Chapter 26
Learning from Errors at Work

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Abstract The manuscript discusses the issue learning from errors at work by starting from the fallibility of daily life. Errors are unavoidable, hence, employees and enterprises have to develop a way of dealing with errors which avoids their repetition. From a theoretical viewpoint a framework for the analysis of errors is developed which acknowledges psychological theories of acting. On this basis, opportunities for learning from errors can be discussed and connected to theories on workplace learning. Then, the state of empirical research on learning from errors at work is to be discussed. Finally, the manuscript ends with unsolved challenges for empirical field research.

Keywords Errors • Learning • Experience • Error culture • Action regulation • Negative knowledge

26.1 Introduction: The Fallibility of Daily Life

'By errors we learn' is a commonly used truism reflecting everyday experiences that demonstrate human fallibility. Undoubtedly, everyone remembers a time when computer software shows an error prompt on the screen and speculation begins on whether the input or the software has caused this error. The estimations of the time spent on computer tasks to handle and recover errors vary from study to study: Brodbeck et al. (1993) estimate it at 10 %, while others have calculated it to be up

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to 50 % (Hofmann and Frese 2011a, b) of the total working time in companies. Panko (1998) found that up to 40 % of spreadsheets used in enterprises contain incorrect figures, which warrant repeated modifications before they are error free. Overall, errors seem ubiquitous in work contexts. Before we turn to the issue of learning from errors at work, we will be discussing a few examples of different types of errors to illustrate their scope.

Insurance companies have a long-standing tradition of investigating error cases, and well-documented areas are, for example, high-security domains such as navigation, nuclear energy and aviation. Airplane accidents are intensively discussed in the related literature, because technology, for example, the black box and voice recording, allows their ex-post analysis. One of the most popular – and also the most tragic – aircraft accidents is the crash of two Boeing 747 jets at Tenerife airport in March 1977. Due to a bomb alarm at the neighbour airport at Gran Canaria, many airplanes had to land at Tenerife airport, leading to congestion. A PanAm aircraft was parked at one end of the runway. Bad weather conditions led to heavy fog at the airport, and the air control had only voice contact with the planes arriving and departing. A KLM jet was scheduled to depart and taxied to the end of the runway. During the starting routines (i.e. systems checks), the captain of the KLM jet believed that he had received permission to take off from the control tower; he started the jet and crashed into the parked PanAm jet. As investigations revealed, this accident was the result of a crew error, wherein the captain had misunderstood the message and the rest of the crew had not intervened. This incident stands as a showcase for many well-documented traffic accidents in which individual or collective failure has ended in tragedy. However, it is not always just individual or collective failure. Another well-known accident resulted from intentional and planned behaviour: the Chernobyl accident of April 1986. An entire group of highly specialised experts started a reactor test. This experiment aimed to test whether under conditions of a complete power blackout, the reactor energy would suffice to start emergency power units. Scientists and engineers with decades of experience followed a concrete plan, wherein they switched off the security systems intentionally, fully convinced that they could control the reactor manually (Medvedev 1991). However, since interventions to a complex system like a nuclear reactor have delayed and hidden effects, the engineers realised too late that a chain reaction had occurred, and the reactor was completely out of control. Thus, errors do not only occur if individuals or teams are inattentive, they also occur despite individuals or teams using their expertise. Further examples of large-scale accidents and the role of human error in them can be found in the seminal books by Perrow (1984) and Reason (1990).

The examples discussed so far indicate that errors can lead to tragic accidents, under different individual or collective conditions. However, since Darwin developed his theory of evolutionary development, we know that deviations are inevitable preconditions for evolutionary development. Hence, errors also can result in positive outcomes. The Bavarian pretzel is, at least as myth claims, the result of a simple mix-up by a Bavarian baker who dunked the pastry into a leach instead of an acid before baking. This led to the brown colouring and specific taste of the Bavarian pretzel.

All these examples indicate the fallibility of daily (working) life. There is no doubt that errors occur each day and that everybody makes errors, under various conditions. Errors may cause adverse effects but may also lead to favourable outcomes. However, it is questionable whether we really can learn from errors (Mehl and Wehner 2010). Most people find it difficult to admit errors and frankly deal with them. Further, compared to personal life, it is more complicated in the context of work, which usually follows the paradigm of efficiency. Hence, the question of what can be learnt from the kind of errors at work under certain preconditions is receiving increasing attention in educational and psychological research. Much of today's discussion about learning from errors through investigation of the causes of errors and development of modified action strategies has its roots in human factors research, accident research and research on risk-taking behaviour conducted in the 1980s and early 1990s (e.g. Frese and Zapf 1994; Perrow 1984; Rasmussen 1987; Reason 1990; Senders and Moray 1991; for an overview, see e.g. Keith and Frese 2008; Wehner et al. 2010). From the 1990s, research also focused the role of errors in learning in schools, in teams and at workplaces (for an overview see Bauer and Harteis 2012; Bauer and Mulder 2008). Several recently published edited volumes discuss the state of research on learning from errors at the workplace and within enterprises (Bauer and Harteis 2012; Bauer et al. 2010; Hofmann and Frese 2011b; Wuttke and Seifried 2012).

The structure of this chapter follows the questions mentioned in the previous paragraph. The question 'What are the kinds of errors'? highlights the fact that errors can be very diverse and have several dimensions such as severity or attribution (individual, social, or contextual factors), and it considers the characteristics of the assumed underlying cognitive processes and their potential for learning. Hence, in the first part of the chapter, we introduce a theoretical framework for the analysis of errors that allows the distinction of typical error cases. The focus of this section is on individuala, because we follow a classic and commonly used conceptualisation that defines errors in the context of individual action. Second, the questions on the conditions, processes and outcomes of learning from errors will be addressed, drawing upon insights from research on learning and instruction. In this section, we extend the scope of the discussion to team and organisational learning from errors. Third, we will elaborate on these issues by summarising the state of empirical research on learning from errors in the workplace with a special focus on recent developments. Finally, we will discuss thus far unsolved challenges and draw conclusions for further research in this area.

26.2 Theoretical Framework for the Analysis of Errors

A theoretical framework for the analysis of errors must comprise (at least) three different perspectives: (1) error definition, (2) classification of potential causes in order to be able to develop a typology of error cases and (3) a systematic description of the processes of identifying errors.

26.2.1 Error Definition

The typical use of the term 'error' refers to situations in which the outcome of an action does not meet a priori set expectations and this deviation is attributed to the actor while assuming that he or she had the required competence to meet these expectations (e.g. Senders and Moray 1991). Such an understanding implies that somebody acted deliberately, (i.e. with respect to a specific goal of action) and that the result of the action did not fit with the reference criterion that was the basis for the action planning. An error, thus, is the unintended, but principally avoidable, deviation from a standard that endangers the attainment of higher-order goals (Bauer and Harteis 2012; Frese and Zapf 1994; Hacker 1998; Hofmann and Frese 2011a; Lipshitz 1997; Oser and Spychiger 2005; Rasmussen 1987; Senders and Moray 1991; Zhao and Olivera 2006). This general definition is the basis of most research approaches investigating learning from errors at the workplace. However, further, the implications need to be made explicit to develop a useful pattern for investigating learning from errors in workplaces:

- The first crucial implication refers to the standard that should be met. The definition of an error does not make sense if there is no reference criterion against which the result of the action is to be judged.
- Second, a crucial characteristic of an error is that it is avoidable. Inevitable and fateful events are not covered by the abovementioned definition of an error. However, if an error is avoidable, then somebody can be deemed responsible for it.
- Third, an error is of relevance to subsequent actions, because it jeopardises the attainment of related goals. A failure without potential adverse consequences is not covered by the error definition provided above.

This conceptualisation of an error is consistent with the hierarchical theory of human action (e.g. Frese and Zapf 1994; Hacker 1985; Hommel and Nattkemper 2011; Miller et al. 1960; Wehner et al. 2010). This well-established approach claims that human action can be described as attempt to attain a complex set of action goals, which comprises branches of goals and sub-goals on different levels. In other words, each complex enterprise (e.g. deciding about investment in an enterprise) is a set of sub-goals (e.g. developing a strategic goal, analysing budgets, comparing credit offers, analysing the market). Hence, failure to attain a specific action goal prevents the attainment of the main goal or one or more sub-goals. Action theory allows describing rationale human action as a series of issues: the basic assumption of action theory refers to competent and goal-oriented actors. This means that actors (at least subjectively) have sufficient knowledge and capabilities and are motivated to attain the goal. Hence, errors are to be distinguished from failures caused by lack of knowledge or inappropriate capabilities and from intended violations of standards (Wehner et al. 2010). The decision for an action goal, hence, needs to follow actors' individual needs and available opportunities, to meet the requirements of action theory, which implies rationality for human behaviour. Therefore, in addition to objective action opportunities, those available from an individual's subjective perspective are also relevant to the definition of action goals (Billett 2006). As soon as a goal is defined,

Table 26.1 Basic assumptions of action theory

Assumptions	
(1) Efficiency	Competent, goal-oriented actor
(2) Realism	Definition of goals follows individual needs and available opportunities
(3) Organisation	Planning of actions for goal attainment
(4) Realisation	Execution of activities
(5) Evaluation	Feedback on goal achievement
(6) Consequences	Completion of action or goal modification (back to 2)

acting individuals start to plan the actions for goal attainment (i.e. a hierarchical set of sub-goals is to be developed), which then are all executed serially. After the execution of all planned activities, individuals seek feedback regarding goal achievement, which then controls whether the action is completed (if the feedback is positive) or if the action goal needs to be modified (if the feedback is negative). Table 26.1 summarises the basic assumption of action theory. Under these assumptions, human behaviour is conceived as predictable and reliable, or in other words, rationale. For the external judgement of human behaviour, individuals' knowledge and capabilities become as relevant as subjective perspective on available opportunities. Hence, attribution of an error can refer to each of these parts of action regulation.

Another characteristic of an error is that its judgement always refers to a standard or a normative criterion related to the desired goal (Heid 1999; Rasmussen 1987; Senders and Moray 1991). Hence, an error is neither a physical entity nor an objective feature of an action. The judgement of an error is by definition a result of an evaluation of goal achievement. External observation of a discrepancy between the actual realisation of a goal and the reference criterion for judging its attainment is implied. This norm dependency raises the question of the operationalisibility of errors and, thus, its principle accessibility to empirical research. However, norm dependency is not an exclusive characteristic of errors; it is rather a general feature of judging the quality of human behaviour, for example, 'creativity' (Csikszentmihalyi 1996) and 'superior expert performance' (Ericsson 1996). Bauer and Mulder (2008) suggested adopting a social negotiation perspective on error judgements: they state that an action should be considered an error if (1) it is judged as a deficient deviation from an expected standard and (2) this is done by knowledgeable members of a given community (e.g. occupation, academic domain, organisation) and (3) at a specific point of time. The latter point is important because the criteria for evaluating an action as an error may change over time. This perspective allows analysis of different understandings of errors and investigations of social discourses and power relations in error judgements. These issues become relevant if a theoretical differentiation of the process of error judgements is followed.

The entire process of identifying and dealing with errors can be differentiated into an action process, which ends in a result that is evaluated and consequences, which result from the evaluation of goal achievement. The crucial question is whether learning occurs as the final outcome. The action follows certain criteria such as

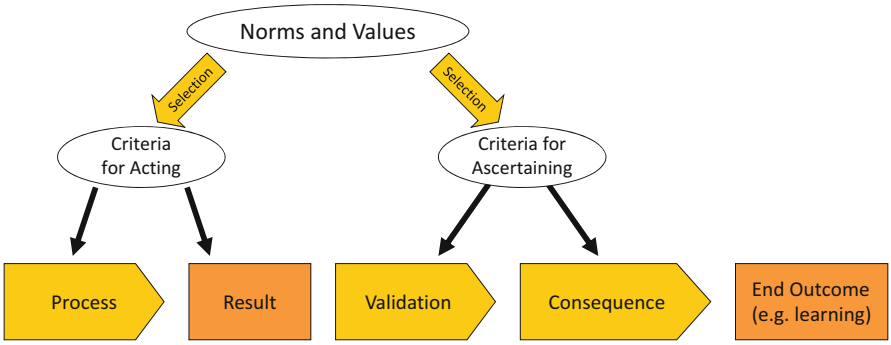

Fig. 26.1 Theoretical differentiation of error judgement

individual needs, available opportunities and a subjective selection of norms and values. These criteria are also relevant for the evaluation of action outcome. However, it is possible – and in work settings, probable – that the criteria for action do not (completely) fit with the criteria for evaluation, because actors and observers may apply different reference criteria. Usually, enterprises are organised in different hierarchies, a usual distinction being that between white and blue collar workers. A main feature of this distinction is that white collar workers evaluate the work performance of blue collar workers. This means that within enterprises, white collar workers often identify errors committed by blue collar workers. For researching learning from errors, the conditions of such an error identification system become as relevant as the way in which they are dealt with. Figure 26.1 shows the different issues of error judgement that may influence learning from errors. First, an action process follows certain action criteria and leads to an outcome. This outcome may be judged by evaluation criteria, and its consequences usually follow the regime of the evaluation criteria. For researching learning from errors at the workplace, it is important to assess whether or not the criteria for acting are the same as those for evaluation.

Generally and consistent with action theory, error judgement can be described as follows: There is an actor who conducts a process that leads to a specific result. This action follows an individual set of criteria that are influenced by subjective attitudes, knowledge and capabilities as well as a subjective selection of individual and organisational norms and values. The result, then, is the object of an evaluation, which again follows certain criteria that may also influence the individual and collective consequences drawn from the error.

To summarise this subsection, we introduced a definition of errors that is used frequently in research on human factors and derives from a classic theory about human action. We also discussed the implications of the process of evaluating actions as errors. For educational research, it is important to identify the conditions that support or hinder this entire process and result in individual and collective learning processes. Next, we will introduce a differentiation of error types as knowledge-based, rule-based, or skill-based errors (Norman 1981, 1984; Rasmussen 1987; Reason

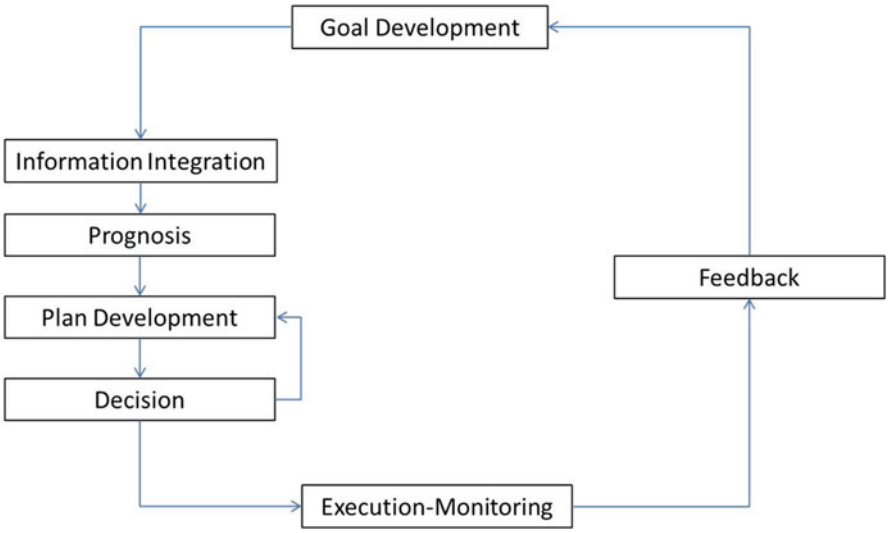

Fig. 26.2 Stages of action regulation

1990). We will only briefly discuss other types of error such as slips and lapses, caused by lack of concentration or awareness, since they probably have a low potential to result in learning.

26.2.2 Typology of Errors 888

To develop a typology of errors, it seems reasonable to start from the theoretical implications of action theory explained above. Figure 26.2 depicts the stages of planned actions, which will guide further explorations.

The starting point of the action process is the development of an action goal, based on individual needs and opportunities, and various mental and physical activities are initiated. After an action goal is decided on, the available relevant information has to be integrated in order to develop a feasibility prognosis. Action plans (i.e. a set of goals and sub-goals) have to be developed, eventually modified and finally implemented. This execution of actions is to be monitored, and on completion, goal achievement must be evaluated and feedback provided. The feedback may then lead to new decisions about the action goals. All these stages demand cognitive activities at various levels of knowledge. Since the understanding of errors particularly focuses on the actor's knowledge and capabilities, it appears reasonable to consider the various levels of knowledge that can be applied at these stages of action regulation. Cognitive theories provide rich insight into knowledge structures that guide action on different levels of performance (e.g. Anderson 1982; Ericsson 2006; Harteis and Billett 2013). Frese and Zapf (1994) applied cognitive theories to the

Table 26.2 Levels of action regulation

Consciousness	Level	Examples
Non-conscious – mental	Metacognitive templates and heuristics: intuition	
Conscious – mental	Intellectual regulation: knowledge based, declarative knowledge, controlled	
	Flexible action patterns: rule based, knowledge compilation, routines	
Non-conscious – physical	Sensorimotor skill level: automatic, procedural level	

Table 26.3 General taxonomy of errors

	Action sequence					
Levels of regulation	*Goal development*	*Information integration*	*Prognosis*	*Plan development / decision*	*Monitoring*	*Feedback*
Heuristic	Heuristic for goal orientation	Cognitive styles, rigidity, heuristics and biases, reflexion, tolerance for ambiguity		Heuristics for plan orientation	Monitoring styles	Heuristics for feedback processing
Intellectual regulation	Goal setting errors	Mapping errors	Prognosis errors	Thought errors	Memory errors	Judgement errors
Flexible action patterns	Habit errors				Omission errors	Recognition errors
Sensorimotor	Movement errors					

(Adopted from Hofmann and Frese 2011a)
Note. Used by permission from Routledge

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action regulation concept and distinguished levels of consciousness (Table 26.2). Human action is largely steered by non-conscious physical skills that comprise, for example, the movement of the body. Other unconscious areas of action regulation include metacognitions and intuitive mental processes. Conscious areas of action regulation are flexible action patterns (routines and rules) on the one hand and deliberate application of knowledge on the other.

Merging the stages of action regulation with these levels allows the distinction of errors, which yields a general taxonomy of errors (Frese and Zapf 1994; Hofmann and Frese 2011a), as shown in Table 26.3.

This general taxonomy allows for the distinction and classification of error cases. Even though it is possible that each of these different error cases triggers different learning processes, it has not yet been clarified whether they demand different circumstances in order to allow learning from errors. Hofmann and Frese (2011a) consider this taxonomy to be reliable and valid and refer to empirical studies showing that the correction of different types of errors involves differing times and attempts,

and these differences are coherent with theoretical assumptions derived from the levels of regulation (e.g. Brodbeck et al. 1993; Zapf et al. 1992). However, Harteis et al. (2008) found large inter-individual differences in the understanding and definition of an error. Moreover, since the levels of action regulation are not directly observable, each concrete observation of a failed action applies the observer's individual assumptions about the actor's level of action regulation. Hence, error judgements seem to be highly subjective. Therefore, although general taxonomies may be helpful as analytic tools to distinguish different types of errors, they appear less helpful to analyse concrete empirical error cases as well as inter-individual patterns of reactions to errors. Mehl and Wehner (2012) provide a more general critique of error taxonomies that is partly based on the uncertainty of causal post-hoc attributions after errors.

26.2.3 Process of Identifying Errors

Opportunities for learning from errors depend on the way in which the error was identified and labelled. In other words, it is important to consider the process of error detection. We focus here on the conditions of this process, considering only learning from errors at the workplace; since a detailed examination of this complex process of error detection is beyond the scope of this chapter (see e.g. Hommel and Nattkemper 2011 and Yeung et al. 2004 for the neural basis of error detection).

Generally, different modalities of error detection can be differentiated by considering whether the actor himself or herself or somebody else detects the error and whether the identification of the error occurs on mediation or immediately. It might be the most fortunate case if an error is self-detected because this implies that workers understand the criteria for error judgement and that additionally they are aware of the action goals. If somebody else detects the error, the situation becomes more complicated, since the detector's and actor's viewpoints regarding the action goals and evaluation criteria may differ. In this situation, the quality of the feedback and the complex process of its interpretation and use by the recipient have to be considered. The difference between mediated and immediate error detection refers to whether error identification is displayed by indicators (e.g. instruments) or via direct observation of the failed process. Considering the theoretical differentiation of error judgement as depicted in Fig. 26.1, three challenges arise for the analysis of learning from errors:

- *Error object*. For an object to be labelled as an error, several options remain. If a damaged car leaves the production line of a car manufacturer, the damaged car itself can be labelled as an error, but the assembly step that caused the damage is also labelled an error, with similar validity. Hence, the process as well as the result of the process can be the object of an error judgement. Further, operations or artefacts can be labelled as errors. The damage itself is an artefact, and operations that lead to the damage can vary dramatically, because they can refer to workers' attitude to the task, to their routines and behavioural patterns and more. Whereas the damage itself might be identified quite clearly, it might be difficult to allocate

a concrete operation as the cause of the error. In order to learn from errors, it appears necessary to focus on processes. Moreover, the opportunities to learn from errors depend on the issue of who has identified the error. Particularly in organisations with a high level of labour distribution, it is not self-evident that the acting individual receives immediate feedback to operations conducted by him or her. It is possible that somebody else – colleagues or managers – identifies the error.

- *Criteria for acting and evaluating*. Given a competent actor, as implied in action theory, the action follows the actor's criteria and his or her norms and values. However, the crucial aspect is whether the evaluator's criteria for his judgement fit with the criteria for action. If both are similar, no problem arises. However, if the evaluation criteria are different from the action criteria, challenges to learning from errors arise, starting from issues of legitimation, acceptance and insight. If there is disagreement between an actor and observer, the situation becomes more complex, especially if one or both follow rather implicit criteria that are not precisely explained.
- *Consequences drawn from errors*. A critical factor for learning from errors is the way in which an individual or group deals with the error. The construct of error orientation (Rybowiak et al. 1999) describes individual influences on dealing with errors or the individual attitude towards errors. On the collective level, constructs like organisational climate for learning from errors (Putz et al. 2012), error management culture (van Dyck et al. 2005) or, in practitioner-oriented literature, error culture (e.g. Löber 2012; Schüttelkopf 2008) describe shared attitudes and practices of dealing with errors in an efficient and learning-oriented way. For consequences drawn from errors, the question of whether an actor's knowledge and capabilities or the intention of action is to be considered for the collective way of dealing with an error might be important, in addition to the extent to which these factors should be considered. Here, the issue of responsibility becomes relevant, which is, especially from an educational perspective, quite an awkward topic since it oscillates between ethics of conviction, domestication and emancipation.

In sum, to prepare the theoretical basis for analyses of learning from errors at the workplace, we introduced possible reference criteria for the judgement of errors, discussed a general taxonomy of errors in terms of its value in empirical studies, and explored the process of error identification to reveal general differences and incongruities that can occur in social work-related processes of detecting and dealing with errors.

26.3 Learning from Errors at the Workplace

Learning from errors at work is a specific mode of workplace learning. Tynjälä (2013) developed a framework of workplace learning that distinguishes the presage, process and product of learning considering individual factors and the sociocultural work environment. Following this framework, the concrete situational characteristics

found at a given workplace shape the outcome of learning from errors. An important question, therefore, is under what individual and environmental conditions learning from errors becomes probable. Further, reflecting on learning from errors needs to be related to the rich insight provided by research on workplace learning. Finally, several perspectives must be developed for researching learning from errors at the workplace.

26.3.1 Prerequisites for Learning from Errors at the Workplace

On the basis of the explanations in Chap. 1 (and following Oser and Spychiger's (2005) theory on learning from errors), several logical prerequisites for learning from errors can be identified (We discuss these theoretical prerequisites here, and a summary of research on what variables predict learning from errors at work will be given in Sect. 26.4.): (a) It should be clarified what exactly the error is. As discussed above, there are various options for definition of the error object. Learning needs to be related to the concrete error object in order to avoid future repetition. To return to the example of the damaged car, it makes a crucial difference if the quality of operation or the attitude to work is identified as an error because both would demand completely different activities that finally aim at learning. (b) For learning from errors, it is equally important to detect the errors and provide feedback. Even though it might appear trivial to consider the detection of errors as a prerequisite for learning, especially in large organisations, labour is widely distributed, making detection of or feedback for errors difficult. If a damaged car leaves the production belt, the defect may not be that obvious (e.g. a defective wiring harness), and the exact person or operation that caused the defect may not be clear either (e.g. inappropriate screwing work occurring several steps after installation of the wiring harness). Hence, even though an error may be detected finally, the responsible person will not necessarily realise the failure or receive feedback. The example of the wiring harness rather suggests that if the error is not detected at all at the workplace, the customer will actually use the defective product, in which case learning from errors will be almost impossible. (c) Third, learning from errors involves the development of an understanding of the error. This, in turn, implies that the causes for the error become evident. Otherwise, it will not be certain that the lessons learnt from an error will allow avoiding the same error in the future. If the reason for the defective wiring harness remains unclear, involved workers perhaps can learn various lessons from the detection of that defect, but avoidance of the error would occur only accidentally and not purposefully. Nonetheless, this deliberate error avoidance would fit with the idea of quality assurance. (d) Last but not least, to make learning from errors probable, the appropriate consequences should to be drawn from error detection. If the detection of a damaged car in the manufacturing plant leads the involved individuals to believe that it is more advantageous to hide the error, it is likely that the error or its causes remain undetected. Hence, learning from errors would be quite unlikely.

We will elaborate on this issue later in the chapter, while discussing the concept of error culture.

Facing these prerequisites of learning from errors and simultaneously considering the theoretical differentiation of error judgement or the characterisation of the process of error detection, it becomes apparent that none of these prerequisites are trivial or self-evident in the context of daily working life. As argued above, in enterprises, work usually is distributed among several individuals and in hierarchical systems, so the actors are evaluated by others. In hierarchies, individuals may not value each other sufficiently or they may not agree with another's judgement. Additionally, competition within a working group or coalition in a department make it difficult for an individual to admit an error. Hence, to support learning from errors at the workplace, it is of prior importance to foster an error culture, which is a way of dealing with errors that aids learning from errors.

Researchers of education highlight several preconditions that support the initiation of learning processes after error incidents (e.g. Harteis et al. 2008; Oser and Spychiger 2005; Seifried and Baumgartner 2009). It appears important for organisations to implement a collective error orientation (also see Sect. 26.3.2 on error culture), which interprets errors at the workplace as an opportunity for learning, because such an orientation promotes the initiation of individual and collective learning activities. It is necessary that the error really interrupts the ongoing process and that feedback be provided to the actors involved. Both these factors allow the development of concernment, an important prerequisite for learning from errors. According to Oser and Spychiger (2005), this concernment first implies that the actor involved perceives his or her own action or decision as the source of the error. If drivers skid off-road in winter because of high-speed driving, they have a good opportunity to learn from the error, if the accident is attributed to inappropriate driving. However, if the attribution of the accident is deemed external (e.g. the shape of the tires), a change in driving behaviour (i.e. learning from the error), on the part of the driver would be improbable. The second aspect of concernment refers to the emotional reaction, in which the error embarrasses the actor in a certain way. Such an emotional reaction adds value to the experience of the error situation. Given the concernment, reflective cause analysis must be conducted in order to learn about the cause of the error and alternative actions or decisions with which the error can be avoided.

26.3.2 Error Culture

Section 26.2.3 listed several approaches that model collective-level constructs describing teams' or organisations' attitudes and behaviours towards errors (e.g. Bauer and Mulder 2007a; Löber 2012; Putz et al. 2012; Schüttelkopf 2008; van Dyck et al. 2005). In fact, the term *error culture* implies that individuals in an enterprise may share norms and practices on how to deal with errors (Reichers and Schneider 1990).

The discussion on error culture is based on the premise that errors cannot completely be avoided in complex production processes or in services provided by humans (Reason 1997). Hence, dealing with errors is an important issue for business organisations. van Dyck et al. (2005, p. 1228) believe that 'in the long run, organisations that have an effective approach to errors may be more profitable because these organisations learn from errors, are more apt to experiment and are more likely to innovate'. While the importance of learning from errors has been well-acknowledged, it has not received much attention in research literature across various disciplines. A key learning from the field of cybernetics and system theory is that relations between variables in complex settings often remain hidden. Thus, errors are unavoidable for two reasons: firstly, it is impossible to overlook and forecast all effects and side-effects of an action. Hence, perfect implementations of plans without deviations from the original intention probably do not exist. Errors are inevitable even if actors follow the best of knowledge in full consciousness. Secondly, even if deviations from intended goals and sub-goals are avoided, unintended effects in disregarded variables may occur, such as through time-delayed effects (Kühl 2002). Most literature on organisational development considers errors only in relation to error prevention (van Dyck et al. 2005). One of the goals of Total Quality Management in organisations is to attain 'zero-errors' through error prevention. These efforts are double-edged, because of the contradiction between detecting and understanding of errors for their elimination, on the one hand, and the perception of errors as adverse events, on the other hand. A similar approach to errors is found in the literature that focuses on the individual instead of the organisation: Individual career planning is a classic area of personnel development and an important area of human resource management. In scientific as well as popular literature on personnel and career development, errors are usually considered as threats that put one's promotion opportunities at risk (e.g. Brown and Lent 2013).

The exploration of practices in dealing with errors, thus, leads directly into a conflict between the apparent inevitability of errors on the one hand and their adversity on the other hand. This conflict is driven by the antagonism between the ratio of productivity and the ratio of learning and development. Workplaces, as parts of enterprises, primarily cater to the provision of goods and services under economically reasonable circumstances. Such circumstances imply profitability: the sum of earnings from goods and services must exceed the sum of efforts for their provision. Performance in work contexts is often measured in profits. Given this perspective, activities that do not immediately contribute to profit appear undesirable. Errors and practices for learning from errors do not directly contribute to profit because they interrupt regular work processes. In fact, they may reduce profit. This perspective is called achievement orientation, which is possibly in conflict with a learning orientation. The latter focuses on processes of learning and development and includes activities to learn from errors. The achievement orientation, on the other hand, implied that employees' work activities are evaluated for their performance, and it forms the basis of organisational management at all kinds of workplaces.

Learning from errors cannot be expected to occur without a supportive organisational environment that fosters a learning-driven approach to errors. This idea is

summarised in the concept of error culture. Unfortunately, this term is prone to misinterpretation in that it seems to suggest that errors are not adverse events or are even desirable in order to create learning opportunities (Peters and Peters 1987). This understanding is naturally incompatible with the goals of many domains of work, especially those that involve high risks, such as health care, aviation, or nuclear energy. Ideally, error culture should be understood as shared norms and practices that transform errors – that escaped prevention – into learning opportunities, with the ultimate goal of reducing the probability of repeating such errors (cf. Harteis et al. 2008; Reason 1990).

On the basis of these premises, Bauer and Mulder (2007b) conceptualised error culture as an integrative organisational strategy. We expand their model by articulating the strategy in the form of the following four goals:

1. To prevent errors as far as possible;
2. To deal with errors that occur in an efficient manner, that is, to correct them quickly and to curtail adverse effects stemming from them ('error management'; Reason 2005);
3. To analyse occurring errors in order to learn from them, that is, to gain insights that help prevent such errors in the future and to create knowledge or even innovations from an error situation. Such learning can occur at the individual, team, or organisational levels;
4. To create conditions within an organisation that are conducive to the attainment of the above goals.

This approach is called an integrative strategy, first, because it integrates the seemingly disparate or even contradictory goals of error prevention and learning from errors. Second, it combines the abovementioned approaches for learning from errors, error management culture and error culture within an organisational climate. Third, it addresses and integrates learning processes and their conditions both at the individual and collective level (cf. Järvinen and Poikela 2001). The latter becomes more apparent when discussing the practices through which these goals may be attained. These practices involve the following:

1. Efforts of organisational safety, risk and quality management that estimate the risk of occurrence of certain errors, measures to reduce their probability (e.g. by means of automation, standardisation of processes and design of the work environment) and creation of error tolerant systems that prevent adverse effects stemming from errors (e.g. Glendon et al. 2006; Reason 2005).
2. Efforts of organisational learning from errors by means of systematic collection and analysis of errors and critical incidents with the purpose of revising and improving current organisational structures and processes (e.g. in form of critical incident reporting systems and quality management tools; Pfeiffer and Wehner 2012; Zhao and Olivera 2006)
3. Team and individual efforts to analyse own errors, their potential causes and the development of strategies to avoid similar errors in future (Bauer and Mulder 2013; Leicher et al. 2013). Such learning will most likely occur informally at the workplace.

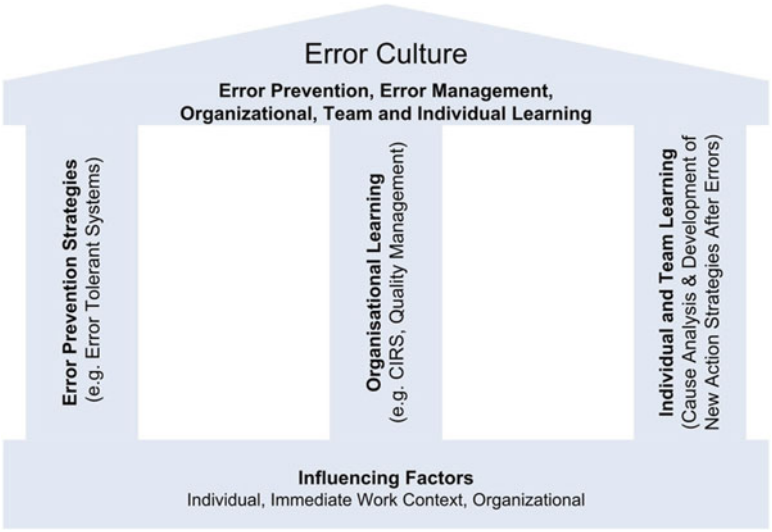

Fig. 26.3 Model of error culture as an integrative strategy (*Note.* Adapted from Bauer and Mulder 2007b; *CIRS* Critical Incident Reporting Systems)

The implementation of these three strategies depends on supportive conditions within the organisation, situational factors of the immediate work environment and individual characteristics of the employees (cf. Billett 2006; Tynjälä 2013; Zhao 2011).

Figure 26.3 represents the discussed goals, strategies and conditions of error culture. It is an integrative strategy that aims to facilitate the attainment of the goals of error prevention, error management and learning from errors. These goals can be attained by means of traditional prevention strategies as well as through combined efforts of organisational and individual learning. They form the pillars of the error culture. To what extent such learning will take place depends on the interplay of individual and contextual factors at the workplace. These variables constitute the bases of error culture, and an additional goal is to create supportive conditions.

This model of error culture not only blends with but also extends previous approaches to learning from errors. A similar model that considers organisational norms and values, competences and instruments for handling errors as pillars of error culture has been proposed by Schüttelkopf (2008). Löber (2012) recently reviewed existing approaches to conceptualise error culture.

From the discussion above, it is clear that the implementation of error culture means to establish an environment that appreciates learning from errors and, thus, accepts restrictions on work performance. Error culture, however, does not imply a neglect of work performance; rather, it represents a long-term approach for the evaluation of work performance. A learning-oriented approach to dealing with errors and learning from errors may impede work performance in the short-term but it may concurrently contribute to enhanced performance if the learning is successful.

It is essentially a matter of the time point of performance measurement if a process is to be judged as cost or benefit. Empirical evidence exists that in the long run a learning-oriented organisational approach to errors leads to higher performance (van Dyck et al. 2005).

In summary, error culture is a learning-oriented approach to dealing with errors. It encourages the organisations to view intra-firm activities not only from an achievement perspective but also from a learning perspective. In the event of an error, it must be possible to interrupt regular processes to focus and analyse the error. For an appropriate understanding of errors, it is necessary to interpret them as results of individual or collective decisions but not as an inevitable incident. Such an understanding leads to alternatives that contribute to the knowledge on how best to avoid the repetition of the same error. However, establishing such organisational practices towards errors is challenging because they require what Edmondson (1999) calls a positive learning climate, comprising, firstly and most importantly, a climate of psychological safety. Psychological safety refers to an employee's subjective perception of the possibilities to act without fear of reprisals from colleagues or supervisors (Edmondson 1999). Secondly, a positive learning climate demands emotional tolerance of the error. Negative emotions are natural reactions of failing, and it is almost certain that emotional reactions are innate with a long history of phylogenetic roots (Damasio 2010). It is important not to fight these reactions back but to allow them to surface and finally dissolve. Thirdly and finally, a positive learning climate allows room for further improvement; that is, the person who committed the error is encouraged to fix the problem at the next attempt and not to avoid the situation that led to the error.

26.3.3 Processes of Learning from Errors

Learning from errors at workplaces requires a solid foundation in the theories of workplace learning in particular and in the theories of learning in general. In this section, we aim to integrate the concept of learning from errors with established theories on workplace learning. For this purpose, we draw upon a systematic review of workplace learning theories in a recently published textbook (Dochy et al. 2011). This volume provides a collection of well-acknowledged theories on workplace learning that provide different perspectives to conceptualise learning from errors. Within the broad domain of experience-based learning, the following theories on workplace learning are particularly relevant to learning from errors.

26.3.3.1 Experiential Learning

In terms of learning theories, learning from errors is best understood as experiential learning (Gruber 2001; Kolb 1984). Concrete experiences (e.g. errors) trigger mental activities that result in the development of new knowledge or the modification of

available knowledge. Different perspectives of the experiential learning theory are relevant here. We distinguish between a cognitive and an activity perspective, which serve different but complementary purposes for conceptualising learning from 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. Further, 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). The activity perspective views learning as a self-organised effort to improve performance (Boshuizen et al. 2004). This perspective is useful in determining the activities that are relevant in order to learn from an error. The activity perspective is grounded in the theories of experiential learning (Gruber 2001; Kolb 1984) that view experiential learning as action-reflection-action cycles. Kolb's (1984) model describes experiential learning as iterative cycles of (i) making a concrete experience, (ii) observation and reflection, (iii) forming abstract concepts and (iv) testing the gained insights in new situations. Applied to learning from errors at work, an experiential learning cycle can be modelled to involve (a) reflection on the causes of an error, (b) the development of new or revised action strategies that aim to avoid the error in the future and (c) experimenting with or implementing the new or revised strategies (Bauer and Mulder 2007a). 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 1999). This appraisal is consistent with the emphasis on the role of social exchange on workplace learning (Billett 2006; Eraut 2000). Communication and exchange can foster the development of shared knowledge and understanding of errors as well as elicit solutions and strategies to handle them (Cannon and Edmondson 2001; van Dyck et al. 2005).

Under this experiential learning perspective, errors can be seen as specific incidents of concrete experiences that diverge from prior knowledge (Bauer and Gruber 2007). When an employee acts according to his or her best knowledge, an error is an incident that reveals the fallibility of the state of knowledge. There is a gap between expectations (action goal) and achievement which becomes the object of observation and reflection, in order to enable the employee to form an abstract concept on the error case (i.e. negative knowledge, theory of the error case). This step in itself constitutes learning from errors, since available knowledge is expanded and modified. However, the avoidance of error repetition requires a fourth step in this cycle: the testing of the new concept in novel situations. Kolb and Kolb (2005) empirically tested different modes of learning, all of which aim at closing the cognitive gap revealed by the experience of an error: diverging, assimilating, converging and accommodating.

26.3.3.2 Transformational Learning and the Reflective Practitioner

Though models of experiential learning are quite useful for modelling learning from errors at work, Kolb's (1984) approach, in particular, has been criticised for its lack of elaboration on reflection (Boud 2006; Järvinen and Poikela 2001; Van Woerkom 2003). Conceptualising reflection on errors therefore requires drawing upon more comprehensive theories of reflection (Bauer 2008). The concept of *transformational learning* (Mezirow 1991) focuses on individual construction of meaning that is based on reflection upon authentic practical experiences. Experiences play a two-fold role in this context: first, they shape the mental frame for the interpretation of the practice; second, the concrete experience of practice shapes the beginning of a learning process. Again, an error can be such an ignition for learning. Mezirow (1997) describes three phases of transformational learning: (i) the critical reflection of practical experience, (ii) discourse about the outcome of the critical reflection and (iii) action as the application and testing of the newly developed knowledge. The importance of reflection for (workplace) learning is also emphasised in Schön's idea of the *reflective practitioner* (Schön 1983). By analysing high performing practitioners, he recognised the importance of tacit knowledge for practical activities and developed the idea of knowing-in-action. However, sometimes actions produce surprising results (e.g. errors), which lead to reflection-on-action, in order to reveal how knowing-in-action may have guided the actor.

In synthesising the research on reflection, Boud (2006) identified several themes that are relevant to conceptualising the processes of learning from errors at work. Reflection refers to cognitive and emotional processes as well as to overt actions that serve to examine experiences. It is frequently triggered by the experience of conflict, such as surprise, perplexity, hesitation, uncertainty, dissatisfaction or discrepancy (cf. Kolb 1984). Particularly, emergent problems and unexpected outcomes may lead practitioners to leave a routinised and intuitive mode of action regulation for a deliberate, knowledge-based and analytical one (Ellström 2006; Eraut 2000; Schön 1983). Consequently, reflection can be considered a conscious, volitional process of interpreting and making sense of experiences (cf. Ellström 2006) and relates to the reactive and deliberative modes of learning discussed by Eraut (2000). Even though reflection has been regarded mainly as an individual activity, the benefits of which concern the individual, it is inherently social and contextual, as its outcomes concern action in and relations with a social and technical organisational environment. Individual reflective processes may profit from social exchange, and a collectively shared practice of reflection may initiate processes of group or organisational learning (Høyrup and Elkjaer 2006; Van Woerkom 2003). Moreover, reflection has to be analysed on an 'instrumental to critical' continuum (Mezirow 1990; Van Woerkom 2003). According to Mezirow (1990, p. 1), '[Instrumental] reflection enables us to correct distortions in our beliefs and errors in problem solving. Critical reflection involves a critique of the presuppositions on which our beliefs have been built'. Thus, instrumental reflection concerns the content and processes of problem

solving and serves learning how to act. In contrast, critical reflection has an emancipatory focus and concerns questioning the underlying and often implicit goals, values and beliefs that lead to action.

These general themes on reflection help gain a deeper understanding of how reflection on errors can be conceptualised (Bauer and Mulder 2008). In this context, reflection means performing a root-cause analysis to identify probable causes of an error (Kolb 1984; Kolodner 1983). Reflection on errors, therefore, refers to a conscious, volitional process, involving cognition, emotion or overt action that serves to examine, interpret and make sense of this experience. An actor may engage in cognitive or overt reflective activities as a response to a conflict induced by the detection of an error, with the aim of analysing its causes. Reflection on errors has a social dimension in that it may be performed collectively, and its outcomes concern action that cannot be considered as separate from the sociocultural context in which it occurs. Locating reflection on errors on the continuum between instrumental and critical reflection is more difficult. The focus of reflection on errors as discussed so far in this chapter is an instrumental one; that is, the goal of reflection is to enhance future problem solving and action. However, learning from errors is not restricted to instrumental reflection for two reasons. First, even if the goal is an instrumental one, the means of achieving this goal can incorporate critical reflection. In-depth reflection on root-causes, results and ways of prevention is necessary to achieve a change (Aspden et al. 2004; Harteis et al. 2007; Van Woerkom 2003). Secondly, errors can also initiate critical reflection, necessitating an in-depth inquiry into the underlying values and presuppositions of the practice. Therefore, learning from errors is not limited to mere adaption and can result in discontinuation of existing practices and development of innovations (Ellström 2006; van Woerkom 2012).

26.3.3.3 Deliberate Practice

The concept of *deliberate practice* (Ericsson 2006) is also relevant to learning from errors, since it primarily implies monitoring of performance and reflection on especially erroneous outcomes. Deliberate practice refers to individual efforts to improve one's knowledge, capabilities and performance by analysing and reflecting on past performance and consciously practice tasks that have not yet been mastered. Deliberate practice is crucial for the development and maintenance of expertise and requires consistent practice, specifically on aspects of activities that (still) seem erroneous (Ericsson 2009).

In conclusion, it is important to discuss the unique aspects of learning from errors as addressed in the various (workplace) learning theories. In educational or psychological research, learning from errors is viewed as a form of experiential learning. However, serious research on learning from errors needs to be grounded in learning theories. Extant literature predominantly focuses either on prerequisites, namely, frame conditions for learning from errors (e.g. error culture or error orientation) or on behavioural issues (e.g. change of practices). However, it does not

usually analyse learning processes. We still need a more thorough understanding of the processes of learning from errors and how they differ from the strategies derived from general theories on experiential learning at work.

26.3.4 Outcomes from Learning from Errors

The main outcome of learning from errors is the development of knowledge about the error and how to avoid its recurrence. This knowledge ultimately needs to be applied in future situations to ensure error prevention. The cognitive perspective on experiential learning explained in Sect. 26.3.3 allows for the modelling of cognitive processes and the representation of the outcomes of learning from errors (Bauer and Gruber 2007; Gruber 2001). This perspective defines learning as the acquisition and improvement of knowledge through experiencing personally relevant episodes and focuses on the memory and knowledge structures involved. In particular, theories of case-based reasoning and the modification of scripts in dynamic memory (Kolodner 1983; Schank 1999) have shown how schematic, action-oriented knowledge structures (i.e. scripts) are extended and modified through reflecting on the experience of deviant episodes, including errors. Through reflection 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 in remembering the deviant episode during recurrences of a similar situation and in choosing 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 the construction of analogies to newly encountered episodes (i.e. case-based reasoning).

The expanded or modified knowledge about the error is referred to as *negative knowledge* by some authors (Gartmeier et al. 2008; Oser and Spychiger 2005; cf. Minsky 1994). In contrast to positive knowledge, negative knowledge focuses on how things are not conditioned or not working. The knowledge differentiates between features of an object and issues beyond its features. Philosophically speaking, a comprehensive understanding of objects necessitates knowledge not only about the objects' features but also about the characteristics that are not part of the objects. Gartmeier et al. (2008) elaborated on parallels between the model of indicated scripts (Kolodner 1983) and the theory of negative knowledge (Oser and Spychiger 2005; cf. Minsky 1994). According to these authors, the term 'negative knowledge' denotes knowledge about the 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 future 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.

26.3.5 Summary

In sum, this section has explored individual and environmental conditions of learning from errors at the workplace characterised by typical approaches to division of labour. The concept of error culture has been introduced to clarify social practices at workplaces that support learning from errors. Different theories on workplace learning have been discussed with a view to providing a theoretical basis for learning from errors. Finally, the concept of negative knowledge has been discussed to elaborate the outcomes of learning from errors. So far, the theoretical frameworks and distinctions for investigating learning from errors at the workplace have been introduced. The next section provides an overview of the state of empirical research.

26.4 State of Empirical Research on Learning from Errors at the Workplace

Despite the long tradition of research on errors and human fallibility in the disciplines of safety management and organisational psychology, the issue of learning from errors has only recently attracted the attention of scholars on workplace learning. The existing lines of inquiry typically adopt an organisational (learning) perspective. Studies on individual learning from errors and its contribution to individual workers' professional development as well as to team-level progress are few in number (Bauer and Mulder 2008; Bell and Kozlowski 2011). When we commenced research on this topic over 10 years ago, there were virtually no studies on learning from errors within this field. The few research works that existed were scattered over several disciplinary fields, with almost no interconnections. However, since then, the field has grown substantially, and today there are several edited volumes, special issues (Bauer and Harteis 2012; Bauer et al. 2010; Hofmann and Frese 2011b; Wuttke and Seifried 2012) and regular conference symposiums on workplace learning research. In this section, first, we summarise findings from an early review on individual learning from errors in the workplace. Second, we highlight some recent promising developments and approaches that we feel warrant further investigation. A more systematic review of the existing research is, however, beyond the scope of this chapter.

26.4.1 Research on Learning from Errors at Work: From the Early Days to 2008

Bauer and Mulder (2008) reviewed eight empirical studies on learning from workplace errors, published between 1996 and 2004. They analysed the conceptions of errors, the definition of learning from errors and the empirical approaches.

Table 26.4 Overview of variables related to learning from errors at work from a review of early empirical studies (Bauer 2008)

1. Unsympathetic and unjust reactions; helping and protective supervisor
2. Supervisor direction setting, coaching, supportive vs. authoritarian; unit characteristics: quality of interpersonal relationships, espoused attitudes to errors (blame vs. learning); perceived consequences of making errors
3. Accepting responsibility vs. distancing and self-controlling strategies
4. Problem-solving orientation (i.e. communicating, discussing and analysing errors) and cooperative goals in the team
5. Support from the management, team psychological safety
6. Learning-oriented beliefs about errors in the team
7. Team psychological safety
8. Self-efficacy, difficulty with change, management job

Note. (1) Arndt (1996), (2) Edmondson (1996), (3) Meurier et al. (1997), (4) Tjosvold et al. (2004), (5) Tucker and Edmondson (2003), (6) Cannon and Edmondson (2001), (7) Edmondson (1999), (8) Van Woerkom (2003)

The findings indicated that – even though the studies made important contributions to breaking new ground – the theoretical and empirical approaches differed substantially. Most of the studies did not clearly elucidate the concept of error and the type(s) of error under investigation. Moreover, though many relied on some form of experiential learning theory for conceptualising learning from errors, the empirical methods for investigating it were too diverse to allow an integration of the findings. These problems notwithstanding, the reviewed studies still addressed a range of approaches to learning from errors at work. Moreover, the independent variables used in these studies (cf. Table 26.4) offer interesting avenues for further theorising and research.

The studies reviewed directly addressed learning from errors at the workplace. Some of our own earlier works took a slightly different approach by investigating how errors are actually dealt with in daily work (Harteis et al. 2007, 2008). One of the most noteworthy findings was that employees from different types of organisations consistently highlighted the importance of socially-shared learning activities to analyse potential causes of errors and to develop action strategies that reduce the probability of their reoccurrence. This finding is interesting as much of the earlier research had neglected the social dimension of reflection, as discussed in Sect. 26.3.3. It seems that learning from errors is – both theoretically and in practice – an activity that depends substantially on social exchange.

26.4.2 Recent Developments

During the last 5 years, research on learning from errors in the workplace has increased substantially. Fortunately, a shift in quality is also evident. That is, more well-defined theoretical frameworks and sophisticated empirical models are being

used, and authors are increasingly aware of relevant studies from outside their own disciplinary field. Below, some recent studies that are conceptually and empirically noteworthy are discussed, because they investigate outcomes of learning from errors, use strong designs or measurement methods, replicate and generalise findings across studies, or test the effects of interventions in (quasi-)experimental designs.

Investigating outcomes of learning from errors. Because learning from errors at work occurs incidentally, it is bound to the specific error situation and its context. Therefore, it is quite difficult to define and assess an outcome measure that could show its effects on an individual's professional knowledge. To our knowledge, a series of studies by Gartmeier and colleagues (Gartmeier et al. 2010a, b, c) is the only empirical work that measured outcomes of learning from errors at work. By using knowledge elicitation techniques, the authors identified different types of negative knowledge held by elder care nurses and showed that – as expected – the quality of this knowledge varies in line with the nurses' degree of expertise (Gartmeier et al. 2010c). These studies are particularly innovative as they provide a pathway for further research on how learning from errors affects the level of knowledge.

Strong designs and measurement methods. The studies described so far in this chapter used either interviews or questionnaires as measurement instruments and relied on cross-sectional designs. These methods have inherent weaknesses in terms of validity and conclusiveness. Recently, some notable exceptions have been published in the context of vocational education that demonstrate how stronger designs and measurement methods can be applied to the investigation of learning from errors. Türling et al. (2012) developed a test instrument that measures (pre-service) teachers' knowledge of typical student errors in the domain of bookkeeping as part of their 'professional error competence'. This test employs both reactions to video vignettes and paper-pencil questions. Even though this approach does not focus directly on learning from errors at work, the idea of developing test situations that allow the investigation of participant responses to (own or others') errors is highly relevant. In a longitudinal study, Rausch (2011) studied industrial clerk apprentices to investigate error occurrence at work, learning and motivational and emotional aspects. Data were collected through questionnaires with an internet-based work diary that participants completed over a period of ten workdays. The diary descriptions enabled the authors to draw a particularly detailed picture of learning from errors at work and its conditions. The findings show, for example, a strong correlation ($r = .6$) between the average reporting of errors and the average perception of learning from work tasks.

Replicating and generalising across studies. Given that learning from errors at work is an emerging field of study, few attempts have been made to replicate findings or to synthesise and generalise across studies. A notable exception is the study by Leicher et al. (2013). Their goal was to investigate whether exploratory findings from an earlier study on hospital nurses' engagement in social learning activities (ESLA) (Bauer and Mulder 2013) could be replicated and generalised to the field of elder care nursing. For this purpose, a sample of $N = 180$ elder care nurses was surveyed using a vignette-based questionnaire. The study investigated a mediation

model of nurses' ESLA used in the earlier study. The model assumes, first, that negative feelings related to an error situation have an indirect effect on ESLA that is mediated by the estimation of an error as relevant for learning. Second, the perception of a safe social team climate at work has also an indirect effect on ESLA that is mediated by nurses' motivational tendency to cover up errors. These results entirely cross-validated the exploratory findings of Bauer and Mulder (2013) on hospital nurses' ESLA and showed that they could be generalised to the domain of elder care nursing. These results are consistent with current approaches that consider error reporting as dependent on a subjective cost-benefit balance (fear of repercussions vs. benefit from learning; Zhao 2011). They also corroborate the finding that there are two levels of discrete predictors for ESLA: one that pertains to the individual reaction and appraisal of the error situation (emotional strain, relevance for learning) and the other that concerns the social context and the anticipated reaction of reporting an error (team climate, covering up errors). A recent qualitative interview study by Seifried and Höpfer (2013) provides further support for the validity of the mediation model within the chemical industry setting. Together, these studies provide strong examples of replication and generalisation of workplace learning research.

These recent developments show that learning from errors at work is a field of study that is growing stronger both in quantity and quality. However, despite these advances, there are still many open questions, challenges and unsolved problems, which will be addressed in the next Section.

26.5 Open Questions and Unsolved Research Challenges

A number of sections in this chapter have acknowledged the difficulties associated with precisely and conclusively (valid across disciplines) defining an error. Research on learning from errors in work contexts still faces theoretical and methodological challenges. One of the fundamental problems is that an error logically emerges only at the exact moment of failing. However, empirically, an error emerges at the moment when an action creates a result that eventually is evaluated to be an error. From a theoretical perspective, an error originates in that moment when somebody identifies the faultiness of an object or process and refers to eventual reasons (e.g. levels of action regulation). These distinctions give rise to the following methodological challenges for the investigation of errors and the ways of dealing them: (a) since errors can be attributed differently, there is a need to adopt a particular research perspective (i.e. micro-, meso-, macro-level of analysis); (b) since the evaluation and the understanding of errors may differ across individuals, the comparability of data collected from different people is questionable; and finally, (c) the clustering of error cases into different categories of severity is necessary.

Table 26.5 Levels of analysis in research on learning within work settings

Levels of analysis	Evaluation studies	Studies on learning transfer	Studies on learning from errors
Micro I: individual reactions and attitudes	Reaction	Transfer motivation	Error orientation
Micro II: individual effects	Success/learning	Learning success	Negative knowledge
Meso: effect on immediate environment	Transfer/behaviour	Horizontal learning transfer	Negotiating change of procedures
Macro: sustaining organisational effect	Organisational success	Vertical learning transfer	Establishing new practices/socially shared negative knowledge

26.5.1 Research Perspective

Most educational research projects on learning at workplaces investigate the effects of trainings by studying work-related training or the transfer of learning into workplace performance. Broadly, such research acknowledges four different levels of analysis: (1) the level of individual reaction on learning stimuli, (2) the level of individual learning success, (3) effects of individual learning on the immediate work environment and (4) effects of individual learning on the organisation (e.g. Baldwin and Ford 1988; Burke and Hutchins 2007; Kirkpatrick 2005). Table 26.5 shows that these levels can also be applied to analyses of learning from errors at the workplace (Harteis et al. 2012).

As discussed in Sect. 26.4, empirical studies on learning from errors use specific theoretical and methodological lenses. A survey of these studies suggests that individuals are the crucial agents committing, identifying and dealing with errors. However, they are always embedded in the environmental and social setting of concrete workplaces. Table 26.4 shows that cross-sectional studies – on the one hand – focus on specific variables at specific levels of analysis. Their results, hence, are specific to that level of analysis. On the other hand, there are studies that focus on specific error-cases that span various levels of analysis, but their results are difficult to generalise. Currently, there is a need to examine the process of learning from errors at different levels of analysis and, the more importantly, the linkage between these levels. Multi-level analysis can serve the purpose but it is difficult to realise empirical designs that fulfil all the criteria for application within the daily workplace setting (cf. Bauer and Mulder 2013; Leicher et al. 2013). The observation that much of research on learning from errors focuses on micro-level analysis suggests that these studies do not offer insights that can be derived from exploring

errors on the meso- or macro-levels. However, the ultimate goal of investigating learning from errors is to improve individual and social practices of dealing with errors. Research designs should be developed and implemented with a view to achieving this goal.

26.5.2 Error Types and Severity

Chapter 1 presented the taxonomy of errors proposed by Hofmann and Frese (2011a). This taxonomy distinguished errors based on different levels of cognitive action regulation. This cognitive approach to classifying errors dates back to the works of Reason (1990) and Rasmussen (1987). Fewer attempts have been made to distinguish errors by their scope, that is, by the severity of the effects resulting from them. While it seems plausible that in practice 'small' errors, which concern just a few persons, will be dealt with differently than 'big' errors, which affect many persons, there is little evidence that explains how scope of errors relate to their learning potential. Several authors have suggested that small-scope errors or the so-called 'near misses' (i.e. errors that did not result in adverse events) bear a special learning potential (e.g. Aspden et al. 2004; Barach and Small 2000; Glendon et al. 2006; Oser et al. 2012). The rationale behind this assumption is that the analysis of small-scale errors is free from the emotional strain and stress of error management, allowing cognitive resources to be allocated to the analysis of potential error causes. To our knowledge, however, this conjecture still has to be validated empirically. An important research question in this context would be if 'small' and 'big' errors are dealt with differently across various test-persons.

From a methodological point of view, the cognitive error typologies discussed by Reason (1990) or Hofmann and Frese (2011a) and severity-based classification are problematic. The first one refers to levels of action regulation, which implies knowledge about the mental processes underlying the error case. However, this knowledge is not easily accessible as a vast number of research on intuitive decision making and behaviour indicate that knowledge may remain tacit (e.g. Betsch and Haberstroh 2005; Sadler-Smith 2010). Severity-based categorisation of errors tends to further complicate the theoretical problems addressed above that arise from individual differences in processes of error attribution. Because the understanding and interpretation of error incidents can differ greatly among individuals (Harteis et al. 2008), it may be difficult to empirically measure, the potential magnitude of an error. For this purpose, it would be necessary to either ask all concerned persons about their perception of the error case (which, of course, raises the issue of error attribution) or involve a third person to judge the case or situation (which raises the issue of validity of that judgement). Another alternative – which further complicates the issue – was introduced by Oser and colleagues (2012) who studied participants' experiences of almost-errors, that is, incidents that almost failed but induced emotional and cognitive responses similar to factual error episodes. Thus, instead of distinguishing types of errors, they recommend a classification based on subjective

experiences of episodes which (almost) fail (Oser et al. 2012). Rausch (2011) also experimented with a promising strategy that focuses on the emotional reactions induced by error situations and their learning implications.

26.5.3 Problems of Validity

While it is important to understand episodes of dealing with errors, it is also equally important to explain the influences that promote or restrict learning from errors in the context of daily working life. This brings into focus the explanatory power of the data generated by empirical studies. It is well known that explanatory power is higher if the various cases observed in empirical studies coincide in their pattern of dealing with errors and their effects. Empirical evidence on how best to support learning from errors originates from clear and coherent patterns of reactions of different test persons or subjects. However, this evidence implies that the individual reactions of the subjects are comparable, which is not necessarily true. In fact, one of the main methodological challenges in investigating learning from errors is the requirement to keep information comparable across all test persons when different approaches to dealing with errors. The issue of authenticity emerges as soon as concrete error episodes are to be integrated into empirical studies. Two options exist: the first option – used in qualitative research – entails asking the subjects to recall and describe error episodes in order to gather reflections and mental processes related to these episodes. The second option involves the use of standardised error episodes that elicit reflections. Both options bear specific advantages and disadvantages (Bauer 2008).

The investigation of recalled error episodes provides access to subjective experiences of dealing with errors, but only in the context of individual interpretations. These may be problematic for two reasons. Firstly, individual biases, memory gaps or social desirability may colour subjects' responses, which may severely limit the validity of such data. Secondly, analysing experiences of different subjects demands the development of analytical patterns that allow for comparison of reports from different subjects, situations and workplaces. However, the data generated refer to different episodes and backgrounds. These analytic patterns reflect researchers' theoretical assumptions about subjects' way of dealing with errors. It is the quality of these reflections that shapes the quality of the analyses, as also the quality of findings and their explanatory power.

The second approach of presenting standardised error episodes (e.g. by vignettes or videos) generates data that refer to the same episode. It allows, therefore, the direct comparison of answers from different subjects. However, this research strategy forces subjects to describe possible reactions within their working environment. At best, it is a hypothetical (and subjectively biased) description of what would happen if the presented error actually occurred. In other words, this approach can only access hypothetical working practices. Its explanatory power depends on whether the hypothetical working practices represent factual working practices.

Both the options of investigating learning from errors bear challenges that relate to the authenticity of research material – whether created (i.e. standardised stimuli) or induced (i.e. remembered episodes). The development of standardised stimuli that are experienced authentically by the subjects requires in-depth knowledge about the workplace conditions. The presented stimuli should be relevant to the individual as well as to the organisation. Otherwise, the generated data may not be useful. For such research attempts, it may be better to first conduct qualitative research that explores the processes and conditions of learning through errors in the sampled working environments. A triangulation study design should be considered to increase the validity and reliability of the data. Further research should probably aim at developing a framework that enables researchers to compare cases of authentic error episodes.

26.6 Conclusions and Practical Advice for Further Research

Over the last two decades, the issue of learning from errors has become increasingly popular in the field of educational research. The theoretical underpinnings discussed in this article reveal challenges for investigating as well as facilitating learning from errors at the workplace. The processes of identifying and dealing with errors are highly dependent on subjective interpretations and assumptions which may differ substantially across subjects. Additionally, the environmental settings at workplaces shape the context for dealing with error cases. Hence, subjective as well as collective influences essentially guide the practice of dealing with errors. Empirical studies usually focus on specific levels of analysis, specific cases or specific organisations. There is still a need for larger field studies, cross-sectional as well as longitudinal. Large cross-sectional studies can clarify the interrelations between individual, collective and organisational approaches to dealing with errors (e.g. by applying multi-level analyses). Longitudinal studies would allow for identification of learning processes and outcomes resulting from errors and their individual and organisational impact. This will help overcome the problem of studies relying on subjects' remembered error episodes and their descriptions of how these errors were dealt with.

Though errors are still a sensitive topic in most work settings, the willingness of organisations to address this issue proactively and to participate in related research projects seems to have grown. One reason for this is that programmatic concepts underlying present-day work organisations support openness to critical issues and workplace learning. The globalisation paradigm has introduced permanent changes in and fierce competition among enterprises in all economic and administrative sectors. Future demands are expected to change quickly and remain at least partly unpredictable. However, enterprises and their employees have to react appropriately and quickly; that is, they should be able to act competently and should commit to the idea of lifelong learning by continuously developing their competences further. Approaches that favour strict regulation of inner-firm processes are considered

inappropriate because future development is not foreseeable. Hence, employees should behave innovatively and creatively within their teams. Such behaviour, however, implies the risk of failing, which necessitates that employees and enterprises adopt an open approach towards errors (e.g. positive error culture and error orientation) (Gartmeier et al. 2009). Educational research on learning from errors is, therefore, relevant and important to most organisations.

Nevertheless, researchers may experience a different reality. Enterprises still perceive inner-firm practices and organisational behavioural patterns as their private concerns and may be sceptical about the usefulness of opening their gates to independent research, particularly on learning from errors. Industrial and service companies often conduct such research either within own departments (e.g. human resource development, organisational development) or by hiring commercial consultancies, because these options allow them to control the results and findings. Independent research, of course, may uncover uncomfortable results, especially if there are wide gaps between programmatic ideas of business philosophies and practices of social behaviour. Moreover, independent researchers are keen to publish findings and discuss them within the scientific community.

Thus, getting field access for research on learning from errors can be quite challenging. Our experience of working with organisations in the industry, service and healthcare sectors suggests that two basic requirements have to be met for getting access. First, as it is probably the case for most research in organisations, it is necessary to get access to and convince one or several upper management members. Typically, this will be a person in charge of organisational development, quality, or personnel management. We found that – once the ice is broken – these people are frequently intrinsically motivated to adopt a critical approach towards errors and to receive suggestions for improvement. Here, gaining trust of the organisational members is as important as making solid mutual agreements on the later use of the gathered data. A key issue is to ensure that data on errors remain anonymous and are not used for taking disciplinary or legal action against individual members of the organisation (a major problem in the health care sector). Moreover, the researchers should be able to provide a compelling plan for the implementation of the study and show how the data will be useful for organisational development. For the latter, it is helpful to highlight the synergies between the research project and efforts that are already being made at the organisation.

Once field access has been granted, a second, and maybe even more challenging, step is recruiting participants from the organisational staff. In our experience, getting access to the company through the management has rarely ensured the participation of big groups of employees. In the case of research on errors, the managements' support might even arouse suspicion and negative reactions on the employees' part. To alleviate such concerns, researchers should communicate with employees' representatives and negotiate the details of data collection with them. Building a trustful relationship will involve stressing the independent role of the research team, clarifying the intended use of the data and explaining how the findings will improve their work. Despite such efforts, problems may occur, especially if the representatives of the management and the employees strive to accomplish their individual

(and potentially opposing) goals and demand concessions from the researchers. Hence, constraints have to be acknowledged which may sometimes require pragmatic thinking on the part of the researchers.

After the study has been conducted, efforts to communicate its results should go beyond providing a written report. Practitioners in organisations frequently lack the skills to interpret research data and to consider their conclusiveness. Moreover, with a topic as sensitive as errors, conflicts of interpretation might occur among the organisational stakeholders. From our perspective, it is a good practice for the research team to conduct joint workshops with all concerned parties to discuss the results and potential conclusions of the study. The researchers' role in this context is to communicate key findings, facilitate their interpretation and clearly state the limitations of the study.

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