Chapter 10
Human Fallibility and Learning from Errors at Work

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Human fallibility and learning from errors are issues that are receiving increasing attention in the field of professional learning and development. Ten years ago, however, there were virtually no studies on learning from errors in this field, though there is a long tradition of research on human fallibility and errors, as well as safety and error management (Frese & Zapf, 1994; Glendon, Clarke, & McKenna, 2006; Perrow, 1984; Rasmussen, 1987; Reason, 1990; Senders & Moray, 1991). More recent developments in this area focus, for example, on critical incident reporting (Barach & Small, 2000; Zhao & Olivera, 2006; cf. also Chap. 14 in this volume) or organizational learning (Argote & Todocara, 2007; Argyris & Schön, 1996; Sitkin, 1992; van Dyck, Baer, Frese, & Sonnentag, 2005). Whereas these lines of inquiry focus primarily on the organizational level, studies on individual learning from errors and its contribution to individual workers' professional development are still rare (Bauer & Mulder, 2008). So far, there is only limited evidence explaining *under which conditions* individuals can *learn what* from *which kind of errors* at work. One reason for this lack of knowledge about error-related learning processes is the huge variability of the types of errors and situations in which errors may occur (Bauer, 2008a; Bauer & Mulder, 2008).

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The goal of this chapter is to provide an overview of several studies on the questions raised above that have been conducted since 2002 at the University of Regensburg (Germany).[1] On the basis of current approaches of professional learning (Boshuizen, Bromme, & Gruber, 2004) and workplace learning (Bauer & Gruber, 2007; Billett, 2004; Tynjälä, 2008), the studies investigated individual learning from errors and its relationship to the development of professional knowledge, skills, and expertise. In this respect, our studies differ from the other lines of inquiry mentioned above, which focus on organizational safety and error management as well as organizational learning. Nevertheless, our findings contribute to these fields of research, because organizational development strategies cannot be implemented without considering individual processes of learning and competence development (Edmondson, 2004).

More specifically, the present chapter addresses the following questions concerning human fallibility and learning from errors at work:

1. How can errors at work be conceptualized from a scientific point of view? How do practitioners in work organizations interpret errors?
2. How can the *process* of learning from errors be conceptualized and empirically investigated?
3. How can the *outcomes* of learning from errors be conceptualized and empirically investigated?
4. What are the individual and contextual conditions for learning from errors at work?

By integrating theoretical frameworks and findings from several studies on these issues, this chapter contributes to advancing our understanding of learning from errors in the workplace and provides a basis for continuing studies on this emerging issue in research on professional learning. The remainder of the chapter is organized along the four stated questions. In the conclusion, we discuss consequences for organizational practice.

Errors at Work

Drawing upon cognitive and action-oriented approaches to human error, errors can be conceptualized and understood as individual actions or decisions that result in a deficient deviation from a desired goal and that endanger the attainment of dependent goals (Bauer, 2004, 2008b; Frese & Zapf, 1994; Rasmussen, 1987; Reason, 1990; Senders & Moray, 1991; Zhao & Olivera, 2006). This definition, firstly, implies a hierarchical theory of human action. Action theory proposes that yielding complex

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goals – such as healing a patient – depends on the attainment of a hierarchical network of related goals and sub-goals (Frese & Zapf, 1994; Leontiev, 1978). Secondly, deviation from such a goal is attributed to the actions of an actor who is assumed to have sufficient skill and knowledge to perform the task, and it occurs contrary to his or her expectations and intentions (Senders & Moray, 1991). Errors can thereby be distinguished from failure caused by a simple lack of knowledge, from accidents and from deliberate violations (Wehner, Mehl, & Diekmann, 2010). Finally, judging an action to be an error is performed by referring to normative criteria that relate to the desired goal (Heid, 1999; Hughes, 1951; Rasmussen, 1987; Senders & Moray, 1991). Therefore, 'error' is not an objective characteristic describing an action or its result. 'Error' is an evaluative term of language that is used by a beholder on the basis of a comparison between an observed state and a normative anticipation, in order to express a deficient discrepancy between the two (cf. Billett in this volume).

The norm-dependency of error judgments described above is the reason some authors believe that the concept of error is ambiguous and hard to operationalize for empirical research (Weingart, 2008). However, norm-dependency is no unique problem of the concept of error, but a general problem of concepts that specify a quality of human action, such as 'creativity' (Csikszentmihalyi, 1999) or 'superior expert performance' (Ericsson, Charness, Feltovich, & Hoffman, 2006). Bauer (2008a) argued, in analogy to a systems-perspective on creativity (Csikszentmihalyi, 1999), that an action can be evaluated to be an error if (1) it is judged as a deficient deviation from an expected standard, (2) by knowledgeable and central members of a given occupation, organization, or local community of practice (Wenger, 1998), (3) at a given point of time. This perspective can be referred to as a social negotiation perspective on error judgments.

Taking the described social negotiation perspective allows analyses of different understandings of errors as well as of social discourses and power in error judgments (Heid, 1999). In an interview study that we conducted in several industrial and service enterprises, we found that the understandings of errors and the criteria for error judgments vary heavily, even within a single company (Harteis, Bauer, & Gruber, 2008; Harteis, Bauer, & Haltia, 2007; Harteis, Bauer, & Heid, 2006). In a first step of the study, we asked managers and staff members ($N = 28$) to provide examples of non-trivial errors that occurred in their daily work. Content analysis revealed a large heterogeneity in the described error situations (Harteis et al., 2007). Secondly, we prompted error situations and asked the participants whether the respective situation would count as an error in their organization. We observed high agreement (79–93%) for situations that concerned production and sales as well as for situations that potentially resulted in a risk for employees' health (Harteis et al., 2008). In contrast, there was considerable lower agreement for other situations that, for example, concerned social relationships at work (39–67%). We found no differences between managers and staff members in this respect.

These findings illustrate that a high level of agreement concerning criteria for error judgments should not be taken for granted. This has consequences for

organizational practice as well as for research on errors and learning from errors. Firstly, organizations should aim at the development of clear, socially agreed, and shared criteria for what constitutes an error in the context of specific tasks. Secondly, researchers should be aware that the understanding of error can vary strongly between them and study participants as well as among the participants. Just like organizations, researchers should not assume that participants have comparable notions of errors in mind, for example, when answering a questionnaire or interview questions. Therefore, a situated approach that anchors questions on errors in concrete error episodes seems to be advantageous to enhancing validity (Bauer, 2008b; Bauer & Mulder, 2011; Gartmeier, Bauer, Gruber, & Heid, 2010; Oser & Spychiger, 2005; Wehner & Mehl, 2008). Moreover, for studies on learning from errors, it seems particularly important to focus on errors that are arguably relevant to learning. Several scholars have argued that different types of errors vary in the learning potential they provide and that learning from them requires different types of activities (Bauer & Mulder, 2007; Glendon et al., 2006; Keith & Frese, 2005; Rybowiak, Garst, Frese, & Batinic, 1999). Typically, errors based on a higher level of cognitive action–regulation (Frese & Zapf, 1994; Rasmussen, 1987) are assumed to contain a higher potential for learning in terms of constructing knowledge from a cognitive re-evaluation of the experience. The rationale for this is that these errors potentially enable individuals to deliberately revise their knowledge and practice through the engagement in learning activities (Keith & Frese, 2005).

The Process of Learning from Errors: Engagement in Learning Activities

The concept of individual learning from errors implies the notion of an experience-based construction of knowledge that emerges from experiencing an error situation (Bauer & Gruber, 2007). Therefore, we contextualize our theoretical framework of learning from errors in theories of experiential learning and informal workplace learning (Billett, 2004; Boshuizen et al., 2004; Kolb, 1984; Kolodner, 1983; Tynjälä, 2008). Different perspectives of experiential learning theory are relevant here. We distinguish between a cognitive and an activity perspective, which serve different but complementary purposes for conceptualizing learning through errors at work. The cognitive perspective explains learning as the acquisition and improvement of knowledge and focuses on the memory and knowledge structures involved. Theories of case-based reasoning and the modification of scripts in dynamic memory (Kolodner, 1983; Schank, 1999) have provided models of how schematic, action-oriented knowledge structures (i.e., scripts) are extended and modified through reflecting on the experience of deviant episodes. Furthermore, this line of inquiry explains how the experience of errors may lead to improved performance and – in the long run – cognitive flexibility through the drawing of analogies to newly encountered episodes (i.e., case-based reasoning). As will be argued in the following section, the cognitive perspective is particularly relevant to the analysis of the

outcomes of learning from errors. In contrast, the activity perspective offers opportunities for understanding the process of learning from errors and for making it accessible for empirical research. This perspective will be elaborated in this section.

The activity perspective views learning as a self-organised effort to improve performance (Boshuizen et al., 2004). This perspective is useful in determining which activities are relevant in order to learn from an error. The theoretical basis of the activity perspective lies, firstly, in theories of experiential learning cycles (Gruber, 2001; Kolb, 1984) that model experiential learning as action–reflection–action cycles. These models have also been acknowledged in more recent work on organizational learning and management (Boshuizen et al., 2004; Glendon et al., 2006). Applied to learning from errors at work, an experiential learning cycle can be modeled to involve the engagement in learning activities regarding (1) reflection on the causes of an error, (2) the development of new or revised action strategies that aim to avoid the error in the future, and (3) experimenting with and implementing the new or revised strategies (Bauer & Mulder, 2007). Each of these activities can be performed individually or in social cooperation with others at work. There is some evidence to suggest that learning activities performed during social interactions with others at work (i.e., joint analysis of causes and the development of new action strategies) are particularly relevant to learning from errors (Edmondson, 2004). This appraisal is consistent with the emphasis on the role of social exchange in recent research on workplace learning (Billett, 2004; Eraut et al., 1998). Communication and exchange can foster the development of shared knowledge and understanding of errors, as well as of solutions and strategies with which to handle them (Cannon & Edmondson, 2001; van Dyck et al., 2005).

Modeling learning from errors by the described learning cycle has the advantage of addressing concrete learning behavior that can be measured in empirical studies. In contrast, asking workers about their learning seems disadvantageous, because people tend to respond using the notion of formal learning if they are asked about "learning" at work (Simons & Ruijters, 2004). A problem with the model is, however, that it is quite generic and needs to be contextualized to the requirements of a specific field. That is, the question of what concrete learning activities are relevant within a particular field of work has to be answered. We have addressed this question in several studies.

In the interview study discussed in the previous section, the participants were asked to describe the reactions to the error situation that they had previously described (Harteis et al., 2008). They also provided information on whether something was done to prevent similar errors in future and whether the error was documented in any way. Indeed, the majority of the participants described activities regarding reflection on the causes of the error (79%). In most of the cases, the error was documented (70%). In another, open-ended question, the subjects were asked to describe in more detail how the error was dealt with. Most of the answers fell into three categories. Firstly, the error was discussed with colleagues in order to analyze its probable causes and to derive conclusions for future acting. Secondly, new agreements, rules or work processes, which were supposed to be less prone to this type of

error, were negotiated. Finally, new control and prevention mechanisms were considered. Answers beyond these three categories concerned, for example, sensitizing co-workers to the error.

In interpreting these findings, it has to be acknowledged that the subjects referred to various error situations that are difficult to compare. It is reasonable to assume that the described error situations differ in their learning relevance. Nevertheless, the findings indicate that, as claimed in the model of error-related learning activities, reflection on potential causes of an error as well as the consideration of new strategies for future action could seem important for learning from errors in work practice. Moreover, these activities seem to be performed primarily through social interaction with colleagues. For organizational development initiatives, it can be concluded that the development of an organizational culture that supports a learning-oriented handling of errors is a major task (cf. Edmondson, 2004).

The findings discussed above could be corroborated in two more interview studies that were conducted in different contexts. In expert interviews in the domain of nursing, Bauer and Mulder (2007) elicited typical examples of knowledge- and rule-based errors, as well as relevant learning activities, for this field of work. In contrast to the earlier study (Harteis et al., 2008), the interviews focused on a specific type of error and related learning activities. The participants ($N = 10$) were identified as experts, based on their long professional experience, their supervisory position and peer-assessment as being highly qualified. Consistent with the model of learning activities and with the earlier findings, the study indicated the relevance of the engagement in systematic reflection on causes of an error as well as the development of new action strategies. Again, the role of social exchange was stressed as crucial for these learning activities.

Another interview study was conducted in cooperation with our colleague Petri Haltia from University of Turku in Finland (Harteis et al., 2007). The focus was on workers in a Finnish shipyard. As in the other studies, the participants emphasized the role of joint reflection and discussion of errors. However, the participants also described constraints for learning from errors through engagement in these learning activities. In particular, they indicated that (team) discussions about errors as well as the use of error reporting tools sometimes had only a superficial function and did not lead to learning. These statements illustrate that in order to learn from errors, in-depth reflection on root causes, results, and ways of prevention should be performed with the intention of changing the underlying causes of an error, rather than merely seeking a quick fix to an error situation (Edmondson, 2004).

Outcomes of Learning from Errors

This section addresses the question of how potential outcomes of learning from errors at work can be conceptualized theoretically and operationalized for empirical research. Above, the case has been made that the cognitive perspective on experiential learning is helpful for this purpose (Bauer, 2008b). This cognitive perspective

explains learning as the acquisition and improvement of knowledge through experiencing personally relevant episodes and focuses on the memory and knowledge structures involved. Therefore, this perspective allows for the modeling of cognitive processes and the representation of the outcomes of learning from errors (Bauer, 2008b; Bauer & Gruber, 2007; Gruber, 2001). In particular, theories of case-based reasoning and the modification of scripts in dynamic memory (Kolodner, 1983; Schank, 1999; Schank & Abelson, 1977) have provided models of how schematic, action-oriented knowledge structures (i.e., scripts) are extended and modified through reflecting on the experience of deviant episodes, including errors. Through reflecting on the causes of an error episode, an underlying script can be enriched by an additional part (i.e., an *index*) that distinguishes the deviant parts from the expected ones. The index assists the actor to remember the deviant episode in recurrences of similar situations and to choose alternative action strategies (i.e., case-based reasoning). Hence, the cognitive perspective explains how the experience of errors may lead to improved performance and – in the long run – cognitive flexibility through drawing analogies to newly encountered episodes.

Gartmeier, Bauer, Gruber, and Heid (2008) elaborated on parallels between the model of indicated scripts (Kolodner, 1983) and the theory of *negative knowledge* (Oser & Spychiger, 2005; cf. Minsky, 1994), which comes from an educational–didactical background. The term 'negative knowledge' denotes knowledge about conditions for errors in specific action sequences (procedural aspect) as well as inadequate assumptions concerning a specific context (declarative aspect). Oser and Spychiger (2005) assume that negative knowledge is acquired through learning from errors and helps to avoid similar errors in similar situations. Hence, as in Kolodner's (1983) model, knowledge about relevant errors in specific task episodes is considered helpful for avoiding errors and choosing a promising course of action.

One relevant yet open question is: how is it possible to empirically assess the described knowledge resulting from error-related learning? To address this question, we conducted a study in the context of elder care nursing. Employees ($N = 37$) working in this field with a professional experience of between 0 and 30 years were confronted with 20 nursing and medical diagnoses of varying typicality (e.g., dementia, diabetes, social isolation, parental role conflict). With every diagnosis, two questions were posed: *What do you think you should pay special attention to in interaction with elderly people with the following diagnosis? What should be avoided?* The verbal protocols resulting from the subjects' reflection upon the questions posed were content analyzed (Gartmeier, Gruber, & Heid, 2010). The aim of this study was to identify the elder care nurses' knowledge about error-enabling conditions and situations in which errors typically occur. Drawing upon the theoretical differentiation between declarative and procedural negative knowledge (Oser & Spychiger, 2005), we investigated the question of whether these facets of negative knowledge could be traced and illustrated in a context-specific way. Moreover, the explorative task of identifying hitherto undescribed forms of negative knowledge was also pursued.

The results showed facets of declarative as well as procedural negative knowledge, while self-reflective as well as vicarious negative knowledge could be identified.

In the latter facet, the care expressed their knowledge about limitations the older people they work with possess on various levels (Gartmeier, Gruber, et al. 2010). The latter two forms of negative knowledge are particularly interesting in the context of elder care nursing. In their statements of self-reflective negative knowledge, the elder care nurses described limitations on the level of their own professional competence and professional role in the provision of care. For instance, they described their limited influence on the progression of certain diseases as well as the limitations of their own area of responsibility for certain work tasks (in delineation of, e.g., the responsibilities of physicians). This category additionally comprises statements in which the study participants described deficient aspects or lack of their own professional knowledge or skills (Parviainen & Eriksson, 2006).

As was already foreshadowed, the study subjects took the perspectives of the older persons they worked with in their statements of vicarious negative knowledge. They described limitations on the level of their abilities (knowledge about what somebody is not able to do, e.g., activities which are inappropriate for certain persons) and recognition (knowledge about what somebody does not recognize or understand, e.g., nursing home residents suffering from dementia and wrongly perceiving certain aspects of reality and "live in their own world").

In addition to the description and categorization of these facets of negative knowledge, Gartmeier, Gruber, et al. (2010) investigated relationships between these facets and different error types as described in the relevant literature. The elder care nurses benefit from their vicarious negative knowledge in their ability to avoid errors on the level of interpersonal relationships to the nursing home residents. Here, the category of *errors on the level of interpersonal relationships* described by Bauer (2008b), such as not confusing or causing nursing home residents to be taken aback, is relevant.

In another analysis of the same data, Gartmeier, Lehtinen, Gruber, and Heid (2010) investigated various degrees of specificity in the elder care nurses' negative knowledge. This research perspective was focused on due to the assumption that a person's ability to avoid errors based on negative knowledge improves along with the specificity with which negative knowledge can be applied to situations at work. Global statements of negative knowledge ("no two persons are the same") were differentiated from diagnosis specific ("don't over-challenge persons suffering from dementia") and further specified statements ("if you bathe persons with cardiac insufficiency, take care that the water in the tub is only lukewarm"), which often had a strongly situational focus. The comparison of different groups of professional experience (0–3, 4–9, and 10 and more years) showed a superiority of the group with the highest professional experience concerning the degree to which highly specified negative knowledge was expressed (Gartmeier, Lehtinen, et al. 2010). This result supports the assumption that error-specific experiential knowledge emerges through the encountering of relevant episodes at work and is further differentiated in the course of increased professional experience. In this process, it also becomes relevant for a wider range of situations. Furthermore, the results of this study underline that a focus upon specific error-cases and situations is a promising perspective for research on (learning from) errors at work.

Conditions for Learning from Errors

In the previous sections, we have conceptualized learning from errors as the engagement in error-related learning activities. The engagement in these activities is assumed to lead to the learning outcomes in terms of the modification of scripts in dynamic memory. The conditions under which individual workers engage in these activities have, however, so far been neglected. There are many open questions regarding individual differences in learning from errors as well as the predictors for the engagement in error-related learning activities. Like any other form of learning that takes place within a work context, engagement in learning after errors has to be understood as being dependent on characteristics of both the individual learner and the work context (Billett, 2004). In particular, engagement in social learning activities after an error cannot be taken for granted because it involves admitting the error to others (Edmondson, 1999). Therefore, studies on how individual workers interpret errors, how they can constructively use errors at work for learning, and what role the social environment of the workplace plays in supporting or inhibiting learning are required. Such studies could improve our understanding of how learning from errors contributes to the development of skilled performance within professional contexts. Furthermore, they are of practical relevance to, for example, the development of organizational programs that aim at fostering learning from errors (Aspden, Corrigan, Wolcott, & Erickson, 2004; Glendon et al., 2006).

Bauer and Mulder (2011) investigated conditions for the engagement in social learning activities after errors in the nursing profession. The study aimed at analyzing the role of variables that have been hypothesized to have an impact on learning from errors, namely the cognitive, emotional, and motivational interpretations of an error situation, as well as the perception of a trustful and psychologically-safe social climate among colleagues (Arndt, 1996; Bauer & Mulder, 2008; Edmondson, 1996; Meurier, Vincent, & Parmar, 1997; Tjosvold, Yu, & Hui, 2004; Tucker & Edmondson, 2003). The type of error focused on was the misinterpretation of a nursing situation and the subsequent making of a wrong decision. In the study, a sample of nurses ($N = 276$) completed a questionnaire. The questionnaire started by presenting three vignettes of error cases that related to the above-mentioned type of error and had been developed from an expert interview study on typical errors in nursing (Bauer & Mulder, 2007). The vignettes concerned (1) the misinterpretation of values on a medical instrument, (2) the misjudgment of complications, and (3) the misjudgment of the risk of bedsores. The nurses were asked to choose one of the vignettes and imagine the situation vividly, and to then rate whether they would engage in joint reflection with colleagues on potential causes of the error and the development of strategies to avoid similar errors in future (i.e., *engagement in social learning activities*). In the analyses, the hypotheses tested were that the engagement in social learning activities depends on the nurses' cognitive, motivational, and emotional interpretation of the error situation (Edmondson, 2004; Rybowiak et al., 1999; Zhao & Olivera, 2006). More precisely, this involves the estimation of the error situation as relevant to learning, the emotional strain evoked by the error, and the motivational

tendency to cover up the error. Furthermore, it was hypothesized that the engagement in social learning activities depends on the perception of a safe team climate, as measured by the perceived level of trust among the team members and the experience of a non-punitive handling of critical situations and errors within the team (Cannon & Edmondson, 2001; Edmondson, 1999; Harteis et al., 2007; Tjosvold, Yu, & Hui, 2004). These hypotheses were tested in a structural equation model that contained the mentioned variables as (correlated) predictors for the engagement in social learning activities.

As expected, the results indicated that the estimation of an error as relevant to learning (β = .28) and the tendency to cover up an error (β = −.33) are significant predictors for the engagement in social learning activities (R^2 = .29). In contrast, the expected relationships could not be found for emotional strain because of the error and for the perception of a safe team climate. However, there were large correlations between (1) the estimation of an error as relevant to learning and error strain, and (2) the tendency to cover the error and a safe team climate. That is, the errors were estimated as more relevant to learning when the participants perceived the situations as emotionally straining (r = .51). Moreover, the reported tendency to cover up an error was low if the participants rated their team climate as being trustful and safe (r = −.44).

The overall pattern of findings described indicates a potential mediation model as a hypothesis for further research that was tested in an exploratory analysis. The findings indicated, firstly, a significant indirect effect of emotional strain on the engagement in social learning activities (β = .18) that is mediated completely by the subjective learning relevance of the error situation. Secondly, an indirect effect of the perception of a safe team climate on the engagement in social learning activities could be found (β = .18) that is mediated completely by the tendency to cover up an error. These exploratory findings require cross-validation in an independent sample and, therefore, should be interpreted cautiously. However, they inspire the assumption that the emotional strain suffered as a consequence of having committed an error creates a subjective need to change the underlying causes and is, thus, indirectly related to engagement in social learning activities (Gruber, 2001; Oser & Spychiger, 2005). Furthermore, it may be hypothesized that a safe team climate reduces the tendency to cover up an error by mitigating perceived disadvantages that may prevent a nurse from communicating an error to colleagues (Edmondson, 1999).

The analyses described above can be considered *variable-centered* because they describe what variables potentially influence the engagement in social learning activities after errors at work. In a second step, these analyses were complemented by *person-centered* analysis that aimed at answering questions regarding how individuals differ in their interpretations of error situations and their engagement in learning activities after errors at work (Bauer & Mulder, 2011). In a latent profile analysis, four qualitatively different latent classes of nurses could be identified in respect to the investigated variables. Of these classes, only Class 1, comprising 58.8% of the sample, showed a clear orientation towards joint reflection and learning after errors. The mean values of this class on the engagement in social learning activities were highest in the sample. Moreover, these nurses rated their team climate as safe.

In contrast, the other latent classes were characterized by answer profiles that seem dysfunctional for learning from errors. The answer profile of the second-largest class (Class 2, 23.7%) indicated indifference regarding the error situation. Nurses in this class report the lowest mean values for all social learning activities as well as for the subjective learning relevance in the sample. Class 3 (13.8%) was characterized by a strong tendency to self-focus and emotional strain, and had the most negative team climate in the sample. This answer profile can be considered an at-risk profile, because it combines a psychologically unhealthy reaction to errors with insufficient social resources (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This combination may lead to a passive state of negative 'brooding' (i.e., *rumination*) rather than an orientation towards problem-solving, action, and learning after errors (Bauer & Mulder, 2007; Rybowiak et al., 1999). Finally, there was a small latent class of nurses (Class 4, 3.7%) who tended to seek social exchange with colleagues after errors, but without a clear learning-orientation. Presumably, talking with others about an error serves primarily as a form of social relief for these nurses, not as a catalyst for learning purposes. This finding is consistent with the results presented above, which indicate that discussions about errors only lead to learning when they are performed with an orientation towards critical inquiry (cf. Edmondson, 2004; Harteis et al., 2007).

In summary, the results of the study support the assumption that the interpretation of an error situation as a learning opportunity is important for the engagement in social learning activities after errors (Edmondson, 2004; Rybowiak et al., 1999; Zhao & Olivera, 2006). In contrast, as can be expected, the tendency to cover up errors because of feared repercussions seems to be an inhibiting factor. This pattern of findings is consistent with the assumption that communication about errors depends on a subjective cost–benefit balance (Zhao & Olivera, 2006). Moreover, the findings from the latent profile analysis provide support for the hypothesis that employees – nurses in the present case – have qualitatively different ways of interpreting and reacting to errors (Arndt, 1996; Harteis et al., 2008).

Conclusion

In this chapter, we have addressed four central questions concerning errors as a catalyst for learning, error-related learning activities and learning outcomes, as well as conditions for learning from errors at work. From our perspective, research on these four questions is crucial to advancing our understanding of how and under what conditions errors at work may contribute to improving knowledge, skills, and practice. From a practical perspective, our findings are largely consistent with current conceptions that aim at establishing a learning-oriented *error culture* in organizations (Glendon et al., 2006). They indicate that establishing such a culture requires a participatory strategy in which staff and management jointly negotiate common values and goals regarding errors, and common strategies for error prevention, error management, and learning from errors. However, as the results of the person-centered

analyses show, there seem to be different individual ways of reacting to errors that organizational development programs have to take into account.

We acknowledge the limited conclusiveness of many of our studies and findings due to their qualitative and exploratory nature. Therefore, their validity and generalizability should be scrutinized in further research. Particularly, the question concerning under what conditions the engagement in error-related learning leads to improvements in knowledge and practice is still open. Nevertheless, our studies can provide potentially useful theoretical conceptualizations and empirical approaches for future research on learning from errors in work contexts.

From our perspective, a great challenge for future research lies in the conducting of intervention studies that aim at fostering learning from errors in the contexts of professional education and work. Many of the existing studies have followed either descriptive approaches (aimed at providing descriptions of how errors are used for learning) or correlational ones (with the purpose of finding correlates regarding individual and contextual conditions for learning errors) (cf. Bauer, Mehl, & Wehner, 2010). More evidence is needed, however, on how learning from errors can be supported in various contexts. For this purpose, we suggest, firstly, that future studies focus on how learning the typical errors in one's field of work as well as elaboration on authentic error-cases can be included in professional education. This demand is consistent with studies showing the didactic value of including errors in training (Dick & Jacob, 2010; Große & Renkl, 2007; Keith & Frese, 2005). In some fields of work, training simulations that provide explicit opportunities to make errors in a safe context constitute a major element of professional learning (e.g., aviation; Helmreich, 2000). More evidence is needed regarding whether and how these approaches can be transferred to other fields of professional training and work.

Secondly, future studies should investigate how both educators and students can be supported to adequately manage occurring errors as well as to define and use them as learning opportunities (Keith & Frese, 2005). The focus on teachers, trainers, or mentors is crucial, because they are responsible for scaffolding error-related learning processes by, for example, guiding learners' reflection on the causes of errors and providing opportunities for deliberate practice that aims at improving learners' individual performance (Ericsson, Whyte, & Ward, 2007). So far, we have insufficient knowledge about how teachers are prepared to fulfill these tasks. Promising initial steps are currently being taken to assess and trainerror-related competencies of (vocational) teachers (Seifried & Wuttke, 2010).

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