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Competence Retention for Non-Routine-Situations in Digital Working Environments (Condition): Studies Based on the Professions of Chemical Technician and Pharmaceutical Technician

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Abstract

Automation related skill decay and its consequences for the quality of professional work was widely being researched in high-risk industries, but no empirical studies concerning process-oriented industries have been conducted so far. The study CONDITION therefore investigated whether the problem of automation-induced skill decay also exists in the workplaces of the chemical and pharmaceutical production. Moreover, we wanted to find out which competences are affected, which factors influence the skill decay and what are the consequences. To answer the research questions a mixed methods approach was used. We started with a systematic literature analysis which was followed by 21 qualitative interviews and an online survey with 210 participants.

We found out that the problem of automation-related skill decay also exists at the workplaces of the chemical and pharmaceutical production. The consequences are mostly economical, but in some incidents also the workers in the plant could be affected. Moreover, we identified some essential competences to master these situations successfully such as process-knowledge, knowledge of the actual plant, the skill to operate the plant by hand and an attitude of calmness and curiosity. To acquire these competences, it is necessary to experience the actual plant. This leads to the conclusion that the problem of automation-related skill decay certainly will become bigger because opportunities for young professionals to experience the actual plant get less since from the very first day they mostly work in a highly digitized and highly automated environment.

Keywords

competence, skill decay, digitization, automation, non-routine-situation

1 Introduction

During the last 10-15 years numerous studies have been carried out to identify and examine new competences that are required for the ongoing digitization of workplaces (acatech, 2016; Hammermann & Stettes, 2016; Schmidt et al., 2016). In contrast, only a few studies (Frank & Kluge, 2018; Webb & Angel, 2018) have dealt with the question of how to maintain existing competences that are still needed, especially in non-routine-situations (NRS). These competences differ remarkably from the competences that are used in the everyday routine at highly digitized workplaces. During NRS skilled workers have to mobilize a wealth of

knowledge and skills ad hoc in order to make decisions quickly and competently. Weyer (1997, p. 245) states for example that in these NRS it is necessary to interpret deviating values, to diagnose the cause of the malfunction in the shortest possible time and to take manual countermeasures in order to avoid a crisis-like escalation.

Because this special knowledge and skills are often not required for longer periods due to automation1, they are exposed to the danger of being forgotten or no longer being able to be activated (quickly enough) (Bjork & Bjork, 2006). This problem, technically referred to as skill decay was already being researched in high-risk industries or high-risk employments such as aviation (Wiener & Curry, 1980), military (O'Hara, 1990) or police (Angel et al., 2012), but no empirical studies concerning process-oriented industries such as chemical or pharmaceutical production have been conducted so far.

CONDITION aims to close this gap by addressing the question if the problem of automation-induced skill decay also exists in the workplaces of the chemical and pharmaceutical production as an example of the process-oriented industry. Furthermore, we wanted to find out in what way this decay applies to the occupational activities of chemical technician and pharmaceutical technician (which competences are affected, which factors influence the skill decay and what are the consequences of it).

2 Methodology

The research questions of the project were addressed using a mixed methods approach. First, we carried out a systematic literature analysis. The aim of this analysis was to check to what extend the research question of the project has already been dealt with in exactly the same or in a slightly modified way and to survey the current state of research in the field of skill decay in order to identify the main influencing factors, which should then, also be taken into account in our own surveys.

The systematic literature analysis was followed by the empirical collection of qualitative data. A total of 21 telephone interviews were conducted with professionals and supervisors. The interviews were semi-structured. The average time of the conversations was 30 minutes. The interviews were conducted by telephone, recorded, transcribed and evaluated using the content analysis according to Mayring (2022). The codes used were formed in a first step on the basis of the outcomes of the literature analyses which led to relevant factors concerning the loss of competence and were supplemented in a second step by codes inductively generated from the source material.

Based on the data from the qualitative interviews, an online questionnaire was developed in a further step. It was aimed at skilled workers (usually chemical and pharmaceutical technicians), supervisors and managers in the chemical and pharmaceutical production. The aim was to investigate the extent to which the findings of the interviews could also be confirmed within a larger group of skilled workers.

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[1] Talking about digitization and automation it is necessary to make clear that these are different topics which are nevertheless closely related. A comprehensive distinction is made by Schumacher, A., Sihn, W., & Erol, S. (2016b) which analyze the terms digitization and automation trying to understand about differences and common ground. They describe digitization as "(…) the conversion of continuous analog, noisy and smoothly varying information into clear bits of 1s and 0s," and stated that automation "Describes the implementation of technology, software and programs to accomplish a procedural outcome with little or no human interference". Moreover they make clear, that "(…) one cannot exist without the other as any kind of automation nowadays requires digital elements to work without human interference and any kind of digitization requires elements to automatically handle and display information. Therefore, research focusing on advanced or smart manufacturing has to include both concepts to allow for a comprehensive analysis." This is what we did in our investigation. When talking about automation we always imply digitization as the base Schumacher, A., Sihn, W., & Erol, S. (2016a) for it.

The general themes of the questionnaire were:

1. General data of the participants and their workplace
    - professional position
    - size of the enterprise/company
    - sector
    - plants serviced
    - work experience
    - degrees
    - age
2. Data about occurrence of (problematic) situations
    - non-routine situations (NRS)
    - reaction to the occurrence of a NRS
    - relevance and recall of knowledge/skills when a NRS occurs
    - relevance of different personal characteristics when a NRS occurs
    - possible consequences of the occurrence of NRS
3. Existing and wished support in (problematic) situations
    - general possibilities of support
    - training in particular

The original target of 700 participants was not reached. The difficulty due to the pandemic in establishing personal contacts in advance certainly played a role. The questionnaire was completed 210 times, with 50 professionals and 160 managers participating, with over 80% of the latter having been trained in chemistry or pharmacy.

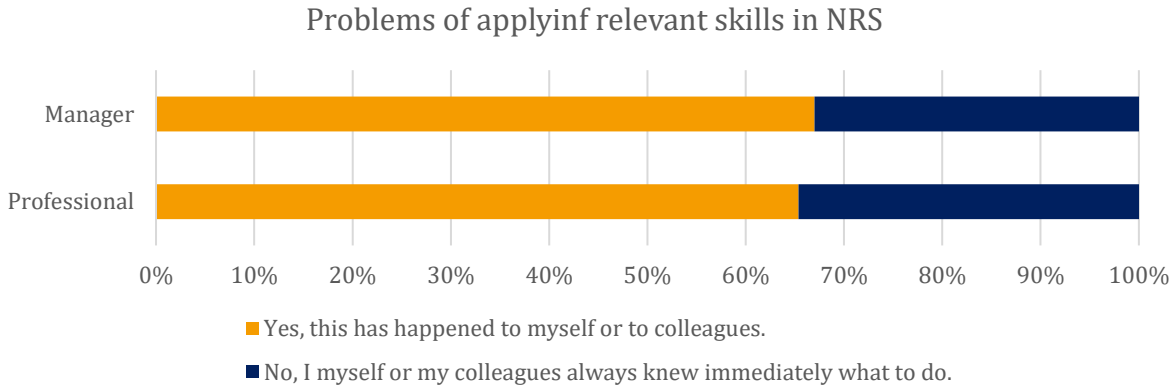
3 Results

3.1 Automation-related skill decay

We found strong evidence that automation-related skill decay also exists at the workplaces of the chemical and pharmaceutical production. Firstly, already on the basis of the data from the qualitative interviews we could see that NRS occur also at the respective workplaces. Moreover, we were able to distinguish three types of NRS: the frequent but unplanned NRS, the rare but planned NRS and the rare and unplanned NRS. Out of the three only the latter appeared relevant for our specific interest since it seems less likely that skill decay plays a role in frequent or planned NRS. The results from the online survey confirmed the data from the interviews. We asked professionals and managers whether one (or more) of the three types of NRS occur in their everyday work. Only 3% (managers) and 2% (professionals) of the respondents respectively stated that they did not experience any non-routine situations in their everyday work. 50% were aware of rare unplanned NRS and more than 60% confirmed that they experienced the other two types.

Secondly, we were able to establish that in this NRS a relevant proportion of the employees (67% of the managers and 65% of the professionals, see figure 1), who had previously reported that rare, unplanned non-routine situations occur in their daily work, stated that they or their colleagues or employees sometime do not immediately know what to do and therefore experience a lack of competences.

Figure 1
Results from the question: „In the past, have you or a colleague ever been in a rare non-routine situation where you or a colleague did not immediately know what to do?“ Managers n=80, Professionals n=26



Thirdly, we could determine that the reason for the loss of competence is to be found due to a largely automated environment. Already the data from the interviews contain statements that support this hypothesis:

“I think it would certainly be good if we were to say in some places, take the process by hand and run it. I don't think the employees could do that anymore. I don't think they would be able to cope with all the temperatures, (...) they are basically dependent on the system, because the automated system can do that. And I'm convinced that it will be difficult if things actually get out of hand, and experience shows that they don't do the right thing” (Manager).

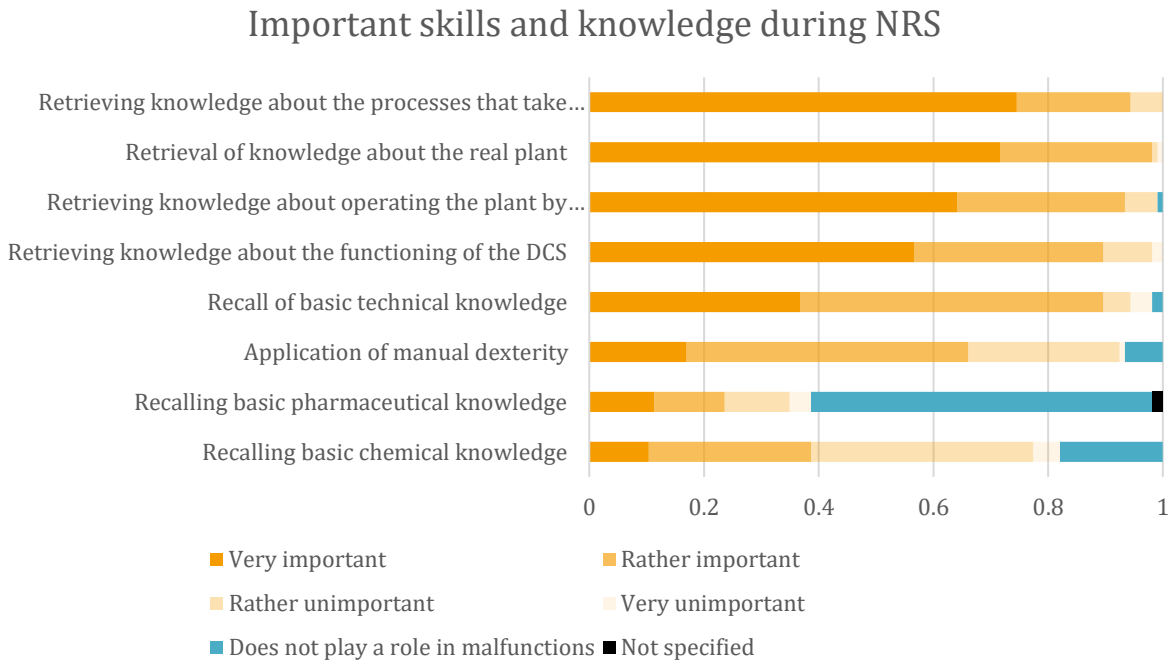
In the online-questionnaire the respondents who stated that they had experienced loss of competences for NRS or saw this in their colleagues or co-workers were asked to identify the reasons for this by rating five possible statements. The results show that forgetting knowledge due to the automation of the systems is named as the main reason for the difficulties in recalling the knowledge and skills relevant in the NRS with more than 75% agreeing strongly or rather strong to the statement: “Due to the automation of the system certain knowledge and skills are no longer needed and are forgotten”.

In conclusion it can be said that there is empirical evidence of an experienced automation-related loss of competence in the workplaces of the chemical and pharmaceutical production, which prevents or hinders the retrieval of the relevant competences in rare and unplanned non-routine situations.

3.2 Competences

Competences consist in our understanding, according to the German Qualification Framework (Arbeitskreis Deutscher Qualifikationsrahmen, 2011), of knowledge, skills and attitudes. Concerning the relevant competences, the retrieval of knowledge about the actual plant, its dimensions and processes that take place as well as the skill to operate the plant by hand (e.g. with no or limited support from the process control system) are reported as most important to handle NRS. More than 90% of the respondents rated these three as very important or rather important (see figure 2).

Figure 2
Results from the question: „Imagine that you or your colleagues are confronted with such a non-routine situation at your current workplace. What is important or unimportant and what is easy or difficult for you or your colleagues in this situation?“ n=106



Attitudes were also seen as particularly relevant in the interviews. On the one hand, they are relevant in the non-routine situations themselves. Attitudes named as beneficial are calmness, composure but also courage. These attitudes support the reliable retrieval of the relevant knowledge and skills. On the other hand, in the run-up to the non-routine situation, an attitude of curiosity and interest in the plant and the processes taking place in it are necessary in order to develop a deeper understanding of the process. Here, the attitude conditions and supports the acquisition of competence.

3.3 Influencing factors

A large number of possible factors influencing the loss of competence could be identified in the literature analyses but within the framework of this research project, not all of them could be comprehensively investigated. According to Bryant & Angel (2000) they can be divided into:

- factors that are rooted in the individual, e.g. previous experience, intelligence, attitude,
- factors inherent in the characteristics of the work task such as cognitive vs. physical task or simple vs. complex tasks,
- factors related to the nature of the original instruction or training, such as the degree of structuring and
- factors that are rooted in the retention interval, i.e. the period between the acquisition of a competence and the current use of a competence, such as the length of the period or opportunities for refreshment within the interval.

In the interviews, mainly factors that are rooted in the individual were addressed. Therefore, in the online survey, we asked to evaluate different personal factors with regard to their relevance for coping with NRS.

It turns out that especially professionally experienced and calm colleagues are trusted to successfully cope with NRS. The reason for this is, on the one hand, that their experience gives

them the relevant competences to cope with NRS. On the other hand, this very experience also leads to them being calmer and more relaxed in the situations (the influencing factor that receives the second highest level of agreement), which in turn enables more reliable competence retrieval.

Thus, experience is on the one hand a cause for the existence of relevant competences and on the other hand also a support for the use of these competences in the NRS.

The experiences that lead to competent action in NRS are, according to the statements from the interviews, experiences that are made with all senses. Not only information is taken in with the eyes or manual activities are carried out, but also smells, sounds and even vibrations are added to the wealth of experience from which experiential knowledge is fed.

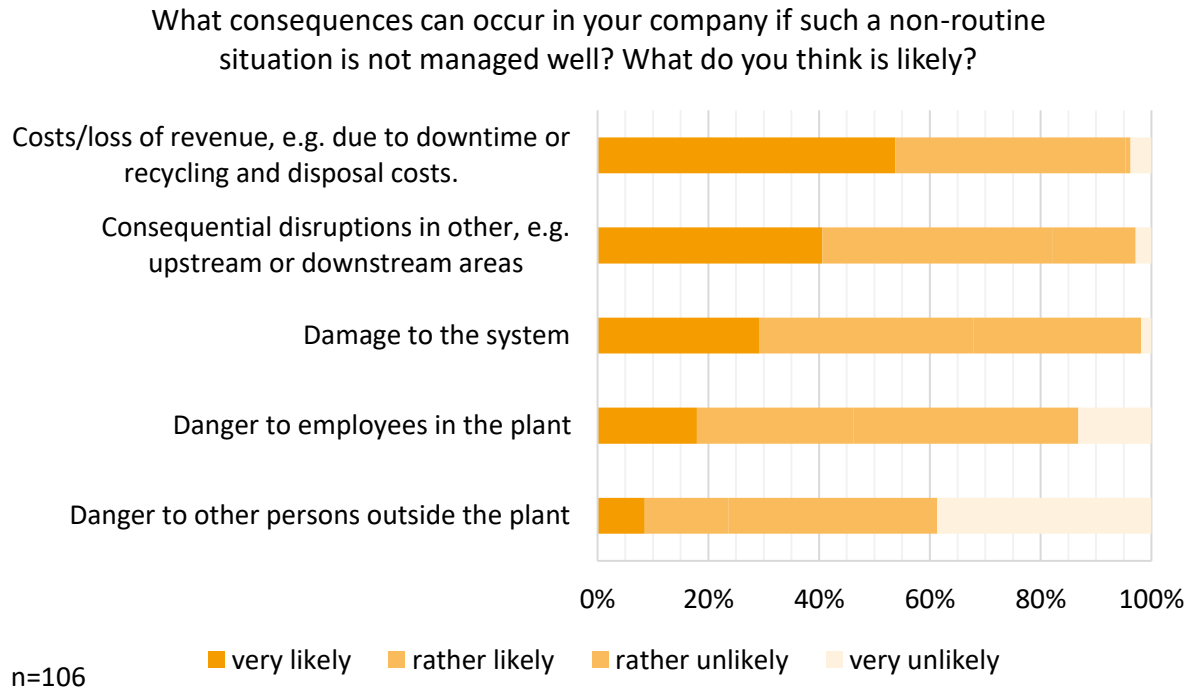
"In the past, when the plant was started up, I went outside and it was running visually well inside, and then I walked around outside and it wasn't just a matter of walking around and looking to see if something was splashing around or something, but you go into the plant and it's like a concert. Every piece of equipment makes its sound and the whole system is like a concert, so everyone plays their part. And if one plays wrong, this wrong tone, you have to hear it." (Professional)

3.4 Consequences

Difficulties in coping with unplanned, infrequent NRS can have (far-reaching) consequences. Participants in the survey were asked to rate the likelihood of such consequences occurring on a 4-point scale from "very likely" to "very unlikely". The most probable consequences were costs or loss of income (see figure 3). Almost all participants (95%) stated that they considered these consequences to be rather or very probable. In contrast to the high-risk-industry, where the problem of automation-related skill decay has been investigated since years, the risk to persons inside or outside the company was rated as not so likely. But still nearly one fifth saw a danger for people in the plant as a consequence of an unresolved NRS.

Figure 3

Results from the question: “What are the possible consequences in your company if such a non-routine situation is not managed well? What do you think is likely?” n=106



4 Conclusion

Our research could establish that the problem of automation-related skill decay also exists in the process-oriented industry. The consequences are above all material and monetary but sometimes also persons are at risk. As our investigation was the first in this field, further research is necessary to concretize our first results and also to get a better idea about the quantitative dimension of the problem.

We were able to identify several relevant competences that are necessary to handle NRS and moreover we learnt that these competences are prone to decay. The crucial influencing factor for the acquisition and retention of these competences is a special kind of experience that is made with all senses in the real plant.

This leads to our final assumption that the problem of automation-related skill decay certainly will become bigger and is not only about the individual but also about the whole staff. Because nowadays young professionals from the very first day mostly work in a highly automated environment that does not allow them make the necessary experiences, they miss the opportunity to acquire the relevant competences they needed to handle NRS.

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Biographical note

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