Chapter 3
Research on Individual Learning from Errors in the Workplace – A Literature Review and Citation Analysis

Andreas Rausch, Johannes Bauer, and Michael Graf

Abstract In the scientific community of research on workplace learning, there is a growing interest in learning from errors in the workplace, including learning from mistakes, incidents, near-misses and so forth. In this chapter, we provide an overview of theoretical approaches to individual learning from errors at work and we present results from a systematic review of publications on individual learning from errors in the workplace, which included 29 relevant publications from 2007 through 2018. Of these, 20 articles reported on empirical research, five articles are theoretical and four articles are literature reviews. Nine of the empirical studies relied on quantitative data, while in six studies only qualitative data was collected and five studies relied on mixed methods. Interviews and questionnaires were the most common methods of data collection. Most studies were conducted in the context of nursing, followed by a variety of commercial contexts. The majority of the articles focus on presage (input factors) and the process of learning from errors, while research on outcomes of learning from errors is scarce. Furthermore, we conducted a citation analysis of the selected publications that revealed the continuing influence of the research group at the University of Regensburg (Germany). The most cited journals in our sample are published in the United States and have broad focuses on either psychology or management, while only two of the top ten cited journals are focused on workplace learning. In summary, research on workplace learning in general and on learning from errors at work in particular seems to be widespread over a multitude of disciplines, and thus over many different journals, while a group of German researchers appears to be particularly active in the field. Differentiated measures of outcomes, domain-specificity, multiple data sources and replication studies are discussed as future directions of research on learning from errors in the workplace.

Keywords Learning from errors · Workplace learning · Literature review · Citation analysis

A. Rausch (✉) · J. Bauer · M. Graf
Faculty of Business Administration, University of Mannheim, Mannheim, Germany
e-mail: rausch@uni-mannheim.de

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3.1 Introduction

In the last decades there has been growing interest in learning from errors as a facet of informal learning in the workplace. In his seminal book *Human Error*, James Reason (1990) points out that for many tasks there are only a few correct ways of performing but numerous ways to bungle them. Though errors in the workplace usually increase costs, generate negative publicity, decrease customer satisfaction, or even cause fatal accidents (Zhao & Olivera, 2006), one hundred percent error avoidance seems impossible (Goodman et al., 2011; Reason, 2000). Therefore, learning from errors that occur despite prevention efforts is fundamental to avoid their reoccurrence (Goodman et al., 2011). In line with Reason (1990), we refer to error as a broad term that includes mistakes and near-misses (see below).

Learning from errors plays different roles on the different levels of workplace learning (Goodman et al., 2011; Harteis et al., 2012). Lei et al. (2016, p. 1318) classify errors at the organizational (or system) level, team level and individual level (see also Harteis & Bauer, 2014). Error-related research on the organizational level usually focuses on error management (Goodman et al., 2011), and error culture (Harteis et al., 2008) in organisations. Research on the team level focuses on team climate and psychological safety as parameters of handling errors (Edmondson, 1999; Edmondson & Lei, 2014) or on effects of error management training (Keith & Frese, 2008), for instance. Finally, the individual level of learning from errors addresses individual learning gain through experiential learning from errors, as well as related reactions and attitudes toward errors (Harteis et al., 2012). Following Tulis et al. (2016), the individual perspective on learning from errors can be further classified into research on general differences in how individuals react to success and failure (attribution styles), research on error-specific dispositions such as error orientation (Rybowiak et al., 1999), and research on individual state reactions to errors such as emotions and coping (Brown et al., 2005; Zhao et al., 2014; Rausch et al., 2017).

In the present chapter, we aim to provide a systematic review of individual learning from errors in the workplace. Hence, organizational factors such as error culture or error management are considered as influencing individual learning, but they are not at the core of this review; general studies of accidents, incidents, reliability, or safety are also excluded. Narrowing the focus on individual learning from errors corresponds with the structure of this handbook and allows us to go more into detail. We draw upon and extend prior literature reviews in this field. Bauer and Mulder (2008), Bauer et al. (2012), Harteis et al. (2012), Harteis and Bauer (2014), and Lei et al. (2016), have already provided elaborate overviews of the field, though from different perspectives. According to these reviews, research on individual learning from errors varies greatly in its theoretical foundations and in empirical approaches (Bauer & Mulder, 2010, p. 111). Moreover, there still seem to be different schools of research on the topic that hardly recognize each other because they come from different disciplines. Hence, in the present review, we aim to extend these previous studies by pursuing three goals. (1) In our narrative review we aim to provide an

overview of outcomes, drivers and barriers of learning from errors based on prior research. (2) Furthermore, since there is a growing body of publications in the past decade, a second aim is to provide a systematic overview of these publications and applied methods for researching learning from errors in the workplace. (3) Finally, a third aim of our review is to identify influential researchers by means of a citation analysis. By providing a differentiated overview of theoretical approaches, empirical findings, and influential researchers, we aim to facilitate further research and theory development.

3.2 Research on Errors and Learning from Errors in the Workplace

In the theoretical section, we define errors from different perspectives, discuss the processes and outcomes of learning from errors in the workplace as well as individual and contextual factors. Finally, we give an overview of Methods and issues in researching learning from errors in the workplace as the basis of our literature review.

3.2.1 Perspectives on Errors in the Workplace

From the perspectives of action theory and self-regulation, errors occur within goal-directed behaviour. In the workplace, the goals which are pursued are work goals, for instance, processing sales orders, mounting a syphon, or driving a bus. Errors are observable as a deviation of an actual state of goal achievement from the expected one. In addition, a critical component of errors is that the non-achievement of a goal could have been avoided. This means the error is not due to intentional experimentation ("trial and error"), intentional violation of norms and standards or uncontrollable circumstances (Frese & Zapf, 1994; Ramanujam & Goodman, 2011; Reason, 1995; Zhao, 2011; Zapf & Reason, 1994; Zhao & Olivera, 2006). This also helps to distinguish individual errors from broader constructs such as accidents or incidents that could also be due to reasons other than individual errors (Goodman et al., 2011). Almost-mistakes, nearby-mistakes or near-misses are labels for action sequences in which an initial error occurred (Reason, 1990) but the consequences are just foreseen and prevented, and the goal is still achieved (Oser et al., 2012, p. 55). While the deviation of actual state and goal state is the manifest (observable or foreseeable) result of an error, the error itself remains latent,[1] i.e. 'non-observable'. That means,

[1] In this context, 'latent' does not entail the concept of 'latent errors' as referred to by Ramanjun and Goodman et al. (2011). They define 'latent errors' as deviations from standards, rules or routines that can *potentially* generate undesired outcomes but have not yet resulted in these negative outcomes.

various errors in perception, thinking or action can be the reason for the non-achievement of the goal (Weingardt, 2004).

From a cognitive perspective, errors can be attributed to different levels of information processing. The most prevalent classification of error types is based on Reason (1990). Errors which result from some failure in the execution of a planned action sequence are referred to as *slips* and errors due to a failure in the storage of an action sequence are referred to as *lapses*. In contrast, *mistakes* are defined as judgmental or inferential failures in selecting goals or planning action sequences. Reason (1990) states that mistakes are more complex because there might be different opinions on desirable goals and adequate plans. Furthermore, even a promising plan can turn out to be deficient once it is put into action. Mistakes can further be divided into failures of expertise, which are located on Rasmussen's (1983) rule-based level or processing, and lack of expertise located on Rasmussen's knowledge-based level of processing. However, in empirical studies, it proved to be difficult to distinguish between knowledge-based errors and rule-based errors. The same holds true for the empirical distinction between slips and lapses. Hence, these subtypes are often merged and only two types of errors—mistakes on the one hand, and slips and lapses on the other hand—are contrasted (Bauer & Mulder, 2007; Gartmeier et al., 2010a; Rausch et al., 2017). These generic distinctions often need to be differentiated further when applied to specific domains. For example, Gartmeier et al. (2010a, p. 11) list the following categories of knowledge-based and rule-based errors in the domain of elder care nursing: inadequate interpretation of a situation, non-application of a new or up-to-date method (i.e. non-application of a good rule), application of out-of-date 'rituals' and methods (i.e. application of a bad rule), lack of knowledge about current guidelines or standards (i.e. deficient knowledge), wrong application of a method because of lack of knowledge (i.e. wrong application of a good rule), not asking someone experienced when uncertain, not challenging orders from a supervisor, errors in interpersonal relationships (i.e. inappropriate communication) (see Bauer & Mulder, 2007 for similar distinctions in hospital nursing).

From an emotional or motivational perspective, errors can be interpreted as a negative feedback within motivated (i. e. goal-directed) behaviour. Thus, errors usually provoke negative emotions because they indicate the avoidable non-achievement of a goal (Rausch, 2012a; Oser et al., 2012; Zhao, 2011). These negative emotions may trigger reflections (Oser, 2007), given that "… the individual is concerned about the incident" (Harteis et al., 2008, p. 225). The absence of any negative emotions after error detection would even challenge the definition of an error because one could question whether there was any goal commitment directing the action (Rausch, 2012a). At least, these goals must have been of very low significance. However, too strong negative emotions may also limit the cognitive capacity to elaborate on an error and its sources (problem-focused coping) but instead result in ego-defences and emotion-focused coping (Brown et al., 2005; Rausch et al., 2017;

Zhao et al., 2014). Furthermore, strong negative emotions may also decrease the motivation to engage in the respective work activity (Schwarz & Bless, 1991; Zhao et al., 2014). Negative emotions as a consequence of one's error also depend on one's role (expert vs. novice) and how others react to the error (supporting vs. blaming), which both point to the social context.

The social perspective on learning from errors refers to who defines errors, who commits errors and how others react to errors. Errors are defined as a deviation from social norms or formal standards (Harteis et al., 2008), which are supposed to be known, shared and accepted in a particular work community (Billett, 2012). This means that any community member is supposed to adopt these more or less observable rules and he or she has little scope for divergent interpretation of what an error is. This is a strong assumption because there might be different reasonable opinions on desirable goals and adequate plans (see above). One might argue whether an unorthodox plan that has led to a deviation from a desired goal constitutes a mistake or whether the actor took a calculated risk. In the latter case, the non-achievement of the goal would be due to intentional trial and error or uncontrollable circumstances. However, depending on the significance of the goal, the work context, and the severity of the consequences, it might have already been a mistake to implement a risky plan (see concept of 'latent errors' by Ramanujam & Goodman, 2011). Hence, for the social perspective of errors, it is important to consider shared values, work practices, norms and so forth within the respective community of practitioners. Concepts such as communities of practice by Lave and Wenger (1991) and Wenger (Wenger, 2008), activity theory (Engeström, 2001) or practice curriculum and pedagogies by Billett (2014) offer frameworks for analysing the development and acquisition of shared practices. Referring to handling errors and learning from errors, a community's error culture and team psychological safety are important factors (Cannon & Edmondson, 2005; Edmondson & Lei, 2014; Harteis et al., 2008; van Dyck et al., 2005). Furthermore, it is important who commits an error. It might be more tolerable if new members of a community commit errors because they are not supposed to have already internalized the prevailing norms and standards of practice. Consequently, critical tasks are usually not assigned to newcomers but instead newcomers are in a position of legitimate peripheral participation (Billett, 2014; Lave & Wenger, 1991). For instance, Zhao et al. (2018) investigated the effects of trainers' reactions to errors in the workplace on trainees' learning from errors. While in formal education, classrooms (should) provide a safe environment for free exploration and learning from errors (see "productive failures"; Kapur, 2014), applying trial and error is not a common approach to solving problems in the workplace because work goals have to be achieved and, thus, errors are usually to be avoided (Rausch et al., 2015). Trial and error and free exploration at work might be tolerated to some extent when applied by newcomers as long as no severe consequences can result from these errors. Again, this error tolerance is subject to negotiation in the respective community.

3.2.2 *Learning from Errors in the Workplace*

Learning from an error in a particular work task becomes manifest in a modified disposition for behavior in similar subsequent work tasks, enabling the person not to commit the respective error again. The process of learning from errors usually involves a conscious reflection and elaboration on what went wrong and why it went wrong. After the detection of an error (and maybe after emotion-focused coping), effortful cognitive and metacognitive activities within a problem-focused coping approach are supposed to facilitate learning (Boekaerts, 2011; Gross, 1998; Lazarus & Folkman, 1987; Tulis et al., 2016). Based on models of experiential learning (Kolb, 1984), learning from errors involves (1) reflecting on the causes of an error, (2) improving one's action strategies and (3) experimenting with and implementing these revised strategies (Bauer & Mulder, 2007; Harteis et al., 2012). However, learning from errors may also occur unnoticed in terms of implicit learning as a consequence of sequences of many small errors without severe consequences, for instance when improving one's touch typing. Particularly in the case of slips and lapses, the knowledge of how to complete the task successfully was available beforehand but only the storage of the intention, the retrieval of knowledge or the execution failed. Thus, learning outcomes often refer to metacognitive monitoring and may be as basic as one's intention to be more focused and attentive the next time.

In case of mistakes, the learning outcome is what Oser et al. (2012) define as *negative knowledge* that "… refers to memories related to events, things, procedures or strategies that are experienced as false, inadequate or ineffective" (Oser et al., 2012, p. 54). This knowledge is also connected to memories of the negative consequences, such as being blamed, and the negative feelings such as shame and guilt that were experienced in the error episode. In similar subsequent situations, this negative knowledge serves as an alert system that helps avoid errors or near-misses (Oser et al., 2012). However, knowing how something does *not* work does not necessarily imply knowing how it works. Hence, negative knowledge has only a supportive function for positive knowledge. To learn from mistakes (i.e. the failure or lack of expertise) often requires further information that may be retrieved from codified sources of information (manuals, guidelines, Internet research etc.) or from others (colleagues, supervisors, customers, mentors etc.). In a diary study on learning from problem solving in the workplace Rausch et al. (2015) found that social interaction such as help seeking and feedback is most important for learning, especially for newcomers.

Outcomes of learning from errors can further be conceptualized on a more fine-grained level following Eraut's (2004a, p. 265; 2004b, p. 207) taxonomy of what is being learned in the workplace. He distinguishes (1) task performance (speed, fluency, complexity of tasks, etc.), (2) awareness and understanding (other people, contexts, situations, problems, risks etc.), (3) personal development (self-evaluation, handling emotions, ability to learn from experiences, etc.) (4) teamwork (collaboration, facilitating social relations, joint planning etc.), (5) role performance (prioritisation, responsibilities, leadership, delegation etc.), (6) academic knowledge and

skills (use of evidence and argument, accessing formal knowledge, theoretical thinking, etc.), (7) decision making and problem solving (when to seek expert help, dealing with complexity, problem analysis, etc.), and (8) judgement (quality of performance, priorities, levels of risk, etc.). Apparently, learning from errors can contribute to all of the above learning outcomes. Zhao et al. (2014) emphasize the effect of error attribution on what is being learned. If an error is attributed to poor task monitoring, then additional resources will be dedicated to monitoring; if an error is attributed to incorrect task rules, then an individual will try to improve his or her action scripts; if an error is attributed to a failure on the global level of the self, individuals will often engage in off-task, self-directed thoughts and ego-defenses that impede one's self-regulation (Zhao et al., 2014; see emotional perspective on errors). However, as is typical in informal learning, learning is often not even recognized as such and "the resultant knowledge is either tacit or regarded as part of a person's general capability, rather than something that has been learned" (Eraut, 2004a, p. 249). In general, research on the very outcomes of workplace learning is scarce (Rintala et al., 2019).

3.2.3 Individual and Contextual Factors of Learning from Errors in the Workplace

According to Tynjälä's (2008, 2013) 3-P-model of workplace learning, individual factors ('learner factors') and contextual factors ('learning context') as well as their interpretation by the learning subject play important roles in workplace learning. Both, individual factors such as domain-specific competences or general personality traits like attribution style and contextual factors such as the organization of work or the perceived work climate are considered to be relatively stable over time. Regarding individual factors, the concept of error orientation comprises several attitudes towards and behaviors in error situations. (1) Error competence refers to one's capability to deal with errors immediately when they occur. (2) Learning from errors refers to the long-term effects of reflecting on errors after they have occurred. (3) Error risk-taking refers to a general openness towards and acceptance of errors in order to achieve higher work goals. (4) Error strain means that someone is afraid of making errors and tends to react to errors with strong negative emotions. (5) Error anticipation comprises the realistic view that even in one's field of expertise errors may occur and also a general negative attitude to errors. (6) Covering up errors describes a tendency to consider errors as a threat and to avoid accusations by not admitting one's errors (Rybowiak et al., 1999). Regarding contextual factors, sociocultural constructs such as psychological safety (Edmondson, 1999; Edmondson & Lei, 2014), team climate (Naveh et al., 2005), learning culture (Littlejohn et al., 2014) or error culture (Harteis et al., 2008) are considered to exert an influence on individual learning from errors. Error culture refers to the extent that social contexts allow for admitting errors, reflecting on errors, discussing their causes and learning

from them, rather than covering up errors and blaming each other (van Dyck et al., 2005; Harteis et al., 2008, Oser, 2007; for an elaborate overview of the influences of an organization's learning culture. Organizational interventions and practices like error management (Goodman et al., 2011) and error management training (Keith & Frese, 2008) aim at an intentional modification of dealing with errors in an organization. The above individual and contextual factors are just a selection of influences which are discussed and investigated in research on learning from errors.

3.2.4 Methods and Issues in Researching Learning from Errors in the Workplace

In their review of methodological practices in on-the-job learning research, Berings et al. (2006) distinguished between research according to the classical paradigm which aims to explain and predict learning and mainly uses quantitative methods and research according to what they referred to as the new paradigm, which seeks to describe and explore learning contexts mainly by the use of qualitative instruments. The authors analyzed six questionnaire studies and eight interview studies to illustrate the variety of implementations. Only one of these studies, van Woerkom's (2003) questionnaire study on critical reflective work behavior, explicitly referred to errors as a source of learning. In his overview of contemporary methods in research on informal learning, Sawchuk (2009) concludes that "case study, ethnographic and interview research are by far the most prevalent forms of research carried out on informal learning and work" (Sawchuk, 2009, p. 326) because inductive and exploratory methods are common in young fields of research such as research on informal learning. However, the number of questionnaires on workplace learning has grown rapidly over the last decade (Böhn & Deutscher, 2019; Park & Lee, 2018). In the context of learning from errors, the error orientation questionnaire (EOQ) by Rybowiak et al. (1999) has been applied and adapted in many studies (Farnese et al., 2020), despite some criticism of its conceptual clarity (Bauer et al., 2004; Bauer, 2008; Böhnke & Thiel, 2016). Bauer and Mulder (2010) developed a questionnaire on learning from errors in the field of nursing that was used in several studies. Based on a domain analysis, the authors developed authentic case descriptions of typical error situations in nursing in which the misjudging of situations leads to the wrong decisions. Engagement in social learning activities (ESLA) after an error were then operationalized by two scales, 'joint cause analysis' and 'joint development of new action strategies', which are rooted in the theory of experiential learning (Kolb, 1984). In contrast to the former studies, Rausch (2014) emphasizes the advantages of a process-oriented data collection by means of diaries, since diary data and data from retrospective self-report questionnaires can differ enormously (Rausch, 2012b). However, in a recent review of research on workplace learning in general, Sutherland Olsen and Tikkanen (2018) found that descriptive studies with qualitative retrospective methods are still prevalent. Furthermore, Fejes and Nylander (2019,

p. 123) analyzed the 57 most-cited articles of three journals in the field of adult education and learning (*Adult Education Quarterly*, USA; *International Journal of Lifelong Education*, UK; and *Studies in Continuing Education*, Australia) between 2005 and 2012. Only 7% of the articles reported quantitative and 5.3% reported mixed methods, while in the vast majority or articles qualitative methods were applied. In our literature review, we investigate whether this preference for qualitative methods such as interview studies, case studies, ethnographic studies is also visible in research on learning from errors in the workplace or whether there is a trend towards more quantitative methods as questionnaires or structured diaries.

Nylander et al. (2018) also conducted a citation analysis based on 151,261 citation links between more than 33,000 different authors to identify 'dominating players' (Nylander et al., 2018, p. 114). The citation analysis revealed that E. Wenger, S. Billett, J. Lave, Y. Engeström, J. Mezirow, S. B. Merriam, D. Boud, P. Hodkinson, L. Unwin, and P. Bourdieu are the ten most cited authors in the field. In our citation analysis, we investigate whether the different theoretical and methodological stances in research on learning from errors are partly due to the influence of prominent researchers in the field of workplace learning.

3.3 Literature Review and Citation Analysis

We have conducted a literature review followed by a citation analysis. In our literature review, we analyzed articles on learning from errors regarding content areas and, if applicable, empirical methods and samples. In our citation analysis, to investigated the attention that the articles received in terms of citations, which kind of publications were cited in the articles, articles from which journal were cited most frequently, which authors were cited most frequently and whether there were noticeable patterns of citation. Moreover, we wanted to find out whether some of the most cited authors in the studies on learning from errors in the workplace are among the 50 most cited authors in Nylander's et al. (Nylander et al., 2018, p. 128f.) study.

3.3.1 Literature Review

3.3.1.1 Sampling

For the review, we conducted extensive research in relevant databases (PsycARTICLES, Web of Science, ProQuest, ERIC) and internet search engines (GoogleScholar) and applied the snow-ball-method to identify articles dealing with learning from errors in the workplace. The articles had to meet the following selection criteria: (1) Title, abstract, and/or keywords had to match the following search terms and their synonyms: a) learn, learning etc., b) error, mistake, near-miss, etc., and c) work, workplace, job, etc. (2) Furthermore, the main focus of the theoretical

or empirical articles had to be on individual learning from errors at work. That means that articles were to be excluded if they mainly focused on further (formal) education and guidance, organizational learning, error culture, etc. without considering individual learning. If, for instance, an article investigated error culture as an influencing factor of individual learning from errors at work, the article was included. (3) We limited our review of articles to those published since 2007 (until late 2018, when this manuscript was prepared). (4) The articles had to be published in the English or German language. This procedure resulted in 29 articles on learning from errors in the workplace that were further analyzed with regard to their basic approach (empirical vs. theoretical), and in case of empirical articles regarding methods and samples as well as their main focus by distinguishing input/presage factors, processes, and outcomes according to Tynjälä's (2013) 3-P-model.

3.3.1.2 Results

Table 3.1 provides an overview of the 29 articles on learning from errors in the workplace. We distinguish between three types of articles; empirical study, theoretical concepts, and literature review. Referring to Tynjälä's (2013) 3-P-model, the focus of a study can be presage (i.e. input factors such as individual dispositions or contextual influences), process (i.e. learning activities, emotional states, coping etc.), product (i.e. what is being learned from errors) or a combination thereof. In addition, the focus can also be methodological if the article elaborates on different ways of measuring learning from errors. In case of literature reviews, no such distinction is made because literature reviews usually comprise all of these four issues. Finally, the number of citations in other publications was investigated in Google Scholar.

There were 20 articles that reported on empirical research, five articles are theoretical and four articles are literature reviews. Nine of the empirical studies relied on quantitative data, in six studies only qualitative data was collected and five studies relied on mixed methods. Interviews and questionnaires were the most common, while critical incident techniques and more or less standardized diaries were applied less frequently. Most studies were conducted in the context of nursing, followed by a variety of commercial contexts. The majority of the articles focuses on presage (input factors) and the process of learning from errors. Only a few articles focused on the product of what is being learned from errors.

Regarding authors, in total, the analyzed 29 articles were published by 31 researchers. Ten authors contributed to more than one article. Table 3.2 lists these ten authors with country, affiliation, research discipline, Researchgate (RG) score (if available; as a rough indicator for one's overall impact), ordered by the number of articles in our sample, to which they contributed (authorships). Remarkably, nine out of ten authors are from Germany and most of them are related to a research group at the University of Regensburg (see discussion). Regarding the RG scores, many of the frequent authors in our sample of articles have a quite high impact in general.

Table 3.1 Overview of the 29 analyzed articles in our literature review

No.	Authors	Year	Title	Type	Focus (presage, process, product and/or methodological)	Method of empirical study	Sample of empirical study	Citations (Google Scholar)
1	Bauer, Johannes Mulder, Regina H.	2007	Modelling learning from errors in daily work	Empirical study	Process	Semi-structured interviews (qualitative)	10 experts in hospital nursing from three German hospitals	103
2	Harteis, Christian Bauer, Johannes Haltia, Petri	2007	Learning from errors at the workplace – Insights from two studies in Germany and Finland	Empirical study (two studies)	Presage Process	Questionnaires and semi-structured telephone interviews (mixed method)	28 white-collar and blue-collar workers from several German companies 14 white-collar and blue-collar workers from the Finnish shipyard industry	21
3	Harteis, Christian Bauer, Johannes Gruber, Hans	2008	The culture of learning from mistakes: How employees handle mistakes in everyday work	Empirical study (two studies)	Presage Process	Questionnaire and semi-structured interviews (mixed method)	160 white-collar and blue-collar workers 28 white-collar and blue-collar workers in Germany	106
4	Gartmeier, Martin Bauer, Johannes Gruber, Hans Heid, Helmut	2008	Negative knowledge: Understanding professional learning and expertise	Theoretical concepts	Process Product	–	–	133

(continued)

Table 3.1 (continued)

No.	Authors	Year	Title	Type	Focus (presage, process, product and/or methodological)	Method of empirical study	Sample of empirical study	Citations (Google Scholar)
5	Seifried, Jürgen Baumgartner, Alexander	2009	Lernen aus Fehlern in der betrieblichen Ausbildung – Problemfeld und möglicher Forschungszugang (learning from errors in in-firm vocational training – Challenges and empirical approaches)	Theoretical concepts	Presage Process	–	–	12
6	Bauer, Johannes Mulder, Regina H.	2010	In search of a good method for measuring learning from errors at work	Literature review	Methodological	–	–	10
7	Gartmeier, Martin Bauer, Johannes Gruber, Hans Heid, Helmut.	2010a	Workplace errors and negative knowledge in elder care nursing	Empirical study (two studies)	Presage Process	Questionnaire including either the report of critical incidents or the situational judgment of error vignettes (mixed methods)	55 German nurses 276 German nurses	26
8	Gartmeier, Martin Gruber, Hans Heid, Helmut	2010b	Tracing error-related knowledge in interview data: Negative knowledge in elder care nursing	Empirical study	Product	Case study with (1) prompting task technique and (2) semi-structured interviews (qualitative)	4 German elder care nurses 3 German elder care experts	17

9	Zhao, Bin	2011	Learning from errors: The role of context, emotion, and personality	Empirical study	Presage Process Product	Quasi-experimental simulation with variations in managerial intolerance of errors; questionnaire and performance assessment (quantitative)	127 Canadian undergraduate students	123
10	Hetzner, Stefanie Gartmeier, Martin Heid, Helmut Gruber, Hans	2011	Error orientation and reflection at work	Empirical study	Presage Process	Questionnaire (quantitative)	84 German client advisors from retail banking departments	30
11	Billet, Stephen	2012	Errors and learning from errors at work	Theoretical concepts	Presage	–	–	16
12	Gartmeier, Martin Schüttelkoopf, Elke	2012	Tracing outcomes of learning from errors on the level of knowledge	Theoretical concepts	Product	–	–	20
13	Bauer, Johannes Gartmeier, Martin Harteis, Christian	2012	Human fallibility and learning from errors at work	Literature review	–	–	–	18

(continued)

Table 3.1 (continued)

No.	Authors	Year	Title	Type	Focus (presage, process, product and/or methodological)	Method of empirical study	Sample of empirical study	Citations (Google Scholar)
14	Rausch, Andreas	2012a	Errors, emotions, and learning in the workplace – Findings from a diary study within VET	Empirical study	Presage Process Methodological	Questionnaire and semi-standardised diary (quantitative)	21 German trainees in a three-year apprenticeship program to become industrial managers	15
15	Leicher, Veronika Mulder, Regina H. Bauer, Johannes	2013	Learning from errors at work: A replication study in elder care nursing	Empirical study	Presage Process	Questionnaire including error vignettes (quantitative)	180 German elder care nurses	28
16	Bauer, Johannes Mulder, Regina H.	2013	Engagement in learning after errors at work: Enabling conditions and types of engagement	Empirical study	Presage Process	Questionnaire including error vignettes (quantitative)	276 German nurses from nine hospitals	37
17	Seifried, Jürgen Höpfer, Eva	2013	The perception of error in production plants of a chemical organisation	Empirical study	Presage Process	Problem-centred interviews (qualitative)	10 German safety representatives and executives from chemical production plants	9

18	Catino, Maurizio Patriotta, Gerardo	2013	Learning from errors: Cognition, Emotions and safety culture in the Italian air force	Empirical study	Presage Process	Interviews, analysis of flight mishap cases, and observation of (de)briefings (qualitative)	37 pilots and other stakeholders at an Italian air base	122
19	Strasser, Josef	2014	Reflexion von Erfahrungen und Fehlern. Eine Voraussetzung für die berufliche Wissensentwicklung von Beraterinnen und Beratern (Reflections of experiences and errors. A requirement for the development of professional knowledge in consultants)	Empirical study	Presage Process Product	Interviews (qualitative)	20 German consultants in the field of social psychiatry	5
20	Yan, Qing Bligh, Michelle C. Kohles, Jeffrey C.	2014	Absence makes the errors go longer – How leaders inhibit learning from errors	Empirical study	Presage	Questionnaire (quantitative)	268 Californian undergraduate and graduate students	20
21	Harteis, Christian Bauer, Johannes	2014	Learning from errors at work	Literature review	–	–	–	13
22	Zhao, Bin Olivera, Fernando Edmondson, Amy C.	2014	Learning from errors in organizations: The effects of negative emotions on motivation and cognition	Theoretical concepts	Presage Process Product	–	–	2

(continued)

Table 3.1 (continued)

No.	Authors	Year	Title	Type	Focus (presage, process, product and/or methodological)	Method of empirical study	Sample of empirical study	Citations (Google Scholar)
23	Hascher, Tina Kaiser, Christine	2015	The acquisition of negative knowledge during field experience in teacher education	Empirical study	Process Product	Structured diary (qualitative)	46 German student teachers in teaching practice internships	5
24	Leicher, Veronika Mulder, Regina H.	2016	Individual and contextual factors influencing engagement in learning activities after errors at work: A replication study in a German retail bank	Empirical study	Presage Process	Questionnaire (quantitative)	178 German retail bankers	9
25	Bauer, Johannes Leicher, Veronika Mulder, Regina H.	2016	On nurses' learning from errors at work	Literature review	–	–	–	4
26	Rausch, Andreas Seifried, Jürgen Harteis, Christian	2017	Emotions, coping and learning in error situations in the workplace	Empirical study	Presage Process	Semi-standardised diary (quantitative)	22 young employees from a German sportswear manufacturer	12

27	Gartmeier, Martin Ottl, Eva Bauer, Johannes Berberat, Pascal O.	2017	Learning from errors: Critical incident reporting in nursing	Empirical study	Presage Process	Questionnaire including error vignettes (quantitative)	73 German hospital nurses (in t1; n = 65 in t2)	4
28	Ye, Qingyan Wang, Duanxu Li, Xi	2018	Promoting employees' learning from errors by inclusive leadership: Do positive mood and gender matter?	Empirical study	Presage	Questionnaire (quantitative)	202 full-time employees from different Chinese companies	4
29	Anselmann, Veronika Mulder, Regina H.	2018	Learning from errors in insurance companies	Empirical study	Presage Process	Critical incident technique (CIT) and questionnaire (mixed method)	206 qualified insurance agents from different German insurance companies	0

Note. Number of citations obtained January 2020 from Google Scholar (including self-citations)

Table 3.2 Most frequent authors in our sample of 29 articles on learning from errors at work

Author	Country	Affiliation	Discipline	RG score	Authorships
Bauer, Johannes	Germany	University of Erfurt (formerly Regensburg)	Education	25.7	12
Mulder; Regina H.	Germany	University of Regensburg	Education	n/a	8
Gartmeier, Martin	Germany	Technical university of Munich (formerly Regensburg)	Medical education	20.0	6
Harteis, Christian	Germany	University of Paderborn (formerly Regensburg)	Education	19.9	5
Anselmann (née Leicher), Veronika	Germany	University of Regensburg	Nursing science/ education	4.5	4
Gruber, Hans	Germany	University of Regensburg	Education	n/a	4
Heid, Helmut	Germany	University of Regensburg	Education	17.3	3
Seifried, Jürgen	Germany	University of Mannheim	Business education	18.1	3
Rausch, Andreas	Germany	University of Mannheim	Business education	14.6	2
Zhao, Bin	Canada	Simon Fraser university	Management and organization studies	n/a	2

Notes. ResearchGate Scores were retrieved in December 2019

3.3.2 Citation Analysis 1: Citations of the Analyzed Articles

The articles in our sample differ in the attention they have received from other researchers in terms of citations (Table 3.1). From panel (A) of Fig. 3.1 it is visible that there is a set of five highly influential papers, each of which has been cited more than 100 times. Because the number of citations depends on the time since publication, among other things, panel (B) plots citation numbers by publication age and type. It is interesting to see that the top cited paper is a theoretical piece (no. 4: Gartmeier et al. (2008)). In this paper, Gartmeier et al. (2008) adapted negative knowledge theory to the field of learning from errors in the workplace. This conception seems to have inspired many other researchers. Of the other frequently cited articles, Zhao (2011) and Catino and Patriotta (2013) are relatively recent empirical studies. They have been published in leading organizational research journals that are of interest to a broad range of disciplines and have high impact factors (*Organizational Studies*, *Journal of Organizational Behavior*; see section below). Finally, Harteis et al. (2008) and Bauer and Mulder (2007) are empirical studies published in more specialized educational journals. They are among the earliest

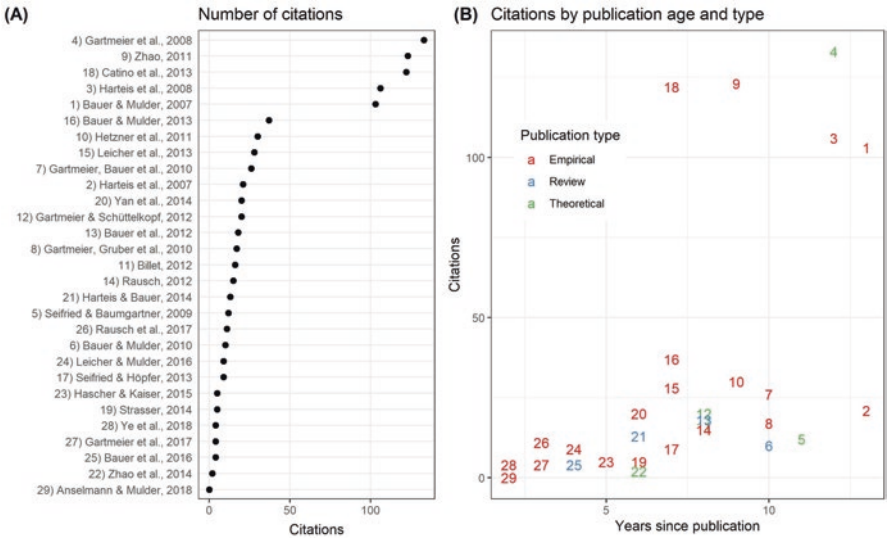

Fig. 3.1 Citations of the analyzed articles on Google Scholar

studies on learning from errors in the workplace and have been seminal to the further development of the field. The existing reviews did not receive as much attention in terms of citations as one might expect. A potential reason may be that all of them were published as chapters in edited volumes rather than journal articles.

3.3.3 Citation Analysis 2: Citations in the Analyzed Articles

In this section, we analyze the citations to other work within our sample of 29 articles on learning from errors at work. Overall, articles from 262 different journals were cited; 174 journals were only cited once. Table 3.3 lists the ten most cited journals in our sample, the number of articles cited, the category of the journal according to Social Sciences Citation Index (SSCI), the country, and the journal impact factor according to SSCI. Regarding the category, only two of the top-ten-cited journals are focused on workplace learning (*Journal of Workplace Learning* and *Vocations and Learning*). These two journals have the lowest impact factors and are the only European journals, while the high-impact journals have broad focuses on either psychology or management and are all published in the United States.

Throughout the 29 analyzed articles, a total of 1494 authors were cited, of which 1233 authors were only cited once. Forty authors were cited at least in ten out of 29 analyzed articles. Table 3.4 lists these 40 most cited authors, the number of articles in which at least one of their publications was cited, the total number of different publications that were cited in our sample, and the number of authorships in our sample.

Table 3.3 Ten most frequently cited journals in the sample of 30 articles on learning from errors at work

Journal	Number of articles cited	Category (SSCI)	Country	Impact Factor (SSCI 2018)
Journal of applied psychology	37	Psychology, applied; management	United States	5.1
Journal of Personality and social psychology	26	Psychology, social	United States	5.9
Psychological bulletin	19	Psychology, multidisciplinary	United States	16.4
Journal of workplace learning	17	Social sciences; organizational behavior and human Resource management; psychology, social	England	–
Academy of Management journal	16	Business; management	United States	7.2
Journal of organizational behavior	12	Business; management; psychology, applied	England/ United States	5.0
Psychological review	11	Psychology, multidisciplinary	United States	6.3
Vocations and learning	9	Education & Educational Research	Netherlands	1,3
Administrative science quarterly	9	Business; management	United States	8.0
Organization science	9	Management	United States	3.3

Notes. Impact factors were retrieved from Web of Science and updated in December 2019

The first ten authors were cited in 20 and more out of 29 analyzed articles, that means in at least two thirds of our sample. However, there are great differences regarding the number of different publications that were cited. For instance, the article 'Error Orientation Questionnaire (EOQ): reliability, validity, and different language equivalence' by Rybowiak et al. (1999) was cited in 25 of 29 articles. But, compared to his co-authors, Michael Frese's contribution to the field is much broader because 18 of his publications were cited at least once throughout the 29 articles. In contrast, his co-authors only appeared in that particular publication. High numbers of cited publications were found in particular for researchers who were also frequent authors in our sample of analyzed articles (e.g., Johannes Bauer, Hans Gruber, Christian Harteis). The results will be discussed further in the next section.

Table 3.4 Forty most frequently cited authors in the sample of 29 articles on learning from errors at work

Name	Number of articles cited in (max = 29)	Number of different publications	Number of authorships in analyzed sample
Frese, Michael	25	18	0
Edmondson, Amy C.	25	16	0
Batinic, Bernard	25	1	0
Garst, Harry	25	1	0
Rybowiak, Volker	25	1	0
Bauer, Johannes	24	30	12
Gruber, Hans	24	26	4
Reason, James T.	23	7	0
Sonnentag, Sabine	22	3	0
Van Dyck, Cathy	21	2	0
Harteis, Christian	19	18	5
Heid, Helmut	19	16	3
Keith, Nina	18	7	0
Zhao, Bin	18	3	2
Baer, Markus	18	2	0
Gartmeier, Martin	17	11	6
Mulder, Regina	16	10	8
Billett, Stephen	15	12	1
Zapf, Dieter	15	9	0
Oser, Fritz	15	5	0
Kolb, David	15	2	0
Cannon, Mark D.	15	2	0
Olivera, Fernando	15	2	1
Tucker, Anita	13	2	0
Ellström, Per-Erik	12	3	0
Bromme, Rainer	12	3	0
Boshuizen, Henny	12	3	0
Spychiger, Maria	12	2	0
van Woerkom, Marianne	11	5	0
Eraut, Michael	11	4	0
Kolodner, Janet	11	3	0
Hui, Chun	11	1	0
Tjosvold, Dean	11	1	0
Yu, Zi-You	11	1	0
Ericsson, K. Anders	10	7	0
Rasmussen, Jens	10	6	0
Schön, Donald	10	3	0

(continued)

Table 3.4 (continued)

Name	Number of articles cited in (max = 29)	Number of different publications	Number of authorships in analyzed sample
Moray, Neville P.	10	2	0
Senders, John W.	10	2	0
Clarke, Sharon G.	10	2	0

3.4 Discussion and Future Directions of Research

Interest in learning from errors as a facet of informal learning in the workplace has grown in the last decades. Research on learning from errors can be classified by differentiating between an organizational (or system) perspective, a team-level perspective and individual level (Lei et al., 2016). In our review, we focused on individual learning from errors in the workplace. Following Tynjälä's (2008, 2013) 3-P-model of workplace learning, individual factors and contextual factors exert influence on learning processes which lead to various learning outcomes. In the case of learning from errors, factors such as an individual's error orientation or an organizational error culture influence one's individual engagement in learning activities such as reflection and social interaction. Negative knowledge is often discussed as an individual outcome of learning from errors. Research on workplace learning usually relies on retrospective self-reports by means of interviews or questionnaires.

To provide a systematic overview of research on learning from errors at work, we conducted a literature review and citation analysis of articles between 2007 and 2018. In total, 29 articles were identified based on the following criteria: (1) keyword matches in title, abstract and/or keywords, (2) main focus on individual learning from errors at work, (3) published from 2007 until late 2018 (when this manuscript was prepared). (4) English or German language.

Regarding the types of articles, 20 of the 29 articles report on empirical research, five articles are theoretical and four articles are literature reviews. Focusing on the empirical studies, in nine studies only quantitative data was collected, in six studies only qualitative data was collected and five studies relied on mixed methods. Interviews and questionnaires were most common, in particular the presentation and evaluation of authentic error vignettes was used in the context of nursing (Bauer & Mulder, 2010). Moreover, the collection of critical incidents and more or less standardized diaries were also applied. Nylander et al. (2018) found that the majority of empirical studies on adult education and learning were limited to qualitative data, while our analysis of research on learning from errors revealed that the most cited studies applied quantitative methods. Most studies were conducted in the context of nursing, followed by a variety of commercial contexts. The majority of the articles focuses on presage (input factors) and the process of learning from errors. Error orientation is often considered an individual prerequisite and measured by the EOQ (Rybowiak et al., 1999). Processes of learning from errors were measured by questionnaires such as Engagement in Social Learning Activities (ESLA) by Bauer

and Mulder (2010). Most studies applied retrospective methods of data collection such as questionnaires. In only a few studies was data collected close to the processes, for instance by means of diaries (Hascher & Kaiser, 2015; Rausch, 2012a; Rausch et al., 2017). Moreover, only a few articles focused on the product of what is being learned from errors. These works often refer to the concept of negative knowledge. The empirical approaches range from the analysis of interview data over the classification of diary data to the measurement of performance improvements as indicators of learning.

In total, the 29 analyzed articles were published by 31 researchers. Most researchers work in general or adult education, while only a few are related to medicine and nursing or business education and management. Ten of these authors contributed to more than one article. First and foremost, it is remarkable that nine out of these ten authors are from Germany. The authors of this review are not aware of any bias towards German contributions in their review except for including two German-language articles. There seems to be a vibrant community of researchers in this field in Germany. On closer inspection, most of these researchers are related to the University of Regensburg or collaborated with researchers from that community. Helmut Heid, Hans Gruber and Regina Mulder had a long-term influence on this strand of research and Johannes Bauer, Martin Gartmeier and Christian Harteis represent a 'second generation' of researchers in this tradition, all three of them had formerly worked at the University of Regensburg.

In our sample of 29 articles on learning from errors at work, articles from 262 different journals were cited; 174 journals were only cited once. Only two of the top-ten-cited journals are focused on workplace learning (*Journal of Workplace Learning* and *Vocations and Learning*). These two journals have the lowest impact factors and are the only European journals, while the high-impact journals have broad focuses on either psychology or management and are all published in the United States. Thus, when choosing an appropriate journal to submit to, a conflict arises between journals of particular relevance to the scientific community of workplace learning and journals of high impact in general.

Within the 29 analyzed articles, a total of 1494 authors were cited, of which 1233 authors were cited only once. The ten most-cited authors were cited in 20 and more out of 29 analyzed articles, that means in at least two thirds of the analyzed articles. High numbers of cited publications were found in particular for researchers who were also frequent authors in our sample (e.g., Johannes Bauer, Hans Gruber, Christian Harteis). This may in part be due to self-citation, which is not unusual because the authors know their own work and how it contributes to their particular line of argument. As Harzing (2011) points out, self-citation should not be seen as biasing a citation analysis because it is often "a legitimate way to acknowledge the academic's previous research in the same field" (p. 4). It is more of a problem, if there is a lack of citations from other researchers. As shown above, the number of articles in which the mentioned authors were cited at least once clearly exceeds their number of authorships. Thus, many well-respected authors in the field were also authors in our sample. Some influential researchers

in the field are not authors in our sample because they were not active anymore (e.g., James T. Reason, K. Anders Ericsson) or because their focus is not on the individual level of learning from errors at work but more on the organizational level (e.g., Michael Frese, Amy C. Edmondson).

Regarding Nylander et al.'s (2018) list of the 50 most cited authors in adult learning research between 2006 and 2014, there are only five authors who are in both lists: Stephen Billett (2nd position at Nylander et al.), Michael Eraut (13th position), Donald Schön (14th position), David A. Kolb (34th position) and Per-Erik Ellström (36th position). Hence, one may conclude that the communities of adult learning research in general and research on learning from errors at work are quite distinct, though learning from errors is undoubtedly a rich source of informal learning in the workplace (Tynjälä, 2008, 2013). Nylander et al. (2018) based their analysis on only five selected journals (*Adult Education Quarterly*, *International Journal of Lifelong Education*, *Studies in Continuing Education*, *Journal of Education and Work* and *Journal of Workplace Learning*), of which only the *Journal of Workplace Learning* is among the ten most cited journals in our review. This may be seen as a limitation of comparability or as another indicator of quite scattered research communities. There is no consensus on a narrow list of relevant journals like it is common in other disciplines as, for instance, in business. Indeed, research on workplace learning in general and on learning from errors at work in particular, seems to be widespread over a multitude of disciplines and thus over many different journals.

Our literature review has some limitations. Despite due diligence, we might have overseen relevant work. For instance, chapters in edited books are not always found in databases. Furthermore, we had limited our literature review to individual learning from errors and thus, excluded publications that focused mainly on the organizational level of learning from errors, error management, error culture or more generally on safety and reliability. Hence, our review represents only one part of this topic and this, of course, influenced our findings. Our citation analysis has limitations, too. As a matter of fact, counting citations is only a vague indicator of an author's impact in the field and we are fully aware that the resulting picture might be biased for several reasons. Nevertheless, we hope we have provided an interesting new overview of our field of research.

Based on our review and our own experiences, we would like to highlight three recommendations for future research: (1) Research on learning from errors should put a stronger emphasis on the measurement of the outcomes of learning from errors. This outcome constitutes arguably the crucial dependent variable, but it has hardly been investigated in detail. One possible reason may be that the range of what is potentially learned from errors is very broad and bound to the specific error situation. Nevertheless, objective measures of one's in-role performance at work would be an informative criterium of work-related learning. (2) Future research should be domain-specific and incorporate the collection of process data, for instance by means of diaries, observational (video) studies or log file analyses where appropriate, instead of solely relying on retrospective self-report measures such as questionnaires and interviews. A combination of various data sources such as subjective diary data, objective behavioural data and objective performance would also

help to avoid common method bias which is clearly an issue if, for instance, attitudes towards errors, coping with errors and learning from errors are all measured by self-report questionnaires. (3) Replication studies on learning from errors at work are still scarce. Leicher and Mulder (2016), Leicher et al. (2013) as well as Rausch et al. (2017) replicated findings from earlier studies to some extent. Further replication studies over various contexts are needed to distinguish general mechanisms of learning from errors from domain-specific patterns.

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Dr Andreas Rausch is Full Professor of Business Education and Workplace Learning at the Business School of the University of Mannheim. His current research interests include workplace learning, simulation-based learning, competence assessment, evaluation of vocational education and training (VET) and further education, domain-specific problem solving and the role of non-cognitive factors. Andreas is committed to empirical educational research with a focus on process analysis by using, for instance, diaries or logfile analysis.

Dr Johannes Bauer is Full Professor of Educational Research and Methodology at the University of Erfurt, Germany. His research addresses the development of professional competences in higher education and during working life. Recent work addressed conditions of research reception and evidence-based practice in teaching. Moreover, he investigates the use of digital tools for training and assessing professional conversation competence in medical education.

Michael Graf graduated with a Master's degree in Economic and Business Education from the University of Mannheim and is now HR Specialist & Analyst at ID Logistics Germany GmbH. There, he is responsible for Germany-wide key figures, analyses and evaluations. In addition, he advises the company's branches in all personnel-related questions and is responsible for HR-related implementations.