Journal of Technical Education

Band 4, 2016, Heft 1

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Journal of Technical Education (JOTED)

ISSN 2198-0306

Online unter: http://www.journal-of-technical-education.de

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Knowledge work in aircraft maintenance

Abstract

Knowledge work encompasses information processing and knowledge development tasks and places the knowledge worker at the centre of analysis. Knowledge and information are the knowledge worker's most precious resource in an increasingly complex working environment. Knowledge work is analysed in the context of the productive technical working environment of aircraft maintenance at Lufthansa Technik AG. The proportion of knowledge-intensive tasks in aircraft maintenance rises with increasing complexity of aircraft and their systems and components. The quantity of information and the resulting challenges for workers also increase accordingly. The findings generated by the study and a theoretical consideration of the subject are used to derive conclusions about the practice of aircraft maintenance and concrete recommendations for action.

Keywords: Knowledge work, aircraft maintenance, knowledge, information, fields of action

Wissensarbeit in der Flugzeugwartung

Zusammenfassung

Wissensarbeit umfasst Tätigkeiten der Informationsverarbeitung und Entwicklung von Wissen und stellt dabei den Wissensarbeiter in den Mittelpunkt der Betrachtung. Für ihn sind Wissen und Information die kostbarste Ressource in einem zunehmend komplexer werdenden Arbeitsumfeld. Wissensarbeit wird innerhalb des produktiven technischen Arbeitsumfeldes der Flugzeugwartung der Lufthansa Technik AG analysiert. Der Anteil wissensintensiver Tätigkeiten in der Flugzeugwartung steigt mit zunehmender Komplexität der Fluggeräte, deren Systeme und Komponenten. Die Informationsmenge und die sich daraus ergebenden Anforderungen an die Mitarbeiter nehmen entsprechend zu. Anhand der gewonnenen Erkenntnisse der Studie sowie der theoretischen Betrachtung der Thematik werden Konsequenzen für die Praxis der Flugzeugwartung abgeleitet und konkrete Handlungsempfehlungen gegeben.

Schlüsselwörter: Wissensarbeit, Flugzeugwartung, Wissen, Information, Handlungsfelder

1 Introduction

Knowledge, information and their availability have become an important resource in all areas of life in a society that is changing ever more rapidly and becoming ever more complex. Not for nothing have the terms "information society" and "knowledge society" – typically used as synonyms – become current (e.g. Arnold 2012, p. 3; Steinhübel 2006, p. 1; Wilke 1998, p. 175). However, the former refers more to the effects of technical informatisation and digitisation, the latter to the progressive shift of all areas of society to be knowledge-based (Hasler Roumois 2013, p. 19). Both concepts highlight the fact that information and knowledge are becoming more and more important as forward-looking production factors and leaving behind traditional factors (land, labour and capital) (Steinhübel 2006, p.1). Optimal use of knowledge as a resource is becoming a decisive advantage when facing the challenges brought by globalisation, technology, increasing international competition and shorter product life cycles. The awareness that sustainable competition is only possible if advances in knowledge are used in an optimal way has penetrated business management to a profound extent. Efficient knowledge management and its decisive influence on an enterprise's competitive advantage has become an oft-discussed topic in both research and economy. The term "knowledge management" is experiencing a veritable boom, as is shown by the plethora of literature on the topic. For this reason it seems surprising that the term "knowledge work" has not enjoyed nearly as much popularity in practice. Knowledge work consists of the data and information processing tasks that generate new and useful knowledge (Hasler Roumois 2013, p. 20), thus placing not management but the worker at centre stage. As described in this paper, knowledge is linked to an individual, and the transmission of knowledge in codified form through information systems to make it available to the whole organisation is only possible to a limited extent. A knowledge worker can pass on information about already known facts, "[...] but not the ability to solve new problems or improve existing solutions" (Pfiffner, Stadelmann 2012, p. 103). It is the knowledge worker's knowledge that causes the business to experience an increase in value, since knowledge is an autonomous production factor. If a knowledge worker leaves a business, he takes his knowledge with him and the business experiences a loss of a non-material asset (ibid.). Knowledge work is thus a decisive factor in the future success of the business. As an important factor influencing knowledge work, knowledge management – the optimal preparation of information for the knowledge worker – is also crucial to the enterprise's profitability. According to the recent work management study by Wrike, for example, lack of information is the largest of the eleven stress factors identified in work (Wrike 2015, p. 5). Since the factors that influence knowledge work must be arranged as much as possible according to the worker's needs, the description and analysis of knowledge work and the realisation of findings generated as a result are of central importance. The existence of an interest in such findings is also evident from the fact that many definitions of knowledge work primarily consider academic activities and largely exclude production-related areas from consideration. That academics are knowledge workers is not surprising. Whether or not skilled workers in a technical environment also increasingly engage in knowledge work has been researched rather less. Since knowledge as a resource has increased in relevance in all areas, one can assume as much. Particularly in an environment in which highly qualified specialists work on technical problems, one finds an enormous need for knowledge as a resource.

This paper investigates the topic of knowledge work in a productive technical environment. Knowledge work is described and analysed in the field of aircraft maintenance at Lufthansa Technik AG. First, the choice of definition of knowledge work is justified. Next, the structure and process of knowledge work are described in detail (Section 2). An empirical investigation is conducted in the field of aircraft maintenance at Lufthansa Technik AG. According to the study design concept (Section 3.1), the questions to be examined are: how knowledge work presents itself in aircraft maintenance at LHT (Section 3.4) and how mechanics and avionics experts at Lufthansa Technik AG describe and perceive knowledge work (Section 3.5). Consequences for praxis are presented in the concluding discussion (Section 4).

2 Knowledge work according to Gerhard Hube

Hube's definition is the most suitable for the environment of aircraft maintenance – for one thing, in this definition, knowledge work in a productive working environment is not simply excluded per se. For another, with his approach Hube creates the possibility of a nuanced consideration of knowledge work within a working environment and of distinguishing different types of knowledge work. Another reason for choosing Hube's approach is that in his paper Hube creates a methodology for analysing and evaluating knowledge work that rests on the foundation of a holistic consideration of people, technology and organisation (Hube 2005, p. 52). In a labour studies approach, human work is seen as a performance of work that is organisationally regulated by humans and technology (Hube 2005, p. 53; Luczak 1998, p. 17). The spotlight falls on "[...] the functions, limits and evaluation criteria of the human contribution to the performance in organisations and in relation to the working environment [...]" (Luczak 1998, p. 17). Hube therefore sets certain requirements for his definition (Hube 2005, p. 53):

Holism: Knowledge work must be investigated and evaluated in a holistic approach. People, organisation, working environment and technology must be included in consideration (see ibid.).

Process character: Factors that influence knowledge work can only be determined if the process of the work is considered. Crucial to the analysis of knowledge work is the "[...] consideration of specific stages that permit description of the work and analysis of influencing factors independently of the degree of complexity, the goals and the length in time of the process" (ibid.). Individual stages can be run through multiple times and it is possible to jump between stages. For this reason, an example process can only serve as orientation (see ibid.).

Design perspective of the working environment: In his approach, Hube places value on sufficient consideration of the design of the working environment and workplace (see ibid.).

Universality: This methodology has universal validity and can be applied to different knowledge-intensive work processes, workplaces and industries (see ibid.).

Uniqueness: Hube takes into account the fact that knowledge work is characterised to a high degree by the novelty and uniqueness of work processes. Activities can only be standardised to a limited extent. To him, it is important that "[...] such uniqueness can also occur in analogue work processes because of unexpected events or novel ideas whose implementation or processing is new to the worker" (ibid.).

Hube develops his definition based on the findings of Pfiffner and Stadelmann (1995), which in turn build on Resch (1988). Hube takes the basic terminology and understanding of fields of action from Resch's approach (Hube 2005, p. 61). "Knowledge work consists of intellectually objectifying activities that bear on novel and complex work processes and results that require external means of controlling complexity and a double field of action" (ibid.). Hube fleshes out the dimensions of the novelty and complexity of the work in order to distinguish knowledge work from non-knowledge work:

Novelty: The task to be performed is new to the worker and he cannot fall back on his own experience-based knowledge (Hube 2005, p. 62). The final decision on whether something is knowledge work or not depends, however, on the worker's individual perception of the task: "Important to this definition of knowledge work is the consideration that the decision on whether something is knowledge work is only made by the worker's individual perception of the task. For an experienced person with corresponding specialist and procedural knowledge, a task with a certain degree of complexity may not yet constitute knowledge work, whilst for another person without such experience this task is already knowledge work" (ibid.).

Complexity: To describe the complexity of knowledge work, Hube falls back on underlying insights in the theory and practice of holistic problem-solving of complex problems: "Complex problems are characterised by a multitude of influencing factors that are strongly linked to each other by a dynamic pattern of links and interactions. The major difference to less complex problems lies in the dynamics, through which factors may change or disappear and the intensity of relationships between factors may vary strongly" (Hube 2005, p. 62). Solving such complex problems relies on the three following basic considerations, for which Hube cites the approach of Gomez & Probst (1995, 1999): Problem-solving is a leadership task and cannot be delegated, complex problems can only be successfully handled through teamwork, and mastering complex problems is a learning process (Gomez, Probst 1995, p. 32 et seq.; 1999, p. 22 et seqq.; Hube 2005, p. 63). To describe the complexity of knowledge work, Hube relies on the stated insights of Gomez & Probst as follows:

Communication and co-operation: "Handling the task requires a high degree of communication and co-operation with other participating people and groups" (Hube 2005, p. 63).

Learning and continuing education: "The novelty and complexity of the work make permanent learning necessary to master work challenges. Existing knowledge must be adapted, expanded and revised in sometimes lengthy processes" (ibid.).

Dynamics: "Low predictability and the large number of special cases often create unexpected situations and unplanned additional tasks. This creates an enormous dynamism that is expressed in ad hoc tasks and high time pressure" (ibid.).

Because of the particularities of aircraft maintenance, an additional point on describing complexity will be added to supplement the definition.

Complexity of the device and the task: The object on which work is being done is already a complex device in itself. Aircraft maintenance means that errors affecting the aircraft and all its systems and components are corrected to return it to "normal condition." The airworthiness of the aircraft is also inspected in regular (maintenance) checks. Work on the aircraft is therefore error-oriented. Deviations from normal condition must be recognised and corrected. This requires a high degree of understanding and a corresponding depth of perception of systems and components. The consequence of the high complexity of an aircraft is that all activities performed on this device are also characterised by a high degree of complexity.

As shown in the figure below, it is possible to distinguish knowledge work from non-knowledge work using the introduced dimensions of novelty and complexity of the work.

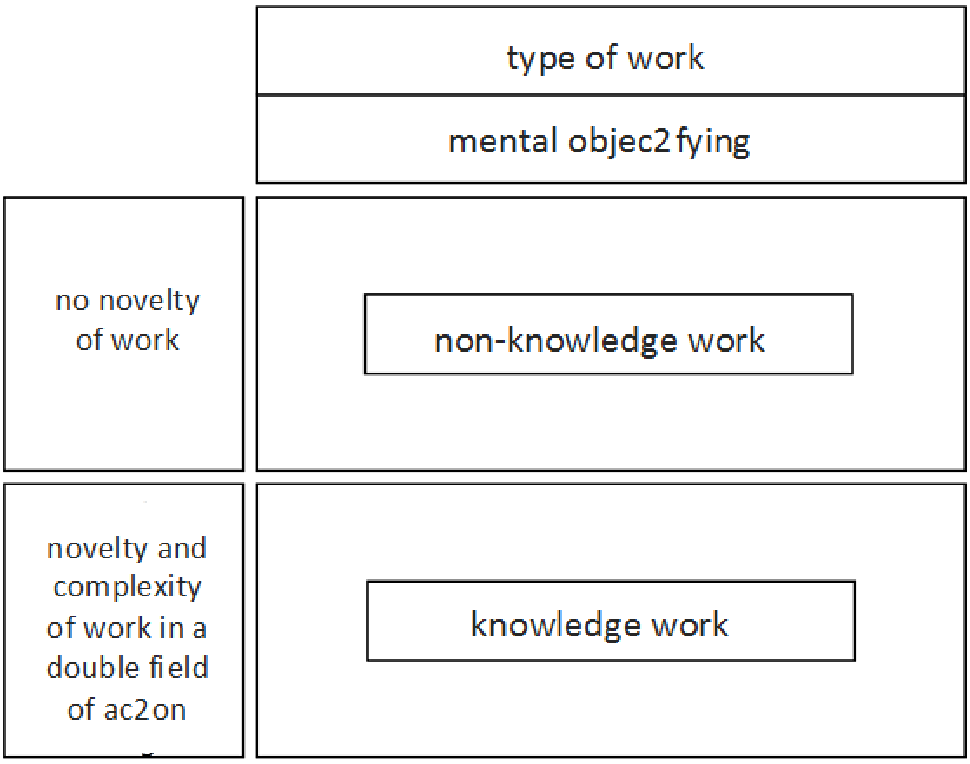

Figure 1: Distinguishing knowledge work from non-knowledge work (Hube 2005, p. 62)

Knowledge work, as defined by Hube, also requires a double field of action: the real field of action and the reference field of action.

Real field of action: "The real field of action is the field of action in which instruments must be used in order to handle the work process, firstly so that orientation in the reference field of action is made easier and secondly so that the reference result can be transferred to the reference problem in the first place. In the real field of action, the decision on which means of controlling complexity should be used and finally the application of these external means creates the real result" (Hube 2005, p. 63).

Reference field of action: "The reference field of action is the field of action needed because of the lack of direct options for influencing the complex reference problem in order to achieve a reference result through internal invisible simulations and decision-making" (Hube 2005, p. 63). Developing the reference field of action is a crucial part of knowledge work, since this is where orientation and planning take place – without these, generating the real result is impossible. In this stage, the worker uses the external resources available to him, such as documents, diagrams, plans or sketches, to plan a further course of action until achievement of the goal and to take into account all circumstances in the real field of action. These work processes require a high degree of concentration.

Hube's portfolio describing different types of knowledge work can be used to specify knowledge work more precisely. He distinguishes between knowledge work in isolated cases and knowledge work as a profession (Hube 2005, p. 63). This differentiation is necessary in order to distinguish workers who are only confronted with novel tasks in isolated cases from knowledge workers who are permanently confronted with novel tasks and perform original knowledge work in response to the peculiarities of the other complexity characteristics (ibid., p. 63 et seq.).

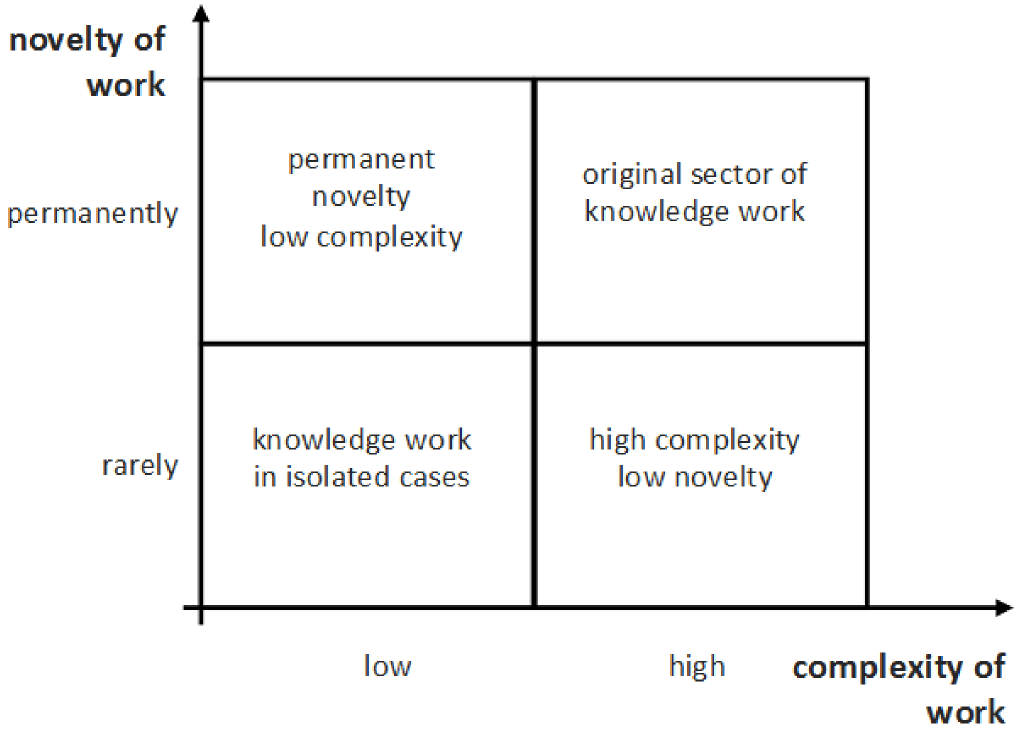

Figure 2: Portfolio describing different types of knowledge work (Hube 2005, p. 64)

3 Empirical investigation

The exploratory study was conducted in the field of aircraft maintenance at Lufthansa Technik AG. The company is a world leading manufacturer-independent service provider for maintenance, repair and overhaul (MRO) of civil- and commercial-use aircraft and components. An aircraft is a complex system of mechanical and electronic components which must be kept in technically flawless condition at all times. Aircraft maintenance activities therefore pose major challenges. Innovations such as new aircraft designs or components are introduced all the time. In addition, the aircraft industry must comply with extensive regulations and high safety standards. Mistakes can have fatal consequences. High quality standards and simultaneous time pressure lead to high employee stress levels. The aviation industry is also subject to intense competition. The cost pressure resulting from globalisation and high customer standards exacerbate the situation in aircraft maintenance and increase pressure on employees.

This empirical study starts from the existing situation in aircraft maintenance. To find out how knowledge work presents itself in aircraft maintenance, it is investigated to what extent employee activities correspond to knowledge work. A comparison of the previously described theory of knowledge work with employee activities is undertaken. Secondly, how employees describe and perceive knowledge work is analysed. Expert interviews were conducted in November and December 2014 for this purpose.

3.1 Research tools and procedure

The interview form used to collect data in the study is derived from the research design. Since the technical, procedural and interpretive knowledge of a specific group of people in reference to their professional field of action is at issue, the expert interview is used (Bogner, Menz 2002, p. 46; Gläser, Laudel 2009, p. 12 et seq.). Its purpose is the exploration and thematic structuring of a specific field of investigation (Bogner, Menz 2002, p. 37; Friebertshäuser et al. 2010, p. 439). The subject is of interest in his capacity as expert in a specific field of action (Flick 2011, p. 214). Because of the high time pressure in aircraft maintenance and the focus on questions corresponding to the epistemic interest, a primer is used to provide guidance (ibid., p. 216; Gläser, Laudel 2009, p. 111 et seq.). It helps generate participant answers, guarantees that the same questions are covered in all interviews and is intended to exclude unrewarding topics during the conversation. To attune the questions as precisely as possible to the topic, they were tested and reworked multiple times before the interviews. Further queries and requests for more precise statements were adjusted according to the situation. The techniques of questioning, focusing and reflecting were used to steer and increase precision. Qualitative content analysis is chosen to evaluate the material obtained in this way. This method is based on the assumption that the collected material contains the interviewees' attitudes and views on their environment (Mayring 2002, p. 114). It allows striking individual cases and latent structures of meaning to be uncovered (ibid.). The goal of qualitative content analysis is, for one, to reduce the starting material, which also allows large quantities of data to be processed. The material is systematically analysed and evaluated in an empirically and methodologically controlled manner (Mayring 2000, p. 2). The evaluation is performed according to rules of content analysis "[...] without degenerating into hasty quantifications" (ibid.). The data is based on a verbal/communicative foundation. One advantage of content analysis in comparison to other textual analysis approaches is its grounding in communication studies (Mayring 2007, p. 42; 2010, p. 48). The collected text material is "[...] understood in its communicative context [...]" (ibid.). The interpretation of the material takes into account a statement's particular context accordingly (ibid.). Another reason to choose qualitative content analysis is a systematic, rule-based procedure (ibid.). First a concrete process model is prepared for the analysis, ruling out arbitrariness in the evaluation process and offering intersubjectivity in the course of action. The central tool of analysis is the system of categories, which is both guided by theory and developed using the material (Mayring 2007, p. 43). The definitions of categories should facilitate clear and comprehensible allocation of the material. This study uses both the methods of structuring and summarising content analysis. Based on a theory-grounded ex ante structure, initial categories are established which are then supplement ex post based on the material. The deductive category definition of the structuring approach allows the evaluation instrument to be moulded by theoretical considerations (Mayring 2010, p. 83). The theory concept introduced above is intended to develop categories that are worked out in an operationalisation process in dialogue with the material (ibid.). The category system is used to filter a certain structure out of the material and all parts of the text addressed by a category are systematically extracted (Mayring 2007, p. 82 et seq.). Use of summarising content analysis alongside the structural approach also guarantees that the content of the collected material is examined. The non-predetermined way of proceeding and the resulting openness are concretely expressed in inductive category formation and permit the uncovering of new facts. In this approach, the categories are derived directly from the material in a process of generalisation without referring to pre-formulated theory concepts (Mayring 2010, p. 83). The result of the research process is a final categorial structure that confirms the theory by its applicability and also supplements and expands it.

3.2 Description of sample

This study interviewed 33 technically productive workers (mechanics and avionics experts) employed at Lufthansa Technik AG in aircraft maintenance (PD maintenance). The goal of the interviews was to obtain as comprehensive a picture of aircraft maintenance activities as possible. A heterogeneous group of people was surveyed for this reason. The proportion of female employees in PD maintenance is very low, which is reflected in the sample. One female and 32 male persons were interviewed. An analysis of gender effects is therefore omitted. A large age range is evident in the reference group. The age of the subjects varied between 23 and 61 years, with the average age being 39.3 years. Different occupations should be distinguished within the sample. In total, 20 experts completed their training at LHT and 13 at a different company. Ten subjects completed training at Lufthansa Technik as an aerial vehicle mechanic (*Fluggerätmechaniker*) and five as an aircraft mechanic (*Flugzeug-mechaniker*). In the course of the reorganisation of technical aviation occupations on 1 August 2013, the occupations of aircraft mechanic or air vehicle mechanic, air vehicle engineer (*Fluggerätbauer*) and engine mechanic (*Triebwerksmechaniker*) were consolidated into the occupation of air vehicle mechanic with three specialisation areas of maintenance technology, drive technology and manufacturing technology (see Federal Employment Agency 2013 [online], p. 1). Professional training as an electronic technician for aeronautical systems (*Elektroniker für luftfahrttechnische Systeme*) was also reorganised on 1 August 2013 and renamed air vehicle electronic technician (*Fluggerätelektroniker*) (ibid.). The subjects include two electronic technicians for aeronautical systems trained at LHT and two air vehicle electronic technicians also trained at LHT. In addition, one expert had completed training as an industrial electronic technician (*Industrieelektroniker*), also at Lufthansa Technik. Five experts in total completed training as aircraft mechanics (3) or air vehicle mechanics (2) in the German Federal Armed Forces. Eight experts completed training at a different company and then moved to Lufthansa Technik where they completed in-house training. The occupations of this group of persons before their training at Lufthansa Technik are: Motor mechanic (4), machinist (1), electrical systems installer (1), tool mechanic (1) and cutter (1). One expert each is stationed in Boston, Tokyo and Bangalore.

3.3 Differentiation of questions

The interviews pursue multiple content-related goals. First, they give a better overview of the work situation of aircraft maintenance employees at Lufthansa Technik AG. Experts are asked e.g. to describe their work process. Which activities the workers perform is relevant to this study. In addition, experts were prompted to reflect on knowledge and the use of knowledge in their work processes and to identify factors that influence their activities. The questions from the primer serve as a foundation for this. The direction of the analysis is to use the text material to draw conclusions about the presentation of knowledge work in aircraft maintenance at LHT AG and about the description and perception of knowledge work by mechanics and avionics experts at LHT AG.

As explained at the beginning of the paper, the topic of knowledge work is relatively unknown in practice considering its relevance and is predominantly described for academic activities. However, recent developments lead to the conclusion that the resource of knowledge is becoming more and more important (see e.g. Bullinger et al. 2014, p. 617; Fetzer et al. 2013, p. 5; Fiedler & Picot 2000, p. 1) – particularly in an environment in which employees solve technically challenging problems. Knowledge work is therefore analysed on the basis of the stated definition following Hube within the productive technical environment of aircraft maintenance.

It is first investigated to what extent the text material contains references to the parameters of knowledge work in Hube's definition. This is done by comparing the described theory to the work situation portrayed by the experts. Secondly, how employees describe and therefore perceive knowledge work is investigated. In addition, salient factors that affect the process of knowledge work are identified.

Two research questions arise from this:

Question 1: How does knowledge work presents itself in aircraft maintenance at LHT?

Question 2: How do aircraft maintenance experts at LHT describe and perceive knowledge work?

3.4 Results of first research question

Analysis of the first category showed that experts are permanently confronted with novel tasks in which they cannot fall back on their own experience-based knowledge. A distinction must be made between experience-based knowledge in regard to the development of problem-solving approaches for novel issues on the one hand and experience-based knowledge in regard to tasks on the other. The former describes knowledge of how to handle novel tasks that the experts develop based on permanent confrontation with unknown tasks. Experts of course use their experience when generating a solution method. The latter is the knowledge they are missing because they have never before faced the particular task. Experts must not infrequently grapple with novel tasks, and many of the interviewed experts could draw on experience-based knowledge in regard to the development of problem-solving approaches for novel issues. The experts are also able to re-plan and execute work processes independently in case of unexpected novelties.

A clear minority of the subjects is one expert who reports novelty to be rare in her work. She has built up years of specialist and experience-based knowledge. Based on the individual perception of her work tasks, this case is one of high complexity with rare novelty and thus of knowledge work in isolated cases.

Analysis of the data material also shows strong manifestation of complexity characteristics for all subjects. The experts perceive the aircraft and their work to be complex. In regard to communication and co-operation, the experts find exchange with colleagues to be of particular significance as the most important source of information of their relevant knowledge. A clear parallel can be discerned to the method of operation of a knowledge worker as described in theory. A knowledge worker builds a network for information exchange with other experts[1] that illustrates the reality of lived exchange. Networking is typical of a knowledge worker's work. To reach goals, a knowledge worker moves in a "[...] complex and multi-layered web of other integrated people" (Hube 2005, p. 87). Exchange happens everywhere and at all times, as shown by an example from the interview material:

> "It doesn't always have to be a super-technical talk. It could be [...] playing skat during lunch, suddenly someone has a thought and you tell all your colleagues." (Person A). "You're having a coffee together or whatever in the break room and it's really [...] you really pick up a lot. Just like, when you're just in between, you've got time until the next machine comes, [...] you pass each other, then you share (.) swap a bit [...]" (Person B).

In this way, as appropriate to a learning organisation, the experts benefit not only from their own experience but from that of their colleagues. The so-called mechanic's code is also generally valid among the experts in aircraft maintenance. "If you need help, you get helped." The disadvantage of this form of knowledge transfer is that knowledge and experience remain in the particular circle of workers and is therefore bound to a particular location. Experts stationed abroad miss out on this exchange, which is experienced as a disadvantage.

New knowledge is of high relevance to the experts, creating a large demand for continuing learning and education. To the experts, the dynamics of aircraft maintenance mean making important decisions under stress. The experts are conscious that lack of time cannot be

[1] The aircraft maintenance experts at LHT have developed the term "snowball system".

allowed to affect the quality of the work. They place great value on safety during work performance and work highly professionally. The experts' activities take place in both the real and the reference field of action. In summary, it was found that knowledge work in aircraft maintenance at LHT presents itself in the primary criteria of novelty, complexity and the double field of action. A clear definition of the knowledge work of mechanics and avionics experts at Lufthansa Technik AG can be undertaken. Hube's portfolio describing different types of knowledge work is drawn on for this purpose. Mechanics and avionics experts at Lufthansa Technik AG perform original knowledge work/knowledge work as a profession.

3.5 Results of second research question

The aircraft maintenance experts at Lufthansa Technik AG describe and experience knowledge work not only through the parameters introduced in research question one, but especially through alternation between fields of action and through a large information burden. Work processes are characterised by alternation between the reference and the real field of action. It was found that experts always switch their field of action when they encounter an unexpected problem for which they need more information whilst executing a task. The organisation and acquisition of the required information are a crucial part of knowledge work. It constitutes the bulk of the experts' work and creates orientation in the reference field of action. This in turn is crucial to further planning of a course of action in the work process and therefore for the generation of a work result in the real field of action.

Overall, it was found that the experts speak about organisational, planning and preparatory activities in the reference field of action far more frequently in interviews than of activities in the real field of action. When the activities mentioned in the interviews are divided among the two fields of action, 93% fall into the reference field.

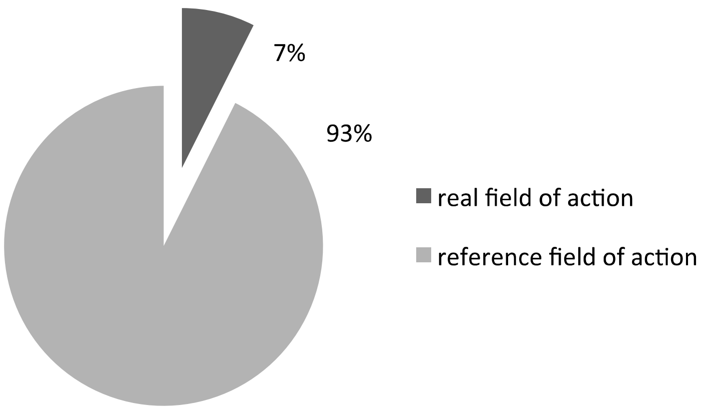

Figure 3: Assignment of activities to real/reference field of action

A closer look at these assignments shows that only 6% of the activities described by the experts fall into the real field; these are divided into orientation (3%), planning (2%) and feedback (1%). One reason why the experts say little about activities that fall under feedback in the real field of action may be the double check that is usual in aircraft maintenance. This is generally performed not by the person carrying out the work, but by a colleague. 9% of the reported activities are execution, such as obtaining tools, performing work on the aircraft or work documentation. At 76%, most of the activities named in interviews fall under orientation in the reference field of action. Activities that involve feedback in the reference field constitute 7%.

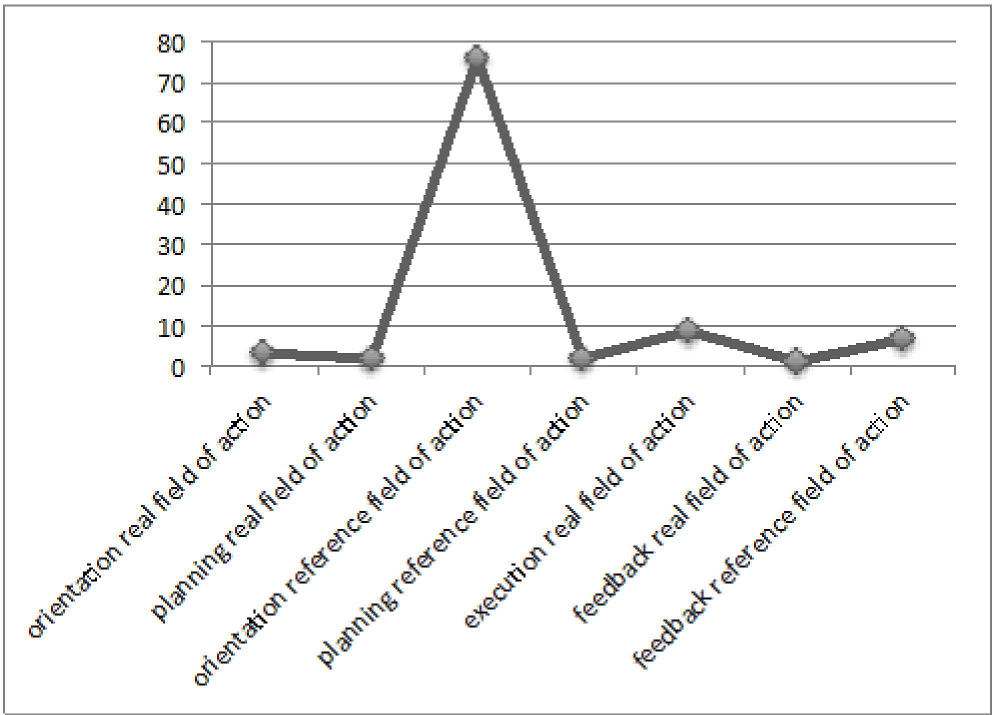

Figure 4: Assignment of activities within the fields of action

The work in the reference field of action is of greater importance to the generation of the real result. Information acquisition is the key activity in orientation in the reference field, even if some experts feel that these activities do not belong to their actual work tasks. This in turn contradicts the fact that almost all experts estimate the importance of new knowledge to the performance of their tasks to be very high. One solution could be to emphasise the importance of learning and continuing education in aircraft maintenance and the connection between appropriation of new information and performance of the desired occupation as early as during training; Section 4 addresses this in more detail.

The experts access diverse information systems independently. They independently plan their information acquisition into work processes. They try to solve problems that arise independently and, if this is not possible, discuss them with colleagues. Easily processed information that can be absorbed without additional research work is important for a smooth work process – just as much as functioning technology. Interruptions have a negative effect on work flow and represent high potential for frustration. Both hardware and software must contribute to the experts' ability to access information quickly and smoothly. However, the interview partners see potential for optimisation on these points. The quantity of information is perceived as voluminous and increasing; this is contingent on the fact that aircraft and components are becoming more and more complex. The proportion of knowledge work in the activities of LHT's mechanics and avionics experts will continue to increase in the future. The ability to select relevant from irrelevant information is already now seen as "essential for survival." This is not always easy, since the special environment of aircraft maintenance sometimes makes it difficult for experts to decide whether a piece of information about safety might become of significance later on. For this reason, many experts try to acquire all possible information, which can lead to a high workload and to overextension. In addition, deciding between executive activities in the real field of action and reference field activities sometimes represents a conflict for experts. If they spend time on acquiring information, they lose time for generating the real work result. However, without information acquisition, the most recent safety-relevant information will not be taken into account in the executive activities, which is insupportable in aircraft maintenance. Many experts therefore develop their own strategy for efficient information acquisition. However, such a personal strategy can constitute a safety risk, especially when it comes to procedural short cuts. This highlights the importance of an information management system that meets the needs of aircraft maintenance experts. For some experts, only their work on the aircraft/the generation of the real result is decisive in their assessment of their own performance. For some interviewees, it is also easier, less taxing and more enjoyable. However, the majority of the experts sees information acquisition as an important and necessary part of their profession or at least as an unavoidable help in the work.

Overall, the interviews reflect an image of professionally interested, motivated, engaged and responsible employees. The term knowledge work is mostly not familiar to the experts, but in key points their work resembles that of a typical knowledge worker as described in the theory.

4 Consequences for practice

Concrete conclusions for the practice of aircraft maintenance at Lufthansa Technik AG can be derived from the study results. To perform their work, mechanics and avionics experts require permanent access to confirmed and approved information. This information should be available to workers directly and without bureaucracy and should be easy to locate. This requires easily accessible, comprehensible and self-explanatory information systems that can be accessed permanently and regardless of location. Use of mobile end devices allows such access to the necessary information. In the best case, the device is personalised and tailored to the worker's individual needs when it comes to screen size and keyboard (laptop, tablet, mobile phone). Exchange within the team is one of the most used means of acquiring and passing on information for aircraft maintenance employees at LHT. These communication and co-operation structures must be reliable. Safety-relevant information must e.g. additionally be addressed in team dialogue by the foreman and supervisor. It is crucial to ensure that this information reaches every worker. In regard to the increase in quantity of information, work sections should be clearly defined and comprehensible to workers. Assignments must be clearly and unambiguously formulated and communicated. The experts also need a workplace that supports alternating between the real and the reference field of action. For knowledge acquisition (such as reading a training document), quiet and bright premises that are separate from the thoroughfares of the maintenance halls should be set up.

This will also strengthen employees' perception of the importance of the crucial part of their work performance in the reference field of action. Orienting and planning activities would be given space.

In regard to continuing training and education of staff, the following conclusions can be drawn from the results: aircraft and their components are becoming more and more complex. The complexity of work in aircraft maintenance is rising accordingly, resulting in an increase of information. Knowledge work is therefore becoming an ever larger part of aircraft maintenance. Workers perceive the quantity of information as increasing and in some cases as a burden. Co-operation with mentors or coaches is therefore advisable. If problems that influence performance arise, the employee has a contact to turn to. This may be e.g. lack of information flow or a high workload resulting from the quantity of information to be processed. Foremen and supervisors are already contacts for the experts for a variety of problems. If workload permits, they can be trained further in this direction by staff development measures.

In addition, employee awareness of the importance of their work in the reference field of action when it comes to the real work result is in need of improvement. Acknowledgement or appreciation by a supervisor or manager of employees' orienting and planning activities in the reference field of action can already have positive effects. To improve awareness of the importance of reference field activities in the long term, however, it is necessary to create a link between work in the real field of action and the knowledge acquisition necessary to do this work during training. Trainees should be aware that their desired profession orienting and planning activities must in large part be performed independently and in addition to the technical activities on the aircraft. Workers must grapple with a vast quantity of information that must be found in different information systems. Learning/permanent continuing education accompanies employees beyond their training and throughout their entire professional life. Support measures for finding individual learning strategies thus constitute assistance for PD-MTC knowledge workers. They can be integrated into existing training and continuing education measures. Likewise, the procedure for organisation and processing of information relevant to work completion should be a fixed part of training. This includes e.g. training employees to use information systems. Integrating training modules on team skills is also advisable. Along with communication of theory, a crucial aspect here is also practice in and reflection of communication, discussion and problem-solving skills (e.g. dealing with misunderstandings, constructive feedback, getting to know the problem-solving stages of project work/the work process and team development). All training and continuing education should be practice-oriented and furthermore oriented towards the particular worker's field of activity.

The proportion of work in the reference field of action and in knowledge work is rising with the increasing complexity of aircraft and their components. The quantity of information that workers must process is rising accordingly.

If the stated recommendations are followed, they can lead to a qualitative improvement in the knowledge work of mechanics and avionics experts at Lufthansa Technik AG.

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Zitieren dieses Beitrages:

Sobbe, E., Tenberg, R., Mayer, H. (2016): Knowledge work in aircraft maintenance. Journal of Technical Education (JOTED), Jg. 4 (Heft 1), S. 81-97.