms of organisation, and work processes. The guiding questions in this phase address how work processes change under digitalised working environments, which the new forms of work organisation and control practices that go hand in hand with them, and what skills are needed to enable employees to find creative solutions to problems as automation increases. In order to achieve this, an understanding of technology is needed that overcomes the dualism between technology and sociality. It is becoming increasingly difficult to clearly separate work processes into social processes on the one hand and technical operations on the other. Instead, we are dealing with socio-technical or hybrid constellations 'populated by human actors and (semi-)autonomous machines that act side by side, with each other, but sometimes also against each other' (Weyer, 2007, p. 35). Competence development cannot be determined by the individual alone (Erpenbeck et al., 2015). Due to the interrelationship between structure and action, it is essential to consider organisational and operational conditions when considering the question of competence development (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft, 2013).

Therefore, it seems worthwhile to take an approach that focuses on the complexity of the work process rather than on individual activities. It is about the interdependence of technical and social processes. In this way, it is possible to investigate how digitalisation interferes with social communication and how social communication processes formulate requirements for the design of technology. With regard to the idea of participation, this means integrating digital media into the work process in such a way that they no longer act as a counterpart to the action-relevant knowledge of the employees, but as an integral part of the work process. The aim is thus to embed digitalisation as a 'player' in the work process and also in competence development.

At the organizational level, corporate reorganization concepts and lean management methods are reducing hierarchical levels and increasing demands for design and decision-making at the intermediate qualification level (project and group work). Not only are almost all processes geared to customer needs, quality, and efficiency, but employees are also becoming a key component and driving force in the ongoing development and improvement process. Examples of this are the instruments 'Continuous Improvement Process (CIP)' or 'Kaizen' as an invitation to the workforce to link corporate objectives more closely with their work activities.

Further, there is an explicit reference to the consequences of demographic developments (Gessler & Stübe, 2008). Depending on the immigration scenario, the population projections assume that the potential labour force will shrink by 28% to 34% between 2008 and 2060 (BMAS, 2013). The quantitative consequences of demographic development are one thing, but the qualitative changes in the structure of the labour force are essential for the world of work. Company-based skills development is called upon to adapt its methods and instruments to the company age and ageing structure. The qualification risks for older employees in the course of technological development and new organisational concepts are addressed here. A further challenge lies in the so-called 'disuse effect' (Frerichs, 2015, p. 207), which occurs when the originally existing qualification assets are restricted and ultimately impaired by decades of concentration of work activities on certain processes and procedures. In addition to these questions about age-specific adaptation qualifications, demographic change has brought up questions about the relationship between the work context and ageing processes, the influence of age stereotypes on learning processes and motivation for continuing training that have been neglected in the debate about in-company skill development up to now. In previous phases, there was no explicit field of research in differentiating the effectiveness of competence development according to age and age-specific criteria beyond general deficit hypotheses (e.g. the performance of older workers is inherently deficient).

With the justified criticism of technology-deterministic approaches, organizational and subject-related approaches dominated until the end of the 1990s. Technicization was primarily addressed in terms of its consequences for the workplace, and from a historical perspective, even before the advent of computers, computerization was understood as a 'process of rationalizing work' (Kleemann & Matuschek, 2008, p. 44). To date, there are hardly any empirical findings on how work and mechanisation are currently 'shaping' each other and what consequences this has for the development of skills in companies. With the focus on company practice, company structures and control mechanisms are moving to the fore alongside the shop floor level. Whether, for example, design and planning tasks with the possibility of intervening in process flows are reserved for the middle employment levels or, in view of the system complexity, are carried out at the engineering level, depends on the extent to which the implementation of networked technologies is understood as a social and work organisation design process that depends on the expertise of skilled workers (Ahrens, 2016).

Depending on how work and learning are staged, specific blind spots of competence development arise. The following table 1 compares the respective themes of the three stages. It can be seen that technology in the form of digitalisation acts as an essential catalyst for strengthening the integrative approach.

Table 1: Themes of the discourses about work and learning

	Humanisation	**Competence Orientation**	**Digitalisation**
Time	1970–1990	1990–2000	The beginning of the 21st century and onwards
Guiding Principle	Socially acceptable work arrangements	Educationalisation of the company	Integrative approach: interaction of technology, organization, people
Technology	Design	Acquisition	Actor
Organization	Development of new rationalisation models beyond Fordist work organisation	Process orientation, Lean management	Networking, new value creation processes
Human	Emancipation	Subjectification	Diversity

Whereas in the 1970s and 1980s social policy issues were brought into the world of work, and in the 1990s education policy focused on the development of approaches and instruments for competence development, we are currently experiencing a phase that focuses on the embedding and shaping of competence development in companies. Instead of a reactive adaptation to technologically induced competence requirements, the focus is on the anticipatory design of competence-promoting and innovative company organisation.

Changing structural conditions are shedding new light on old questions concerning work and learning. The distinction between the three stages shows that the connection between work and learning can is yet to be solved, even though sufficient instruments for competence assessment and development are available. The assumption is therefore obvious that it is not a question of resolving the contradiction between working and learning inherent in the system by formulating pedagogical criteria and thus running the risk of ending up in a niche existence in the reality of the company[6]. Nor does it seem promising to overcome the contradiction between working and learning by means of work-process-oriented learning that embraces the economic logic of action and reacts primarily to technologically induced competence requirements and thus runs the risk of exposing itself to the accusation of pure adaptive learning. Critics accuse work-process-oriented learning of providing adaptation training under the label of competence development. However, this criticism is only justified at first glance, because complex knowledge and the learning of methods for problem solving can only be learned through real problems and these can be found primarily in the concrete working environment.

Based on this analysis, our research question is whether and how work-integrated digitalised learning opportunities can be enabled in highly automated working environments to promote continuous vocational education and training.

2 Work-integrated Learning

Work-integrated learning 'is truly integrated into current work processes and practices and makes use of existing (learning) resources within an organization (e.g., project documentation, notes, mails, etc.)' (Lindstaedt & Thurner-Scheuerer, 2012, p. 1588). Learning in the work process is therefore context- and person-dependent: 'On the one hand, there is the affordances – the degree by which the workplace is invitational to individuals to engage and participate, and on the other hand, there is how individuals elect to engage with what they are afforded.' (Billett, 2012, p. 3479). First, five forms of learning in the work process – implicit learning, reactive learning, deliberative learning, expansive learning and meta-cognitive learning – are presented. Second, we systematise the conditions of a work environment that are conducive to learning. We extend this concept by the perspective that some working environments, especially highly automated ones, have a different character, which we call learning-hostile working environments. Learning-hostile work environments do not initiate and enable learning from their affordances. Instead, they make learning more difficult.

6 For example, through subsidised learning projects, learning stations and the like.

2.1 Forms of Learning

Experience-based knowledge (or experiential knowledge) is dependent on personal, social, and material conditions that cannot be fully formalized, which is why Polanyi states: 'we can know more than we can tell' (1966/1983, p. 4). Experience-based knowledge is nevertheless communicable, not explicitly and formally, but rather situated (Lave & Wenger, 1991). In their knowledge creation model, Nonanka and Takeuchi (1995) call this communication process 'socialisation': situated learning is social learning from role models (Bandura, 1977). The role model is internalised, routinised and turned into experience-based knowledge by means of imitation and application. The strength of this form of learning lies in the development of implicit 'know that' (implicit-declarative knowledge), implicit 'know how' (implicit-procedural knowledge), implicit 'know when' (implicit-conditional knowledge) and also, with limitations, implicit 'know why' (implicit-conceptual know-ledge).[7] However, the learning potential is limited. Implicit learning (Eraut, 2004) is defensive, unconscious, and limited to the reproduction of existing practices in the workplace.

Dialogue expands the learning potential. The prerequisite is that the knowledge gained from experience is externalised reciprocally and reflection is initiated in processes of mutual understanding. Reflection in dialogue has a threefold reference: first, it is the reflexive reference to one's own practice and understanding or reflection of one's own experience, then the reflexive reference to the foreign practice and the possible understanding, and finally the reflexive reference to the similarities and differences of these references. In reflection, experiential knowledge detaches itself from the object, which is why a task-related recontextualization by means of application is necessary in order to combine knowledge that justifies action, guides action, and is effective for action (Evans, 2016). Learning is cognitive, but still limited to the experiential knowledge of the Community of Practice (CoP). Eraut (2004) calls this mode 'reactive learning'.

A further step is the validation of the findings (verification or falsification) in relation to explicit knowledge stocks or the 'state of the art' of a 'landscape of practice' (Wenger-Trayner et al., 2015), whereby, in turn, recontextualization becomes necessary following the above-mentioned step. As an analytical process, learning refers to the practices within a domain. Eraut (2004) calls this mode 'deliberative learning'. Learning that exceeds the knowledge of a domain can then be called expansive learning: 'In expansive learning, learners learn something that is not yet there' (Engeström & Sannino, 2010, p. 2). This form of learning is not explicitly identified by Eraut.

The four forms of learning mentioned above differ significantly in their horizontal references: workplace knowledge, knowledge of the community of practice, domain

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7 Crooks and Alibali (2014, 348–349) distinguish six forms of conceptual knowledge: (1) connecting knowledge ('understanding of relationships and connections within a domain'), (2) general principal knowledge ('understanding of principles that govern a domain'), (3) knowledge of principles underlying procedures ('understanding the basis for procedures, or knowing why a procedure works') (4) category knowledge (understanding the 'categories that can be used to organize knowledge within a domain'), (5) symbol knowledge ('awareness of what symbol means'), and domain structure knowledge (understanding of the underlying structures of a domain). Some of these forms are implicitly learnable (e.g. symbol knowledge). Others require explanation (e.g. domain structure knowledge).

knowledge and knowledge beyond the respective domain knowledge. Vertically, again through reflection (self-reflection and with others) and based on validated or non-validated explicit knowledge, meta-knowledge (meta-declarative, meta- procedural, meta-conditional and meta-conceptual knowledge) can be developed through 'meta-cognitive learning'. Meta-knowledge includes 'knowledge about knowledge' and 'regulation of knowledge'. Meta-knowledge promotes strategic thinking and self-regulated learning and forms the prerequisite for expansive learning and innovation (Hacker et al., 2009). Meta-cognitive learning requires not only professional recontextualisation, but also personal recontextualisation, which is crucial for the development of professional identity (Evans, 2016).

The third dimension, besides horizontal and vertical expansion, is the factor 'time'. Dreyfus and Dreyfus (1986) distinguish different levels of experience: (1) novice, (2) advanced beginner, (3) competence, (4) proficiency and (5) expertise (Dreyfus, 2004). Empirical studies show that at least ten years of practical and reflective experience are necessary to achieve the status of an expert (Ericsson, 2014a). Nevertheless, '10 years of experience in a domain does not guarantee that expert performance is attained' (Ericsson, 2014b, p. 10) and the 'progress of competence development is not linear' (Ericsson, 2014b, p. 11). Expertise is linked to time, reflected experience and personality and is expressed as 'knowledgeability' (Wenger-Trayner et al., 2015), 'wisdom' (Hawse & Wood, 2017), or 'mindfulness' (Hyland, 2017).

2.2 Forms of Work Environments

The shift towards learning on the job began in the early 1990s (Ahrens & Gessler, 2018). The starting point is, in particular, dissatisfaction with the results of institutional learning. On the one hand, institutional learning seems to generate an excess of qualifications, but on the other hand, the skills required at the workplace are not acquired (Fitzgerald, 1986). Learning at work 'may benefit from being unfettered from the constraints of formal settings' (Billett, 1992, p. 152). In the late 1990s the constraints of learning at work became apparent. For example, the limited development of conceptual knowledge at work was observed (Billett & Rose, 1997).

An influential and sometimes criticized study investigating the impact of the working environment on work performance was on the Hawthorne Experiments of the 1920s and 1930s (Gillespie, 1991). In this tradition, Hackman and Oldham developed the Job Diagnostic Survey, which focuses on how to 'diagnose existing jobs to determine if (and how) they might be redesigned to improve employee motivation and productivity' (Hackman and Oldham, 1975, p. 159). In occupational psychology, motivation is a central topic. From the perspective of vocational education and training, learning functions as the key issue (including motivation). Even if the objectives are not identical, the key dimensions overlap. The original five dimensions provided by Hackman and Oldham (skill variety, task identity, task significance, autonomy, and feedback) can be used to identify the learning potential of work.[8] For our purposes, the dimensions have been further developed using other sources (Frieling et al., 2006; Dehnbostel, 2008). The perceived individual observation of these dimensions in combination with the individual ability and motivation to shape the perceived potential in relation to extended peer support can increase or decrease the learning potential of a job (table 2).

Table 2: Working environments that encourage and inhibit learning

Job Diagnostic Survey	**Criteria**	**Characteristics of the Working Environment**	
		Working conditions that promote learning	**Working conditions that impede learning**
Task identity	Completeness of the action	Low division of labour with reciprocal tasks/problems and associated individual activities, including problem definition, goal setting, planning, implementation, and evaluation (evaluation: feedback through work).	High division of labour with focus on isolated activities (e.g. planning only, execution of separate activities only, external evaluation instead of self-evaluation).
Skill variety	Request for action	Diverse, complex tasks, vagueness and indeterminacy, problems, project orientation.	Monotony of work with low action requirements and repetitive activities.
Autonomy	Scope for action	High degrees of freedom and decision-making processes in work require and create responsibility.	Decisions are made based on routines, rules, guidelines, specifications; reduced responsibility.
Task significance	Meaning of action	The goal, importance, function, and context of a task or a problem are clear and are experienced as significant.	The own task is perceived as secondary and less important.
Feedback	Social embedding and social support	Suggestions, support, and feedback from colleagues, team members, superiors, and customers; common ground.	Limited feedback on individual, social and professional performance.
--	Degree of reflection	Work organisation includes, enables, and requires self-reflection.	Time pressure at work prevents self-reflection.
--	Development orientation	Tasks are demanding and in the zone of proximal development.	Excessive demands (stress) or the demands are too low (boredom).
--	Error culture	Mistakes happen inevitably and are understood as a learning opportunity.	Errors are prevented and sanctioned (zero error policy).

Source: Gessler, 2019, p. 685

Working environments do not automatically facilitate learning and the development of self-, social, and professional competence. Some working environments, e.g. project work, continuously create problems and promote and require permanent learning on, near, and off the job (Gessler & Stübe, 2008). Highly automated work environments, on the other

[8] Fuller and Unwin (2004) developed a similar fruitful conceptual approach, which they call the 'expansive – restrictive continuum' and which bases on shortcomings the authors identified in the concept of situated learning. The authors thus explore the relationship between work and learning through the learning perspective, while we explore the relationship through the work perspective.

hand, are characterised by extensive monotony (if everything works out as planned) with narrowly defined subtasks.[9]

After the work-oriented turnaround in the 1990s (see above), the complementary function of learning at the workplace (on-the-job) and formal or non-formal learning (off-the-job) was recognised in the early 2000s: 'Learning on-the-job was perceived to be more real life and focused on the "how". Learning off-the-job was less pressured, broader in scope, more theoretical and concerned with "why". The findings indicate that these two environments make valuable, but different contributions' (Harris et al., 2001, p. 263).

What is the relationship between these two learning approaches? Based on empirical studies (Verespej, 1998; Bruce et al., 1998; Marsick & Watkins, 1990/2015), it can be assumed that about 60% of the competences needed at the workplace are acquired in the workplace through incidental learning (not intentional, not strongly structured) and informal learning and training (intentional, usually not strongly structured). About 40% of the required competences are therefore acquired through more or less structured non-formal and formal experience.

3 Design-Based Research (DBR)

The design-based research approach 'blends empirical educational research with the theory-driven design of learning environments' (The Design-Based Research Collective, 2003, p. 5). Anderson and Shattuck (2012) reviewed one decade of application since the emergence of the paradigm in education sciences at the beginning of the 21st century. The authors extracted the following guiding principles.

Design-based research ...

- is situated in a real educational context.
- focuses on the design and testing of a significant intervention.
- uses mixed methods.
- takes place in several iterations.
- involves a cooperative partnership between researchers and practitioners.

The purpose of DBR is described in the sixth principle: 'Designs evolve from and lead to the development of practical design principles, patterns, and/or grounded theorizing.' (Anderson & Shattuck, 2012, p. 17).

[9] We will see later that highly automated work environments are characterized in practice by automation and malfunctions or interruptions.

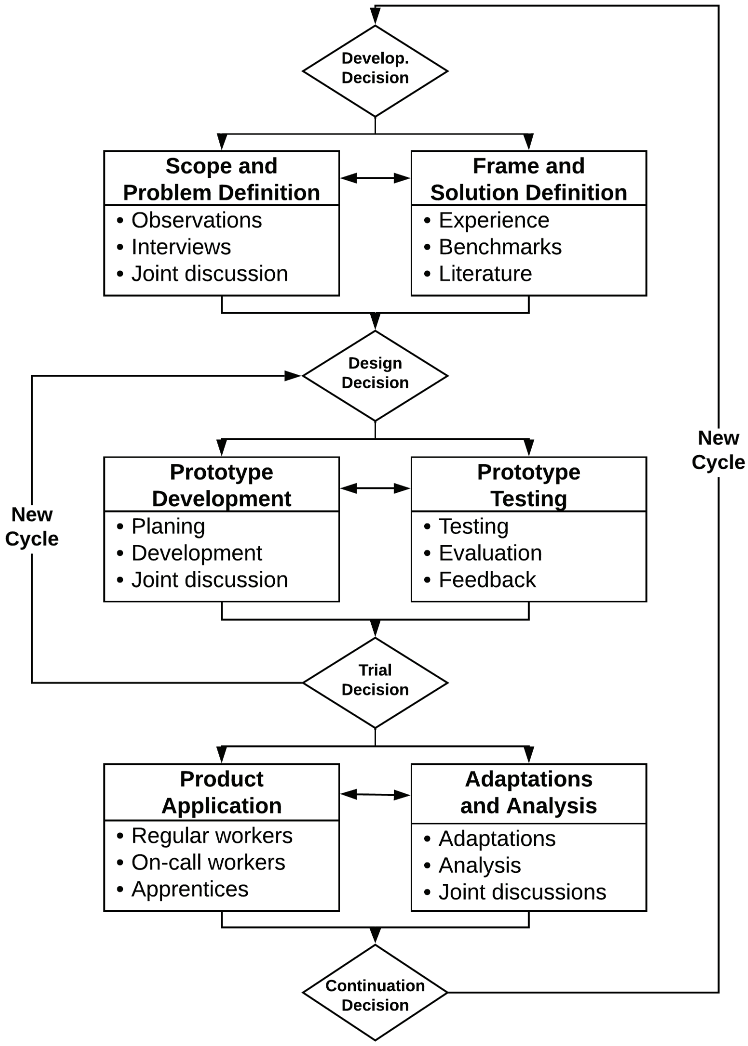

Figure 1: Schematic representation of the applied approach

Cobb et al. (2003), McKenney and Reeves (2012) and Euler (2014) have developed, among others, phase-oriented process models to put these principles into practice. The common ground in these works is the differentiation of at least three stages: (1) an orientation or analysis phase, (2) a design or development phase and (3) and a phase of evaluation or retrospective analysis. Another common theme is that these phases interact with each other. They are circular. Our design-based research process was based on the aforementioned principles and stages. In the retrospective analysis we have synthesized the realized model in action (Figure 1).

The process began with the company's permission to disrupt the work process. From the perspective of a manufacturing company, observations and interviews in the work process are first and foremost interruptions. Later on, it became apparent that even more extensive interruptions were necessary. For example, we stripped the encapsulated production system for one day to be able to take interior shots and videos of the 'ghost machine' (original quote of an employee). We have focused heavily on joint problem analysis. The workers repeatedly described similar problems to us, but for a long time we did not recognize the connecting pattern. The basic problem and the need for further training was that the skilled workers were able to operate the production system according to the instructions but did not know how to deal with malfunctions. There are two main reasons for this: (1) Malfunctions are so diverse and different that learning from experience is very difficult. In other words: knowledge is not sufficient to solve problems. Implicit work-integrated learning, reactive work-integrated learning and deliberative work-integrated learning are not sufficient to learn and act successfully in such an environment. (2) In order to be able to solve malfunction problems, it is rather necessary to develop theses about possible cause-and-effect relationships, to make assumptions, and to test them, so that the problem can finally be solved in a step-by-step process of learning. However, this approach was not possible until now because the skilled workers did not understand how the production system worked. The jointly defined learning objective was therefore to gain an understanding of how the production system works. The development of the problem and solution definition was circular, and the decision of the companies to continue with this approach (design decision) was then linear.

The prototype to be developed faced several problems at the same time: we first had to focus on one module of the production system in order to develop a prototypical learning application for this limited area. In this process our initial assumption was confirmed: work process knowledge cannot simply be derived from explicit knowledge structures and job descriptions, but rather arises in the concrete task processing and the solution of (complex) challenges in everyday work. A further problem was the question of when and how the employees should learn. The solution for this was the microlearning approach (next section). After we had developed our first learning sequence, we were able to develop others. The process steps 'prototype development' and 'prototype testing' were repeated several times. The resulting loop ended with the trial decision. In order to test the person-independent range of the developed application, three groups of people were given the opportunity to learn with our learning sequences: skilled workers, on-call workers, and apprentices. In the following sections we will describe the development of the learning sequences.

4 Work-integrated Digitalised Microlearning

Our initial thesis is that work environments that are hostile to learning not only do not initiate or enable learning through their structured nature, but actually make it more difficult. By means of didactic interventions, these working environments can be designed to contain learning, for example, through microlearning.

4.1 Microlearning

In the field of educational science, especially in teacher training, the term 'microteaching' has been used since the 1960s. This term refers to training of a relatively short duration (a few days to several weeks) in relation to an ambitious goal: the change of teaching behaviour. In his review Klinzing summarizes that microteaching has positive effects on the acquisition of social and teaching skills (Klinzing, 2002).

Although one would assume that microlearning and microteaching are two sides of the same coin, this is not the case. Microlearning has been used since the 2000s in the context of technology enhanced learning and web-based training. Not only are the origins different, but also the form and objectives: the time intervals in microlearning are much shorter (a few minutes) and the objectives are less complex (e.g. information, a stimulus to induce thinking). Hug (2018, p. 323) lists categories and individual topics that are discussed under the heading 'Microlearning', such as:

- Time: relatively short duration, effort, measurable time consumption.
- Content: small or very small units, narrow subject areas.
- Curriculum: embedding in a curriculum or module, part of informal learning contexts.
- Form: 'knowledge nuggets', fragments, episodes, individual skills, competencies.
- Process: separate, concurrent, situated, or integrated activities, iterative methods.
- Attention: degree of awareness.
- Mediality: face-to-face, mono-medial vs. multi-medial, medial constellation, (inter-) medial, cross- or transmedial, multicodal, multimodal.
- Types and forms of learning: activating, repetitive, reflective, pragmatic, instrumental, constructivist, behaviourist, incidental, classroom learning, learning in the workplace, learning in companies, conscious vs. unconscious learning.
- Names: microlearning, episodic learning, rapid learning, bite-sized learning, nanolearning, on-demand learning.

The enumeration makes it clear that microlearning can be implemented against the background of different learning theories and objectives, it differs in form, content, and process from case to case, and even the term 'microlearning' appears arbitrary. Hug states 'There are, if any, many ways of microlearning.' (2018, p. 327).

The term microlearning defines a perspective and not a form. The didactic design of microlearning (e.g. design of a teaching sequence) thus differs from a meso-didactic (e.g. design of a teaching unit) and a macro-didactic approach (e.g. design of a curriculum) and is at the same time in relation to these perspectives (e.g. embedding of sequences in units and units in curricula). However, microlearning cannot be differentiated from such different concepts as 'discovering learning' or 'instructional design', as it is not a concept in itself, but rather a perspective that can be shaped as a concept, either discovering or instructing, producing or repeating, or abstracting.

What is special, however, is the micro-perspective that is applied to learning, with which a definition can finally be formulated: microlearning is the application of a micro-perspective to learning processes. In the didactic design, the following aspects must be clarified with regard to our question (Meyer & Jank, 2002):

- Learners: who learns with what prior knowledge and what prior experience, imprints, and inclinations?
- Didactic approach:
    - Target (what for?)
    - Competence (with what result?)
    - Place (where?)
    - Time and time intervals (how long?)
    - Media (with what?)

- Didactic implementation:
    - Contents (what?)
    - Learning environment (how, when, where, and with what?)
    - Learning actions (what self-activity?)
    - Social form of learning (with whom?)
    - Embedding: The relationship between micro-, meso- and macro-levels (which reference?).

Even microlearning units are characterized by an internal structure, which is why we can speak of adopting a nano-perspective. A structure would be, for example, of the following sequence: (1) Active start (e.g. 3 minutes), (2) Demonstration or exercise (e.g. 6 minutes), (3) Reflection or discussion (e.g. 4 minutes) and (4) Anchoring and outlook – what comes next? (Overschie et al., 2010)

4.2 Design Principles

In the following table 3, we take up the criteria of a working environment that is hostile to learning and derive didactic principles for designing our microlearning approach from this.

Table 3: Work environments that promote and discourage learning

Criteria	Working conditions that impede learning	Didactic Principles to enable learning
Completeness of the action	High degree of division of labour with focus on isolated activities (e.g. planning only, execution of separate activities only, external evaluation instead of self-evaluation).	Creating an overview, clarifying connections.
Request for action	Monotony of work with low action requirements and repetitive activities.	Demonstration of authentic and exemplary interruptions with a call for action to analyse them (e.g. determination of cause-effect relationships and identification of effect relationships).
Scope for action	Decisions are made on the basis of routines, rules, guidelines, specifications, rules; reduced responsibility.	Carrying out evaluations, determining options for action and consequences.
Meaning of action	The own task is perceived as secondary and less important.	The meaning of action can be shaped by an extended scope of perception and by acceptance of responsibility.
Social embedding and social support	Limited feedback on individual, social and professional performance; individuality.	Enabling discussion and feedback of developed problem analyses, evaluations and the identified options for action and consequences.
Degree of reflection	Time pressure at work prevents self-reflection.	Short reflection units.
Development orientation	Excessive demands (stress) or the demands are too low (boredom).	Staggered problems.
Error culture	Errors are prevented and sanctioned.	Dealing with malfunctions (errors) of the production system are part of the regular work.

The following key questions had to be answered in the development phase: (1) How can learning be integrated into the work process without disturbing it? (2) What knowledge must be made available for the learning activities? (3) How should the required knowledge be prepared and presented so that it can be used as a resource? (4) How can learning be initiated and made so attractive that it can be self-directed? (5) How can isolation be broken; how can social embedding be made possible and the exchange of knowledge be promoted? (6) How can the effectiveness of the approach be determined?

In the next section we outline the didactic approach, the realized learning environment, and the realized training.

4.3 Development, Testing and Application

The operational context at Hella Fahrzeugkomponenten GmbH (Hella) was in the field of headlamp cleaning systems ('M-Telescope'). Production is carried out on a highly automated system which was identified as a suitable field of analysis and design due to its capacity utilisation and technical topicality. The foreman responsible for this area is the supervisor of 18 employees, who are divided into 14 indirect and 4 direct employees. The direct employees work directly on the machine as assemblers. The indirectly employed personnel are responsible for the organisation and operation of a plant. A skilled worker in the sense of this term is a person who has successfully completed training in a state-recognised occupation and is employed in work processes corresponding to the job description. These skilled workers are also referred to in the company as FfT (Fachkräfte für Technik, skilled workers for technology). The majority of the occupations requiring training are machine fitter, industrial mechanic, construction mechanic, or mechatronic technician.

Due to the strong demand, the plant is operated in a three-shift operation. At the plant for the production of the M-telescope, two technical specialists are employed per shift. This is necessary because of the size of the plant, which is 6 x 21 metres (figure 2).

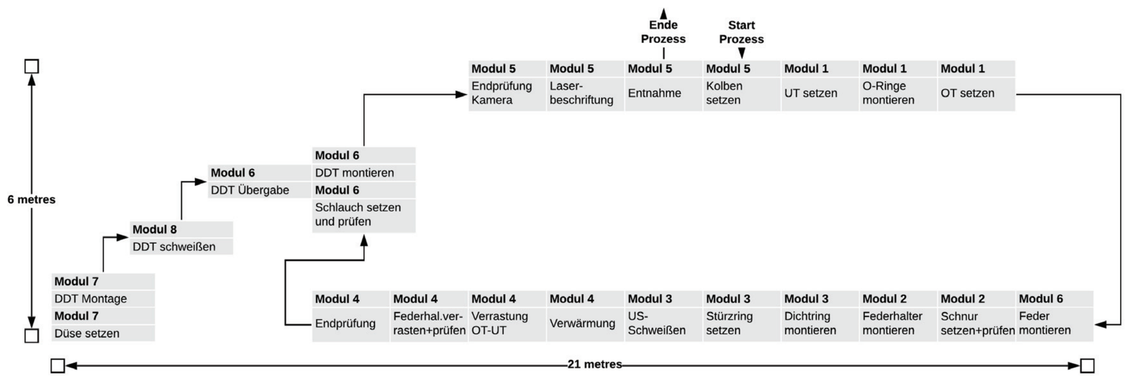

Figure 2: Schematic representation of the production system

The specialists, therefore, have different areas of responsibility. The tasks of the lead-FfT are, in addition to the supervision of their plant area, the organisation of conversions and substitution arrangements, documentation, and communication with the maintenance workshop.

A master craftsman (responsible, among other things, for personnel resource planning) is the direct technical superior of the skilled workers. A production planner is responsible for the budget and a process engineer can be called in, in the event of special problems or interruptions. If there were to be malfunctions on the weekend, the on-call service of the electrical workshop, the process engineer, and/or specialists for camera and laser systems are also called for support.

Didactical Approach

The focus was on the work processes of the skilled workers who operate the systems. After evaluation of the interviews and workplace observations, the following typical work processes could be identified at the company's application partner Hella: operating the system, maintenance work, converting the system, creating production orders, and dealing with faults. Our interviews and workplace observations showed that fault analysis and elimination, in particular, represent a high technical challenge. Fault analyses or analyses or interruptions become equally easier and more demanding. Although, according to the statements of the plant engineers, while the number of product faults has decreased, the complexity of plant faults is increasing. There is a change in the quality of faults, as faults in the system are often individual – each machine is unique and designed and programmed for a specific purpose. Standardized solution strategies are therefore less and less likely to provide a remedy. The 'individualization' of system faults is accompanied by increasing complexity, so that in addition to the experience of the specialists, special expert knowledge – for example in laser technology or robotics – is often indispensable for troubleshooting. The consequence is that problems and malfunctions are increasingly of an information technology nature and can therefore be dealt with in a cognitive-logical abstract way and less and less by means of physical empirical knowledge that is based on sensory perception. The consequence is that highly automated systems are often perceived by specialists as a kind of 'ghost machine', in which they use the operating elements, but without always having the corresponding conceptual knowledge. In this case, competence development focuses on improving the knowledge of the production system ('understanding the complexity'). The subjects of learning are the interaction of the networked components as well as the functions in the context of the production system. The learning objectives are (1) the development and assurance of process and system understanding, (2) building up expertise in the field of current technology so that employability is maintained, (3) understanding and being able to analyse the technology and the interaction of the networked components of the plant.

In order to prevent faults from occurring, machine operators must understand the technical relationships, both the product materials and the wear processes. This also applies to malfunctions and breakdown of the production system. By means of didactic intervention, the specialist should be enabled to assess whether a corresponding specialist (e.g. the process engineer) needs to be called or whether the malfunction can be remedied independently. The place and subject of learning is the production system. Learning takes place at the workplace during times that do not require the attention of the specialist in the production process (including the trouble-free time). The approach chosen in the project comprises video-based microlearning units. A learning management system was developed as well as video sequences and interactive graphics, which were specially designed for this work-integrated learning and didactically prepared according to the areas product, feeding process, production process. The videos were recorded at the production line with the help of an action camera in order to make automated, 'encapsulated' production processes visible. Two aspects speak for the use of videos. In view of the pictorial and procedural nature of most digital media, communication today is increasingly practiced visually or audiovisually. Texts are no longer the primary medium for conveying knowledge. In addition to the pictorial and procedural mediation of knowledge, the learning potential of videos should be emphasized, especially in the case of work processes that are difficult to access.

The only tool required to display and maintain the learning management system (here: WordPress) is a digital end-user device with a browser. From any smartphone, tablet, or desktop computer a connection to the learning management system (LMS) can theoretically be established via the Hypertext Transport Protocol. For the skilled workers at the production plant, the LMS was hosted centrally and a tablet was provided for display. The skilled workers can thus access the system during the work process.

Didactical implementation

In the LMS, a graphical user interface was initially developed which allows information and content to be presented quickly and clearly to skilled workers at the plant. Due to the requirement that the system can be accessed from a tablet, the user interface of the system was adapted to this special application. The user can navigate to specific parts of the M-Telescope via a start page. Table 4 shows the structure of the LMS.

Table 4: Structure of the learning management system

Levels of Knowledge	Context	Possible Contents
Orientation and overview knowledge	Manufacturing	Cooperation, TPM, CIP, information transfer, shift handover, knowledge management etc., product knowledge.
Coherence knowledge	Annex	Plant & processes, communication of plant components, MES system, ERP system, production process.
Detail and Functional knowledge	Modul/manufacturing cell	Networks, data transfer, SPS, programming.
Systematic specialist knowledge	Components	Functionality of system components such as sensors, actuators, CCD, laser, robotics etc.

In the learning management system, different additional documents are available to employees for different work and production steps of the plant (cells), which in turn are subdivided into individual modules:

- Plant Update (Tech-Blog): Here the technical specialists find chronologically and thematically sorted changes to the M-telescope plant. These changes to the system are updated by the process engineers in the learning system. Pictures can be added for illustration.
- Problem solutions/documents: Here the technical specialists find documents that provide support for fault clearance and problem solutions.
- Maintenance instructions: Here the technical specialists find inspection plan checklists for the maintenance of certain components or plant parts in tabular form.
- Spare parts: This tab allows the technical specialists to search for spare parts directly on the tablet.
- Discussion: This is where technical specialists can discuss asynchronous with their colleagues.

Each module consists of four subcategories (overview, product, feeding processes, production processes), which contain differently coded information:

- Photos of the plant, on which important components were specially marked.
- Process videos in which an action camera is mounted on a workpiece carrier and in which the production process can be viewed from within the encapsulated system.
- Additional explanations in text form cross-references photos and videos to systematic domain knowledge.
- Animated text and image elements in a specific flow chart to illustrate the processes of the plant.
- Interactive graphics, e.g. with so-called hot spots, which the skilled worker can tap on to obtain further information.

The learning contents were selected and structured in such a way that elaborated insights can be gained on the basis of concrete individual examples (exemplary learning). On the one hand, learning had to be self-organised (due to the unpredictability of time windows) and on the other hand, it was socially embedded. Figure 3 gives an overview of the structure of a learning sequence.

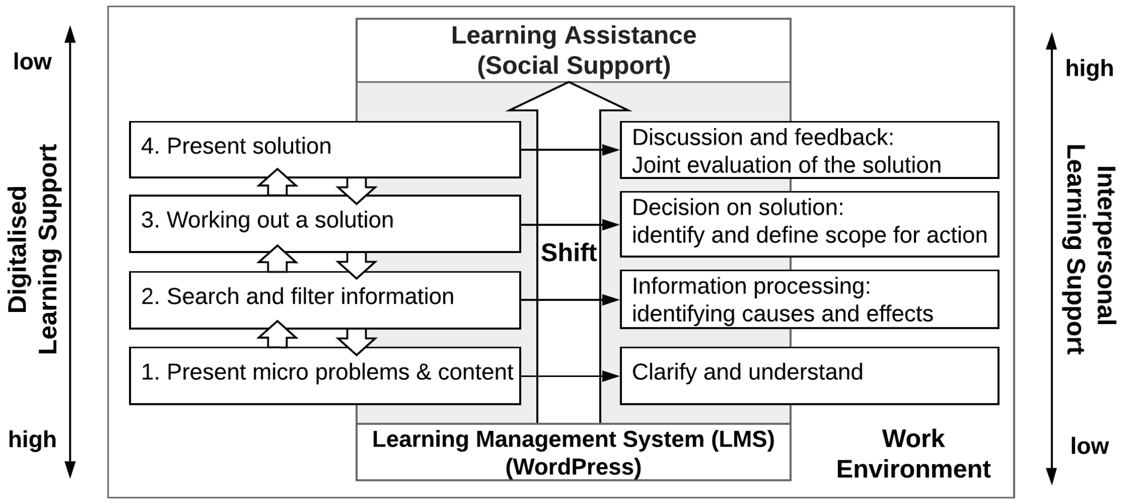

Figure 3: Structure of a learning sequence

The knowledge resource for self-directed learning is the learning management system. The initial ignition is based on tasks that form a problem, such as:

- Task: in the first work step of cell one, the pistons are placed on the workpiece carrier (WT) in module 5.4.
- Problem: (1) What can happen if the piston is misaligned? (2) In which station does this have an effect and why? (3) In which station is the cause likely to be found? Justify your considerations. (4) What happens then, if an incorrect piston is fed?

The technical basis of the developed and tested learning management system (LMS) is the open source content management system (short: CMS) WordPress. WordPress is the world's most widely used CMS and enjoys great popularity in many application areas due to its extensive basic functionalities and its diverse expansion potential. Historically, WordPress was designed and developed as blog software, but with the constant growth of the

WordPress community in the past years, it has developed more and more in the direction of a classic CMS, without losing functionality as a blog system.

The only tool required to display and maintain the learning management system is a digital end-user device with a browser. From any smartphone, tablet, or desktop computer a connection to the LMS can theoretically be established via the Hypertext Transport Protocol. The LMS is centrally hosted and a tablet is provided for display by the production line staff. The skilled workers can thus access the system during the work process. A graphical user interface was initially developed in the LMS, which allows information and content to be presented quickly and clearly to skilled workers at the plant (see Potential 1: Making information and content available). Due to the requirement that the system can be accessed from a tablet, the user interface of the system was adapted to this special application. For this purpose, a schematic representation (top view) of the plant is stored as a navigation element. The user taps on the tablet on the corresponding navigation element, depending on which cell or module he needs information about, and is forwarded to it (see Figure 4).

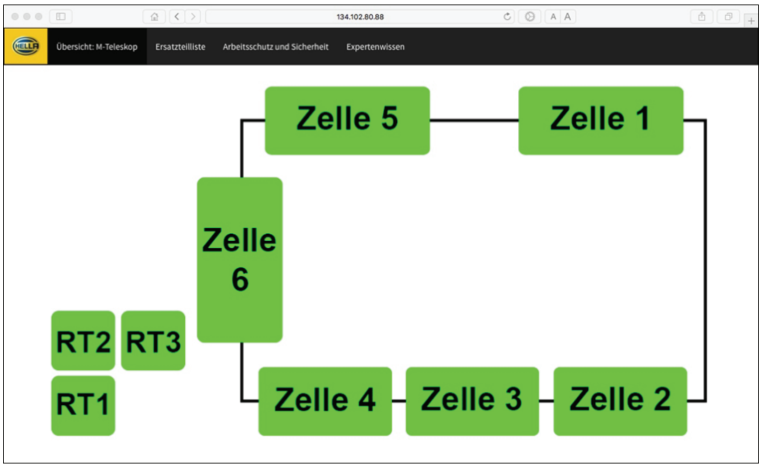

Figure 4: Schematic representation of the production plant for navigation[10]

After the cell has been selected in the navigation, a new display page is called up on the tablet. Here the skilled worker finds information about the selected cell or module. The technical information of the M-telescope system is integrated here in the form of sliders (see Figure 5).

[10] Each production cell (german: 'Zelle') consists of different modules. For example, production cell 5 consists of 4 modules.

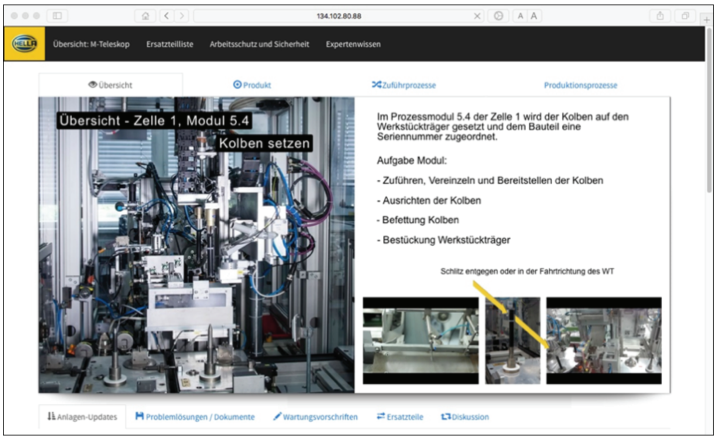

Figure 5: Slider in the learning management system – here: overview

Sliders are graphical display elements that can consist of several 'sheets' and can be compared to a presentation file in PowerPoint. These sliders contain information on the cell or module of the M-Telescope system, which was used for the potential of visualization, animation and navigation, in particular.

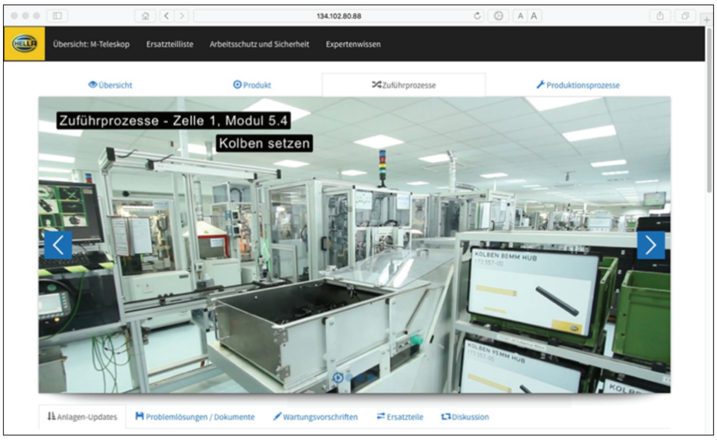

Figure 6: Slider in the learning management system – here: process step

For each module four tabs were designed, which contain differently coded information.

1. Photos of the facility, on which important components were specially marked.
2. Process videos (Figure 6) in which an action camera is mounted on a workpiece carrier and in which the production process can be viewed from inside the encapsulated plant.
3. Explanations in text form.
4. Animated text and image elements in a specific flow chart to illustrate the processes of the plant.
5. Interactive graphics, with 'Hotspots', which the skilled worker can tap on to obtain further information.

By means of graphical navigation page with several tabs, the skilled workers can select which information they would like to be displayed for the selected module.

5 Retrospective Analysis

A 'hallmark' of the DBR approach is the 'relationship between the development of theory and the improvement of instructional design' (Cobb et al., 2003, p. 13). A 'primary aim' is, therefore 'to place the design experiment in a broader theoretical context, thereby framing it as a paradigm case of the more encompassing phenomena specified at the outset.' (p. 13). Furthermore, the practical implications are significant: '"What works" is underpinned by a concern for "how, when, and why" it works, and by a detailed specification of what, exactly, "it" is.' (p. 13). The combination of these two perspectives is the focus of the following retrospective analysis.

Non-routine work in highly automated work environments

Pfeiffer notes that 'in the eyes of most labor market statisticians, production and machine-based work is monotonous, repetitive, and physically challenging' (Pfeiffer, 2018, p. 209). In contrast to this assumption, Pfeiffer state that 'the work done by such employees is far from routine.' (p. 213). Pfeiffer concludes: 'From the perspective of qualitative labor research, then, the customary distinction between knowledge work as a non-routine activity and production work as a routine activity does not stand up to close scrutiny.' (p. 214). Our DBR experiment confirmed this result. The value of the work and the challenge for the skilled workers was especially the non-routine handling of malfunctions. Beer and Mulder (2020) also confirm these observations. The authors conclude after reviewing the recent status on research on the effects of technological developments on work characteristics that 'quantitative evidence indicates positive relationships between computer work and increasing levels of interruptions as well as an increasing demand for multitasking.' (Beer & Mulder, 2020, p. 7). Highly automated work environments have therefore two faces: They are first of all, learning-hostile work environment due to their restrictive work conditions (e.g. isolated subtasks, little social exchange, unclear feedback of the work–here: unclear feedback of the automated production system in the case of malfunctions). But: Due to the malfunctions resulting from complexity, learning opportunities are available and, in so far as they are exploited, these working environments can offer enormous learning potential – but, this potential is difficult to tap. For continuing vocational training in highly automated working environments, this means in particular that the development of personal, technical and social competences to deal with malfunctions, interruptions and uncertainties are required.

Implementation of learning and promotors as supporters

The development and implementation of work-integrated continuous vocational education and training is already demanding, as this form of training is linked to the concrete working environment and the inherent knowledge. The knowledge to be imparted can only partly be derived from existing knowledge stocks. This leads to the problem that content is not only to be selected, but knowledge must first be generated. In highly automated working environments, these conditions are even more stringent. The entire production system in our experiment was encapsulated. It also presented itself to us as a 'ghost system'. Working conditions that impede learning are also working conditions that impede the development and implementation of an instructional design! Finding: Our initial assumption was that work process knowledge could not directly be derived from explicit knowledge structures and job descriptions, but rather arises in the concrete task processing and the solution of (complex) challenges in everyday work. This assumption was fully confirmed. And, in connection with this finding: We were only able to set up the work-integrated continuous vocational education and training outlined above because an internal employee was available as an expert and relationship promotor. This insight leads to a more comprehensive perception of the importance of promoters, as captured in the promoter model. The promoter model bases on the idea that innovation and development processes are not self-runners, but resistances (so-called 'barriers') have to be overcome. Typical barriers are barriers of expertise (barrier of not-knowing), hierarchical barriers of will (barrier of unwillingness), administrative barriers (barrier of not-allowing) as well as barriers that delimit the organisation (Barriers of not knowing the external organizational environment). Promoters are the catalysts in the innovation process: they provide resources, to overcome these barriers (Hauschildt & Chakrabarti 1988; Hausschildt et al. 2016). In our DBR study, these promoters were available. The fundamental decision to conduct the experiment had cost-relevant effects, for example, when we had to stop the production to tap the inherent knowledge. To cross the 'barrier of unwillingness' would not have been possible without the ongoing support of a power promoter. We have already mentioned the vital role of the relationship promotor (barriers of not-knowing each other) and expert promoter (barrier of not-knowing). However, the process promoter (barrier of not-allowing) was also crucial in our case, e.g. to be able to conduct interviews with the skilled workers or to install a local network in the production. Based on our findings, the implementation of a work-integrated continuous vocational education and training is an innovation process, which is why we assume that it can only succeed if the four promoter functions are in place to support the development and implementation of the instructional design.

Resistance to learn and participation

The form of learning (e.g. self-directed learning with tablet) was new for the skilled workers, and we also used the malfunction-free and idle time slots in the work process as 'opportunity windows' for our microlearning approach. During these malfunction-free idle time slots, the specialists work in a self-organised manner to ensure that the process runs smoothly, which is why we assumed that any distraction in theses time slots of autonomy could meet with resistance. The intended work process embedded learning offer could also be seen as a sophisticated form of labour intensification (Sayer, 1986; Tomaney, 1990; Green & McIntosh, 2001). But, the opposite was the case: the malfunction-free idle processes were also times of indecisiveness (What am I to do? What is expected of me?), which is why the offer and possibility to explore the machine was very positively received. The lack of learning experience was also not a problem, rather, the training was not perceived as training, as the learning environment embodied an image of the working environment enhanced by videos etc. The 'virtual stay' in the learning environment was exciting and maybe more pleasant than the stay in the reality, as it provided explanations, background knowledge, and insight that the working reality could not provide. Our results also extend existing findings: Predictors for participation in non-formal vocational education and training are usually person-related indicators such as prior knowledge, prior formal qualifications or occupational classifications (Kaufmann, 2015). These factors played no role in our setting. Rather, all persons who were in contact with the production system or who could come into contact with the production system participated in the training programme. Skilled workers, on-call workers and apprentices participated and this regardless of prior knowledge and formal qualifications, job classifications and also the status of employment (full-time or part-time work).

Digitalised Microlearning

On the basis of a structured literature review study, Schall (2020) states that evidence-based studies on actual learning outcomes, conditions for success and the benefits of microlearning were not found. Schall therefore suggests that at a company level it is necessary to investigate what effects the use of microlearning in personnel development has on both employees and the economic development of the company and which factors (e.g. social support and discussion) lead to added value. The question of the effectiveness of the learning approach is also not answered by our study and remains open.

In our study, nevertheless, the microlearning approach has proven to be a viable way to enable learning in highly automated work environments! We can confirm the possible application, although we cannot yet determine the degree of learning effectiveness. However, as shown above, the microlearning approach was embedded in units both in the learning management system (orientation and overview knowledge/contextual knowledge) and in the combined task/problem settings (where and how does the malfunction affect and where could it have originated?) A production system 'lives' on the relation of its components, accordingly these relations have to be considered when designing microlearning. In short: the learning action takes place on the micro level. However, planning and design as a didactic action, and the development of understanding as the goal of the learning action (here: understanding the functionality of the production system) are carried out on the meso-level or contextualised. In our learning approach we have explicitly included a social component of exchange and support. This approach is also confirmed in the above-mentioned review study against the background of handling interruptions and malfunctions of the production system. Beer and Mulder (2020, p. 13) state: 'Workflow interruptions and an increasing workload also increases the importance of communication skills for explicating the boundaries of one's own engagement to colleagues and leaders.'

Outlook

During the implementation it became apparent that microlearning is not only useful for the actual target group but also for other target groups: On-call workers and apprentices. However, the feedback also showed that the system created was not a substitute for instruction and that learning in the work process was welcomed but also judged to be problematic (Quote from an employee: 'If you want to formulate an idea there, you need rest, then you cannot do it when the system is running'). Learning opportunities were integrated into the work process, but not into the work itself. Informal learning was made possible, but not incidental learning at work.

The creation of the learning environment as well as the identification of the exemplary tasks required not only an in-depth examination of the system design and the production process, but also an interruption of production. For example, to be able to create the videos of the 'inner life', production had to be stopped and the enclosure and cladding dismantled. This effort would not have been necessary if the development of the learning environment had been considered, planned, and implemented at the same time as the development of the production plant. It can also be assumed that the concurrent design of the learning environment (form and content) is less time-consuming than the subsequent design.

Adaptation-oriented CVET (Anpassungsweiterbildung) is generally described as an adaptation of the qualifications of an employee to changing working conditions and requirements. The concept presented here can be assigned to this form of CVET. Continuous vocational education and training is, furthermore, often differentiated into a curative or corrective and a preventive or future-oriented form of training (Arnold et al., 2016). Initially, the CVET provided here appears to be purely curative. In fact, however, in view of the risk of knowledge devaluation through automation, a strengthening of experiential knowledge has actually taken place, whereby the curative form not only creates the prerequisites for being preventively effective, but furthermore already represents learning in highly automated working environments and is thus itself preventive. The distinction of curative/preventive seems to be analytically meaningful. In work-integrated CVET, however, these forms are connected with each because the curative or corrective learning *in* a context cannot be separated *from* the regulation of the context and thus the preventive or future-oriented learning *about* a context.

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