Learning from Errors at Work

Studies on Nurses' Engagement in Error-Related Learning Activities

vorgelegt von

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1. Learning from errors at work: Benefit from potentially adverse events

Many people would probably agree that it is desirable to learn from one's errors. It is part of conventional wisdom that errors – although undesirable events – bear the potential to improve and to gain new insights. Popper (1968, 1992) built his philosophy on the idea that errors are the only way to approach truth as well as a functional mechanism for societal development. On the individual level, research on the development of professional expertise and workplace learning indicates that the experience of errors plays a crucial role for the acquisition and differentiation of flexibly applicable professional knowledge (Eraut, Alderton, Cole, & Senker, 1998; Ericsson, 2006c; Gruber, 1999a).

This thesis aims to explore under what conditions employees are able to put their errors at work to good use by engaging in activities that aim at learning from them. This question emerged from observations that companies and their employees often act under particular error avoidance strategies (Tjosvold, Yu, & Hui, 2004; Van Dyck, Frese, Baer, & Sonnentag, 2005; Zapf, Frese, & Brodbeck, 1999). But if errors are a useful source of learning and development, why are people averse to committing errors, particularly, if they occur in a work context (Wehner & Mehl, 2003)? On the individual level, one reason for our dislike of errors is that they cause us distress (Zapf, 1991). They indicate where we are deficient, where we did not pay enough attention, or misjudged the situation, thus questioning our standing and our pride as proficient workers. Furthermore, errors may be dangerous and can cause undesirable things to happen (Perrow, 1984). On the level of an organisation they can endanger the creation of economic value, but can also be hazardous to a company's employees or customers. The research on safety and accidents is full of examples of minor errors leading to disastrous outcomes (Perrow, 1984; Reason, 1990). As a consequence, there is a long tradition of research on human factors and safety management, aiming to provide approaches for estimating a system's reliability, evaluating the potential damage from specific errors, analysing error causes, and preventing errors (Flanagan, 1954; Glendon, Clarke, & McKenna, 2006; Rasmussen, 1987b; Senders & Moray, 1991; Zimolong, 1990).

However, the described error avoidance approach creates a dialectical tension: on the one hand, companies and their employees are keen to avoid errors; on the other hand, scholars have indicated that errors cannot be prevented completely and that too a heavy reliance on error prevention can have detrimental effects (Van Dyck et al., 2005; Kohn, Corrigan, & Donaldson, 1999; Perrow, 1984; Rybowiak, Garst, Frese, & Batinic, 1999; Senders & Moray, 1991; Volpert, 1992; Wehner, 1992; Wehner & Mehl, 2003; Zapf et al., 1999). Examples of such detrimental effects are that the potential occurrence of errors is insufficiently anticipated, that employees lose their skills in dealing with them, and that learning opportunities are missed. For these reasons, a shift from an exclusive error prevention approach towards an error management strategy has been proposed (e.g., Zapf et al., 1999). Error management concepts suggest, in addition to prevention, dealing with errors in an efficient way and learning from them. This approach is based on the assumption that a systematic analysis of occurring errors, e.g., through incident reporting databases (Barach

& Small, 2000), can provide organisations with information about necessary adjustments of knowledge, strategies, and behaviour. Consequently, the case has been made that learning from errors is an important technique of organisational learning (Argote & Todocara, 2007; Argyris, 1982; Cannon & Edmondson, 2001; Ellström, 2001; Kriegesmann, Kley, & Schwering, 2005; Peters & Peters, 1987; Senge, 1990; Sitkin, 1992).

In contrast to the existing lines of inquiry on error prevention and organisational learning from errors, the issue of individual learning from errors at work has received only marginal attention in research. There are only a few scattered studies focussing explicitly on how and under what conditions errors encountered in daily work processes can contribute to the learning of teams and individuals (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996; Meurier, Vincent, & Parmar, 1997; Tjosvold et al., 2004). A potential reason for this gap in the literature is that studies on human error and safety typically conceive humans as a source of unreliability that needs to be controlled by error prevention systems (Zapf et al., 1999; Zimolong, 1990). Some authors assume that humans cannot reliably avoid error (e.g., Reason, 1990) and focus on creating work systems that reduce the probability of errors and are error-tolerant by restricting their possible impact. Consequently, these perspectives have made only minor contributions to a theory of (individual) learning from errors (Ohlsson, 1996).

However, there is evidence from studies on learning environments – in school as well as in work contexts – indicating that the experience of errors can contribute to individuals' learning and to the improvement of their knowledge and performance (Ellis & Davidi, 2005; Heimbeck, Frese, Sonnentag, & Keith, 2003; Keith & Frese, 2005; Klockmann, 2005; Van Lehn, 1988; Meyer, Seidel, & Prenzel, 2006; Oser & Spychiger, 2005; Weingardt, 2004). Moreover, research on experiential learning, case-based reasoning, and learning through work has indicated that errors are significant sources for professional learning (Cseh, Watkins, & Marsick, 2000; Ellström, 2001; Eraut et al., 1998; Ericsson, 2006c; Gruber, 1999a; Kolodner, 1983). However, what is missing are theoretical frameworks explaining individual learning from errors during daily work, research instruments that allow its measurement, as well as systematic empirical research that directly addresses the issues of how learning from errors is related to the individual interpretation of an error and to fostering or inhibiting conditions for learning at the workplace. To know what conditions may enhance or constrain individual learning from errors at work is relevant for explaining individual differences in learning from errors and for the practical goal to create work environments that support learning from errors. Conditions on the individual and the contextual level of analysis have to be considered, because experiential learning through work emerges through the engagement of individuals in activities and interactions under the conditions of a specific workplace (Billett, 2001c). This engagement results from an interaction of the individuals' personal characteristics with the affordances and constraints the workplace provides. As for learning from errors, it has been claimed that especially the individual interpretation of an error situation as well as the quality of social relationships at the workplace shape individual responses to errors (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1999; Ellström, 2001; Rybowiak et al., 1999; Tjosvold et al., 2004). However, the few existing studies on learning from errors at work do not yet

underpin these claims systematically enough, as will be discussed later. A potential reason might be that no systematic attempts have been made to derive an operationalisation for the measurement of learning from errors from learning theory (Bauer & Mulder, in press).

1.1. Research questions

In this thesis, the aim is to contribute to closing the stated gap in research by addressing the question: *What individual and contextual variables foster or constrain employees' engagement in learning after the experience of an error at work*? This broad question is broken down into four intertwined, more specific research questions that guide the investigations. The first research question addresses prerequisites for conducting empirical research on learning from errors, namely, the conceptualisation and measurement of learning from errors.

Research Question 1. *How can learning from errors at work be conceptualised and measured?*

Research Questions 2 and 3 concern determining variables on the individual and the contextual level that are hypothesised to predict the individual engagement in learning from errors. These variables are the individual interpretation of the error situation and the perceived quality of social relationships at work.

Research Question 2. *To what degree does the individual interpretation of an error situation foster or constrain the engagement in learning from errors at work?*

Research Question 3. *To what degree does the perception of the social context at work foster or constrain the engagement in learning from errors at work?*

Although the main focus here is to investigate how the interpretation of an error and the perception of the social context predict the engagement in learning from errors, the interrelation between these predictors needs to be addressed (Research Question 4). As stated above, learning at work is assumed to be shaped by an interaction of individual and contextual variables (Billett, 2001c; Eraut et al., 1998).

Research Question 4. *How are the variables regarding the individual interpretation of an error and the perception of the social context at work interrelated?*

1.2. Outline of the thesis

The process of answering the stated research questions requires, firstly, the development of a theoretical framework that elaborates individual learning from errors at work. This framework addresses the questions how 'error' can be conceptualised, how errors that emerge in daily work processes can contribute to individual learning, and what individual and contextual variables may foster or constrain learning from errors at work. A clarification of these components is required in order to develop a research instrument for learning from errors that is based on available theories on errors and learning (Research

Question 1), and to elaborate hypotheses about the relations among the interpretation of an error, the perception of the social context, and learning from errors, that can be investigated empirically (Research Questions 2—4). A research model for learning from errors at work will be developed that includes variables regarding the individual interpretation of an error situation and the quality of social relationships at work as predictors for the engagement in error-related learning activities.

For addressing the research questions empirically, on the basis of the theoretical framework, three empirical studies are conducted in the domain of hospital nursing. The first reason for selecting this domain is that learning from errors is an urgent issue in nursing, regarding quality management and patient safety (Bogner, 1994; Kela & Kela, 2006; Kohn et al., 1999; Meurier et al., 1997; Meurier, 2000; Tucker & Edmondson, 2003). Secondly, the highly standardised nature of work processes in nursing facilitates the identification of errors and provides transparent criteria for judging actions as errors, as will be elaborated later (Büssing & Glaser, 2002; Deutsches Netzwerk für Qualitätsentwicklung in der Pflege, 2007). The studies contribute to answering the research questions in the following way.

Study 1. In Study 1 the theoretically derived conceptualisation of errors and error-related learning activities is contextualised to the domain of nursing in order to attain an operationalisation (Research Question 1). For this purpose, experts in nursing are interviewed about concrete errors that occur in nurses' everyday work and about learning activities that enable nurses to learn from these errors. The data on errors are required for the construction of authentic error cases that can be used as stimulus material in later studies. The data on the learning activities help to advance the theoretically developed framework of learning activities, to contextualise it to the domain, and to select concrete learning activities for an operationalisation of learning from errors.

Study 2. In Study 2, two research instruments for measuring learning from errors at work are developed on the basis of the findings from Study 1, applied, and compared (Research Question 1). They differ in the way in which they ground the questions on error-related learning activities in concrete error episodes. In the first instrument, vignettes of error cases that are developed from the interviews are presented to the subjects. In the second instrument, the participants are asked to describe self-experienced error episodes. Both instruments have in common that the questions on learning activities relate to the specific error situations. The findings from this study inform the decision to apply one of these instruments in the third study. Furthermore, the study provides a pre-test of the assumed relationships among the variables under investigation (Research Questions 2—4).

Study 3. Study 3 involves the application of the developed research approach in a cross-sectional field study in order to test the hypotheses about the relationships among the interpretation of an error situation, the perception of the social context, and the engagement in learning from an error, and to create more differentiated hypotheses for further research on learning from errors (Research Questions 2—4). This is accomplished in a model generating structural equation modelling process (Jöreskog,

1993) in which an initial model (a) is specified on the basis of substantive hypotheses, (b) tested, and (c) respecified on the basis of the findings and substantive considerations in order to advance the model and to provide new hypotheses for future research.

The three empirical studies build upon each other: An initial, theoretically founded conceptualisation of learning from errors is contextualised to the domain under study and operationalised (Study 1). Research instruments are built, tested, and improved on this basis (Study 2). The gathered knowledge is applied in order to test and advance assumptions about learning from errors that are derived from theory and existing findings (Study 3). Together, the studies enhance our understanding of how learning from errors at work can be conceptualised and investigated (Research Question 1), and of how the individual interpretation of an error situation as well as the perception of the social context at work may shape the engagement in learning after an error (Research Question 2—4). By doing so, the studies begin a process of answering the broader question of what individual and contextual variables foster or constrain employees' engagement in learning after the experience of an error at work, and help to ask more precise questions about learning from errors in further research.

Admittedly, the scope of this research is limited in several respects. Most important, the findings are limited to the chosen domain of nursing. It is unclear to what degree the findings generalise to other fields of work. Nevertheless, the case here adds to research on professional learning and development by providing a research approach as well as initial findings for an under-investigated, but highly relevant, way of professional learning and by situating the investigation in a domain in which this way of learning seems particularly important (Edmondson, 1996; Eraut et al., 1998; Kela & Kela, 2006; Meurier et al., 1997; Meurier, 2000). The theoretical framework of learning from errors and the suggested research approach can potentially be adjusted and applied to other fields of work and to other research questions.

The following parts of this thesis are organised as follows. In the next chapter, the theoretical framework of learning from errors is developed (Chapter 2). This framework elaborates the components of learning from errors, that is, (a) the error situation as antecedent of learning, (b) the learning process and its outcomes, and (c) individual and contextual determinants that may affect the individual engagement in learning from errors. From the discussion of conditions for learning from errors, a research model and hypotheses will be derived that are subject to investigation in the empirical part. In chapter 3 these hypotheses are summarised and an overview of the empirical studies is provided. The following chapters present the methods, findings, and conclusions from the three studies (Chapters 4, 5, & 6). A concluding chapter will summarise the findings in relation to the stated research questions and provide an outlook on issues for further research (Chapter 7).

2. Theoretical framework of learning from errors at work

This chapter presents a theoretical framework that conceptualises learning from errors at work. The discussion involves elaborating on (a) the conceptualisation of 'error' as antecedent of learning, (b) the learning process and its potential outcomes, and (c) individual and contextual determinants that are hypothesised to affect the individual engagement in learning from errors. An overview of these components of learning from errors at work is provided here, before a discussion of them in more detail in the following sections.

1. Conceptualising learning from errors requires defining what constitutes an error and what types of errors can particularly be assumed to provide a potential for learning (Section 2.1). These questions will be addressed by drawing upon cognitive and action-oriented approaches to human error that have elaborated intensively on error definitions and taxonomies (Frese & Zapf, 1994; Rasmussen, 1987b; Reason, 1990; Senders & Moray, 1991). This theoretical perspective is relevant here because it enables the conceptualisation of 'error' and of types of error in the context of goal-directed action at work (Hacker, 1998; Volpert, 1992). The discussion will start with providing existing definitions of error. Then two common characteristics of these definitions will be elaborated. Firstly, errors occur in goal-oriented action. The explication of the underlying theory of action (Hacker, 1998; Volpert, 1992) will lead to a typology of errors on the basis of a differentiation of levels of cognitive regulation of action (Reason, 1990, 1995). This typology is relevant here, because different types of error imply a different learning potential (Bauer & Mulder, 2007; Glendon et al., 2006; Keith & Frese, 2005). Secondly, errors involve a deficient deviation from a desired goal. Evaluating actions as errors involves the judgement of knowledgeable members of a field of work by drawing upon normative criteria. A definition of 'error' for the purpose of this study will be derived from this discussion.
2. In a second step, it must be clarified how learning from errors takes place and what can be learned from an error. The concept of 'learning from errors at work' implies the notion of constructing or modifying knowledge through the experience of errors encountered during daily work. Therefore, Section 2.2 starts with contextualising learning from errors in experiential learning theories and theories of learning through work (Billett, 2004b; Eraut et al., 1998; Gruber, 1999a; Kolb, 1984; Kolodner, 1983; Schank, 1999; Schön, 1983). Learning from errors will be conceptualised under two different but complementary perspectives on experiential learning: firstly, under a cognitive perspective that explains learning as the acquisition and modification of knowledge and focusses on the memory and knowledge structures involved (Kolodner, 1983; Schank, 1999; Schank & Abelson, 1977); secondly, under an activity perspective that focusses on learning in terms of the engagement in deliberate overt or cognitive learning activities (Eraut et al., 1998; Gruber, 1999a; Kolb, 1984; Schön, 1983). Whereas the cognitive perspective explains why errors provide learning chances and how learning from errors can contribute to improve action in work contexts, one of its drawbacks is that it focusses mainly on modelling cognitive processes and structures which cannot be measured directly in empirical research. The

learning activity perspective compensates for this problem by identifying concrete activities that lead to the learning processes and outcomes described by the cognitive perspective. Thereby it provides fruitful possibilities for operationalising the learning process. An initial set of learning activities will be derived from conceptions of experiential learning cycles (Gruber, 1999a; Kolb, 1984) that model experiential learning in terms of (a) reflection, (b) the development of new action strategies, and (c) experimenting with and implementing the new strategy.

3. Finally, Section 2.3 elaborates on conditions on the individual level and the level of the social context at work that are hypothesised to relate to learning from errors on the basis of substantive considerations or initial evidence. The selected variables on the level of the individual interpretation of an error are the estimation of an error situation as a chance for learning, the degree to which negative emotions are evoked by an error, and the tendency to cover up an error (Rybowiak et al., 1999). On the level of the quality of the social context, the perception of a safe team climate is investigated (Edmondson, 1999). From this discussion, hypotheses about the relation of these variables with the engagement in learning from errors will be derived.

Together, these three components build a conceptual framework of learning from errors that is required for addressing the stated research questions. The conceptualisations of 'error' and 'learning from errors at work' provide a theoretical basis for operationalising learning from errors for the empirical studies (Research Question 1). The discussion of individual and contextual variables that are hypothesised to affect learning from errors guides the investigations to answer Research Questions 2—4.

2.1. Characteristics of errors

An explanation of how individuals can learn from their errors at work requires clarifying the concept of 'error' as the antecedent of the learning process and elaborating on the question whether different types of errors bear a similar potential for learning. The goal of this section is to attain a conceptualisation of error and to make a decision which specific error type to focus upon in the empirical studies.

2.1.1. Errors as inadequate actions in relation to a goal

Cognitive and action-oriented approaches to human error provide a basis for explaining what constitutes an error, what types of error can be distinguished, and what kinds of errors provide particular chances for learning (Frese & Zapf, 1994; Rasmussen, 1987b; Reason, 1990; Senders & Moray, 1991; Volpert, 1992; Zapf et al., 1999). These approaches analyse errors from the perspective of goal-directed action and its cognitive regulation. Their conception of error is commonly used in applied studies on the occurrence and reduction of human error in work settings (Bogner, 1994; CIRSmedical, 2005; Glendon et al., 2006; Hofinger, 2002; Holzer, Thomeczek, Hauke, Cohnen, & Hochreutener, 2005; Kohn et al., 1999; Strauch, 2002). For the purpose of the present study, drawing upon

these approaches allows us to define error in the context of action in the workplace and to introduce a typology of errors that is based on the cognitive regulation of action.

Cognitive and action-oriented approaches to human error define errors as individual actions that result in a deficient deviation from a desired goal (e.g., Frese & Zapf, 1994; Rasmussen, 1987a; Reason, 1995; Senders & Moray, 1991; Zhao & Olivera, 2006). Action in this sense also encompasses decisions and omissions (Meurier et al., 1997). The following definitions are illustrative for this line of literature.

> "For my present purpose an error is the failure of planned actions to achieve their desired goal. All errors involve some kind of deviation." (Reason, 1995, p. 18)
>
> "We could, therefore, define an error as a human action that fails to meet an implicit or explicit standard. An error occurs when a planned series of actions fails to achieve its desired outcome, and when this failure cannot be attributed to the intervention of some chance occurrence." (Senders & Moray, 1991, p. 20)

These and other definitions share two characteristics (Frese & Zapf, 1994; Strauch, 2002) that are shortly addressed here, and elaborated in the following paragraphs.

1. Errors occur in goal-directed human action. Understanding how errors relate to action in work contexts requires the introduction of a theory of human action and its regulation (Frese & Zapf, 1994; Hacker, 1998; Volpert, 1992). The position will be advanced that a distinction of levels in the cognitive regulation of action leads to a differentiation of types of error (Hacker, 1998; Rasmussen, 1987a; Reason, 1990) and that especially knowledge- and rule-based errors bear a potential for learning (Bauer & Mulder, 2007; Glendon et al., 2006; Keith & Frese, 2005).
2. Errors involve a deficient deviation from a desired goal or state. Evaluating an action as 'error' implies making a judgement in respect to criteria which are implicit in the desired goal (Hacker, 1998; Rasmussen, 1987b; Reason, 1995; Senders & Moray, 1991; Volpert, 1992; Wehner & Stadler, 1989). Hence, the question of what constitutes an error depends on evaluative norms, the validity and acceptance of which may depend on the respective sociocultural environment. This norm-dependency of errors can cause problems for research on learning from errors, because one and the same action might be evaluated to be an error, or not, in different social and cultural contexts. Although this problem cannot be solved completely here, the position will be taken that it can possibly be addressed in empirical studies by focusing on authentic cases that have been judged to be errors by knowledgeable members of the domain under investigation.

2.1.2. Characteristic 1: Occurrence in goal oriented action

The first element of the error definitions presented above is that errors occur in the context of intentional, goal-directed action. Elaborating on this characteristic requires clarifying the underlying theory of human action. Action Theory (Hacker, 1998; Volpert, 1992) de-

livers an appropriate perspective for this purpose because several scholars in the field of human error directly draw upon this theory (Frese & Zapf, 1994; Zapf et al., 1999) or use identical categories to analyse the cognitive regulation of action (Rasmussen, 1987a; Reason, 1990). This communality results from joint roots in the Russian tradition of activity theory (Leontiev, 1978) and in cybernetic applications of computer-models in psychology (Miller, Galanter, & Pribram, 1960). Two features make Action Theory particularly relevant here. Firstly, it allows us to locate and describe errors in the process of action at work and enables a differentiation of error types according to the level of cognitive action regulation. Secondly, Action Theory employs similar conceptions of knowledge and learning like theories of experiential learning at work that will be used later to conceptualise learning from errors. Therefore, both lines of theory are compatible and can be integrated to build a framework of learning from errors that is required for this study. Below, first, action will be defined as a hierarchical-sequential process. Secondly, a distinction of levels of action regulation will be introduced that, thirdly, will be applied to a differentiation of error types. Finally, the learning potential of different error types will be discussed.

Action as hierarchical-sequential process. Action Theory defines action as "... goal oriented behaviour that is organized in specific ways by goals, information integration, plans, and feedback and can be regulated consciously or via routines" (Frese & Zapf, 1994, p. 271). Action represents a mediator between subjects and their environments and serves the attainment of desired outcomes. It comprises the definition of goals and subgoals, and the derivation of action plans based on one's knowledge and information about the environment.

Action has two dimensions, a hierarchical and a sequential one (Hacker, 1998):

1. In the hierarchical dimension, goals as well as actions are arranged on three strata according to their complexity (cf. Leontiev, 1978). Complex networks of actions which contribute to the achievement of superordinate goals are called *activity* and build the top stratum. While activities consist of dependent *actions* (second stratum), actions consist of dependent *operations* – e.g., movements – which build the lowest stratum[1]. Accordingly, *activities*, *actions*, and *operations* can be represented as nodes in a pyramid of hierarchically nested goals, dependent subgoals, and sub-subgoals (Hacker, 1998; Volpert, 1987). The nodes consist of so-called cyclic functional units. They comprise (a) a comparison of the actual state with the defined goal, (b) an execution to yield the goal, and (c) another comparison of the feedback resulting from the execution with the desired goal (cf. 'Test-Operate-Test-Exit'-units; Miller et al., 1960).
2. While the hierarchical dimension is structured by the complexity of goals, the sequential dimension describes action as an ordered sequence of attaining lower level goals that are required before a superordinate goal can be attained (Hacker, 1998;

[1] Unfortunately, the term 'action' is used in two ways: First, to refer to the specific level of *actions* and, secondly, in a broad sense for 'human action', encompassing all three levels. In order to distinguish these understandings, the term 'action' will be set in italics when referring to the specific level of *action*, and in normal type when referring to the broad understanding.

Volpert, 1992). Hence, 'sequential' implies the step-by-step processing of subsequent nodes in the hierarchical pyramid of related goals and subgoals.

The distinction of a hierarchical and a sequential dimension of the action process helps to enhance our understanding of errors and their role in human action in the following way. As stated above, errors involve the failure of an execution to yield a specific intended goal or subgoal, at a specific position in the hierarchical-sequential action process. Errors endanger the attainment of subsequent goals and higher order goals if no compensating steps are taken, because attaining higher order goals is dependent on attaining related subgoals (Volpert, 1987, 1992). Hence, an erroneous action establishes a 'critical situation' (Badke-Schaub, 2002) in which the achievement of the desired goal is endangered. From thereon the error may be detected and corrected, or defences in the environment may work so that no damage results (i.e., a 'near-miss'; Aspden, Corrigan, Wolcott, & Erickson, 2004; Barach & Small, 2000; Dovey & Phillips, 2004; Glendon et al., 2006; Hofinger, 2002). Otherwise, the higher order goal is failed and an 'adverse event' may occur (Reason, 2005).

In order to further understand how the hierarchical dimension of action relates to errors, a more precise description of levels in the cognitive regulation of action is required.

Levels of cognitive action regulation. The introduced hierarchical differentiation can also be applied to the cognitive regulation of action (Hacker, 1998; Rasmussen, 1987a), making a differentiation of error types according to the level of regulation necessary (Frese & Zapf, 1994; Heckhausen & Beckmann, 1990; Norman, 1981; Rasmussen, 1987b; Reason, 1990, 1995). The discussion below addresses the question how action is regulated and how the mental representation underlying it can be modelled, before turning to the differentiation of error types in the following paragraph.

Three levels of cognitive regulation can be distinguished (Hacker, 1998; Rasmussen, 1987a), that also build the basis of error taxonomies (e.g., Reason, 1990): (1) skill-, (2) rule-, and (3) knowledge-based regulation[2]. These levels of action regulation are not alternative processes, but "(...) categories of behavioural control which are probably all active at all times" (Rasmussen, 1987c, p. 294).

(1) Skill-based regulation concerns the performance of highly automated patterns of behaviour which are typically not controlled consciously. However higher levels of regulation monitor the ongoing action in relation to goal attainment. Skill-based regulation mainly occurs in the performance of sensorimotor operations, but is not restricted to them. The underlying knowledge is part of the individual's tacit knowledge, that is, it guides action but cannot be verbalised easily by the subject (Ellström, 2006; Eraut, 2000; Simons, 2005).

(2) Rule-based regulation occurs by applying routinised procedures to familiar situations. Rules are considered to be if<situation>—then<action> relations which are stored in memory and can be applied flexibly. They can be specified or adjusted to meet

[2]Frese and Zapf (1994) introduced a fourth level of metacognitive regulation. However, this is dropped by the authors themselves in a more recent publication (Zapf et al., 1999).

the requirements of a specific situation at hand. Conscious control is possible, but not necessary, at this level of action regulation. Rules can be acquired experientially from former occasions, by following instructions or guidelines, or can be developed situationally by conscious problem-solving (Rasmussen, 1987a).

(3) Knowledge-based or intellectual (Hacker, 1998) regulation is applied in situations which are novel in a sense that they cannot be accomplished with a set of existing rules. In such situations, a plan for action has to be developed on the basis of a goal-means analysis and relevant knowledge (Ellström, 2006). This includes deliberate, conscious problem solving, making predictions on the basis of mental models, experimenting, evaluating alternative solutions, and decision making.

The knowledge representations which the different forms of action regulation are based upon and that enable a person to act are called 'operative image systems' in Action Theory (Hacker, 1998). They are conceptualised "(...) as the sum of internal long-term representations of condition-action-result interrelations" (Frese & Zapf, 1994, p. 286). Operative image systems are knowledge structures that guide action and its regulation in a given situation. The term operative emphasises their action-oriented character. They comprise schematic behavioural information for given situations (e.g., movement schemata, flexible action schemata), as well as strategies, metaplans, and heuristics for intellectual regulation. Operative image systems are learned and modified through acting, i.e., through the engagement in work tasks. This is an important link to conceptions of experiential learning at work that model changes in individuals' knowledge through the engagement in work tasks and through the experience of episodes at work, as will be elaborated later (e.g., Billett, 2001b; Eraut, 2000).

The discussion of levels and bases of action regulation is important for conceptualising error, because errors can occur on every level and at any stage of the hierarchical-sequential regulation of action. Hence, a conceptualisation of error has to take into account these different levels of cognitive control in order to distinguish specific types of error (Frese & Zapf, 1994; Heckhausen & Beckmann, 1990; Norman, 1981; Rasmussen, 1987b; Reason, 1990, 1995), as will be discussed in the next paragraph.

Types of errors. Reason (1990, 1995) distinguishes two basic categories of errors: (1) *slips and lapses* (SL) and (2) *knowledge- and rule-based errors* (KRE)[3].

1. SL are failures of execution, that is, they concern the performance of an action. They result from problems in unintentional memory and attention processes and are often caused by internal or external distractions (Zhao & Olivera, 2006). In both cases, the action plan is appropriate to attain the desired goal, but the action is not performed as intended (Norman, 1981). The difference between slips and lapses is

[3]Reason calls them 'mistakes'. While this terminology is commonly accepted in research on human error and safety management, the terms 'error', 'mistake' and 'failure' are used inconsistently in research on individual and team learning from errors (Bauer & Mulder, in press). Therefore, I find it more precise to use 'error' as the superordinate term together with the appended adjectives (cf. Senders & Moray, 1991).

that slips relate to observable behaviour and result from attention problems, whereas lapses are caused by memory failures (Glendon et al., 2006; Reason, 1995).

2. In contrast, KRE concern the action plan and result from problems in the intentional application of knowledge and rules, that is, intrapersonal if-then-relations. They occur during conscious problem solving and involve decision making, inference, as well as judgement of the situation. In KRE, actions are performed as intended, but the underlying plan is deficient or inappropriate to attain the goal (Senders & Moray, 1991). Rule-based errors typically involve the misinterpretation of a situation, e.g., when well rehearsed procedures are over-generalised and wrongly applied to situations that seem to be familiar. Subcategories of rule-based errors are the 'wrong application of a good rule', 'non-application of a good rule', and 'application of a bad rule' (Reason, 1990). Knowledge-based errors result from deficiencies in the available knowledge – e.g., incomplete mental models, insufficient or wrong knowledge –, but also from bounded rationality in analysing a problem, and faulty causal thinking (Reason, 1995; Zhao & Olivera, 2006). They usually occur in novel situations which cannot be accomplished with a set of existing solutions and require deliberate planning and problem solving. The distinction between rule- and knowledge-based errors is not a sharp one, because rules are a form of knowledge, too. Besides this conceptual problem, they are empirically hard to distinguish (Bauer & Mulder, 2007). Reason (1990) treats them both as one category, as will be done here.

Below, it will be discussed in what way errors of either type provide a potential for experiential learning.

Types of errors and learning from errors. The introduced distinction between error types is relevant here, because the position has been advanced that different types of errors bear a different learning potential, or at least require different forms of learning (Bauer & Mulder, 2007; Glendon et al., 2006; Keith & Frese, 2005). Individuals can hardly learn from SL in a cognitive way and avoid them reliably, because the underlying causes are not entirely under their control (Reason, 1990, 2005). In the error management literature a system-perspective is preferred which claims that only the work system can be changed in order to minimise errors, not the fallible human condition (Reason, 2005). SL can be addressed effectively by attending to the work conditions and environment (Glendon et al., 2006). For example, if nurses keep mixing up certain remedies, then it makes sense to change the environment and put them in separate places.

In contrast to SL, KRE are based on intentional decision processes and the application of declarative and procedural knowledge. Therefore, they are accessible to learning in the sense of a change in knowledge and skills as the basis of competent action. Keith and Frese (2005) argue that the highest learning profit will occur from errors on higher levels of regulation. Glendon et al. (2006) favour learning and training as a means for reducing KRE. Hence, a narrow system perspective that is generalised over all types of errors is inappropriate. An exclusive focus on 'the system' neglects the fact that individuals are able to learn from their errors (e.g., Ellis & Davidi, 2005; Keith & Frese, 2005) and

underestimates the potential of individual error-related learning processes and competence development.

Drawn together, the position advanced here is that empirical studies on learning from errors should clarify which type of error they focus upon and provide a rationale for the ways these errors can contribute to learning. For the purpose of this study, it is decided to focus on KRE for two reasons: first, because the underlying causes of KRE may be subject to intentional change through the engagement in learning activities. In section 2.2 learning activities that are relevant for this type of error will be identified. Secondly, there seems to be a lack of research addressing KRE, leaving a gap in knowledge of a relevant category of errors (Glendon et al., 2006; Meurier et al., 1997; Zhao & Olivera, 2006).

So far, it has been discussed that errors occur in goal oriented action and that different types of errors have to be distinguished, based on the cognitive regulation of action and the knowledge underlying it. The following section elaborates on the second characteristic of error, the deviation from a desired goal.

2.1.3. Characteristic 2: Deficient deviation from a desired goal

The second characteristic of errors is that they imply a deficient deviation from desired goals (Hacker, 1998; Norman, 1981; Rasmussen, 1987b; Reason, 1995; Senders & Moray, 1991; Volpert, 1992; Wehner & Stadler, 1989). The discussion of this characteristic enhances our understanding of errors by casting light on the process of evaluating actions as errors and by addressing the inherent problem of norm-dependency. The term 'evaluation' is used in a broad sense here, that includes everyday processes of integrating data about an object (e.g., an action) and explicit or implicit standards (i.e., norms) to a global judgement of the object (Scriven, 1991; Westermann, 2002). Below, first the concepts 'deviation' and 'goal' will be defined. Secondly, it will be discussed how far the norm-dependency of judging actions as errors constitutes a problem for this study. Thirdly, a social evaluation perspective will be introduced that explains the process of evaluating actions as errors. Taking this perspective, the conclusion for the empirical studies will be to focus on concrete cases that are judged to be errors by knowledgeable members of the domain of nursing.

Deviation and goals. According to Volpert (1992), 'error' is a subclass of the broader concept of deviation. A deviation occurs, when against planning and justified expectation a goal is at least temporarily not achieved. Deviation is the broader concept because it stands for unsuccessful actions in general and not every deviation is caused by human error. In this respect, Volpert's (1992) use of the term 'deviation' is similar to the concept of 'failure' in motivational and attributional theories (e.g., Atkinson, 1986; Heckhausen, 1975; Weiner et al., 1971). In errors, the deviation is attributed to the action(s) of an actor and occurs contrary to his/her expectations and intentions (Reason, 1995; Senders & Moray, 1991; Volpert, 1992; Zapf et al., 1999). This characteristic distinguishes errors from deliberate violations of rules and standardised procedures (Reason, 1990; Volpert, 1992; Zimolong, 1990). Furthermore, it only makes sense to speak of an error if the

deviation would have been potentially avoidable by the actor (Frese & Zapf, 1994; Heid, 2005; Senders & Moray, 1991; Volpert, 1992; Zapf et al., 1999). Avoidability implies that the actor needs to have had sufficient skills and knowledge as well as available alternatives to act in a way that would have led to the expected and desired result. If this is not the case, the term accident is more appropriate (Senders & Moray, 1991).

In an action context, speaking of deviations only makes sense in relation to goals (Kleinbeck, 2006; Volpert, 1992). Goals are anticipative cognitive structures, that is, they anticipate desired states or results and guide the action process (Frese & Zapf, 1994). They imply first a motivational dimension – i.e., the desired state, which reflects individual, organisational, or societal wishes and needs – and secondly a cognitive dimension – i.e., they structure action and provide criteria of comparison for the effectiveness of an action. In work contexts, goals usually are implicit in the work tasks which are provided by the organisation and involve an implicit or explicit standard by which the achievement of the goal can be judged (Hacker, 1999; Kleinbeck, 2006; Volpert, 1992). Therefore, the norm-dependency of goals and errors has to be addressed.

Norm-dependency of goals and errors. The concept of goals implies a normative component in that goals reflect individual, organisational, or societal wishes and a normative standard is necessary to judge their attainment. If error is defined as a deficient deviation from a goal, then error itself is a normative category. As Rasmussen (1987b) argues, error can only be defined with reference to human intentions or expectations. Hence, error is an evaluative term of language which is used by a beholder on the basis of a comparison between an observed state and a normative anticipation, in order to express a deficient discrepancy between the two, not an objective characteristic of an action or a result (Bauer, 2004; Weingardt, 2004).

This normative component of errors complicates research on learning from errors because the validity and acceptance of norms and standards depends on the respective sociocultural environment (Bauer, 2004; Billett, 2001c; Harteis, Bauer, & Heid, 2006; Rasmussen, 1987b; Senders & Moray, 1991; Weingardt, 2004). One implication is that the same action may be evaluated to be an error or not if the context changes, e.g., from a high technology unit of a university hospital to a rural hospital. Billett (2001c) argues that even in occupations that seem to be similar at the sociocultural level, what is regarded an acceptable practice is largely shaped by the situational requirements of specific workplaces, influenced, however, by the goals and norms of the sociocultural practice. Even within one context, "(...) changes of the criteria of judgement, i.e., changes in requirements to system performance, in safety requirements, or in legal conventions, will be able to turn hitherto accepted performance into erroneous acts" (Rasmussen, 1987b, p. 24). Hence, the interpretation of what an error is and whether specific actions can or should be evaluated as errors, may vary substantially between contexts, between individuals in the same context, and even within one individual if the context changes. For the purpose of studies on learning from errors, this results in the task to justify why the errors under study are arguably errors for the investigated domain.

Social evaluation perspective on error. In the light of the problems discussed above, research on errors and learning from errors seems to be a dubious endeavour, because it seems to be impossible to get a firm, objective grasp on error. Although studies on human error have emphasised that actions can only be evaluated to be errors in relation to goals (Rasmussen, 1987b), these studies have not elaborated how these evaluative processes can be modelled and have not addressed the problem of norm-dependency. However, this problem is not unique to the concept of error, but concerns also other concepts that specify a quality of human action, such as 'superior expert performance' (Ericsson & Lehmann, 1996; Ericsson, 2006a) or 'creativity' (Csikszentmihalyi, 1999). Research on these concepts has addressed the problem of norm-dependency by indicating that the social evaluation of an individual's actions by knowledgeable members of a community is an important criterion for judging expertise or creativity (Csikszentmihalyi, 1999; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004; Palonen, 2003; Sternberg & Lubart, 1992).

The proposal made here is to draw an analogy from Csikszentmihalyi's (1999) model of creativity to the problem of explaining how individual actions are judged as errors. The concepts error and creativity both concern the evaluation of actions as outstanding, in either a desirable or an undesirable way. The core of this analogy is the evaluation of actions by knowledgeable members of a community by drawing upon evaluative criteria. Although Csikszentmihalyi's (1999) approach to creativity and the conceptions of human error discussed above differ in their scope of analysis – the latter employ a micro perspective on cognitive processes underlying human action and its regulation whereas Csikszentmihalyi takes a sociological perspective on how creative achievements contribute to the development of culture – the analogy is helpful for conceptualising error by modelling processes and conditions of evaluating actions as errors.

According to Csikszentmihalyi's (1999) model of creativity an individual action is acknowledged to be creative, if (a) it is judged as outstanding, novel, and useful by people with a central and powerful status, (b) in a given 'domain', i.e., a specific practice with its related rules, values, and standards, (c) at a given point of time. Norms are present in this approach in a twofold way: first, in the socioculturally and historically developed values and standards of the domain, which provide a reference framework, and secondly, in the judgement of a contribution by knowledgeable individuals that is based on their interpretation of the domain's standards and values. The reference to a given point of time acknowledges that the domain and its standards are not static but develop in the course of time.

In analogy, an action can be called an error if (a) it is evaluated as a deficient deviation from an expected standard (Senders & Moray, 1991; Volpert, 1992) (b) by knowledgeable peers or central people in a given domain, organisation, or a local community (Hakkarainen et al., 2004; Wenger, 1998), (c) at a given point of time. This social evaluation perspective on error is implicitly present in the definitions of error that were introduced above and it is illustrated more explicitly in the following two statements:

> "A nursing error was defined as any wrongful decision, omission or action for which the nurse felt responsible, that has adverse or potentially adverse con-

> sequences, *and that would be judged wrong by knowledgeable peers at the time it occurred* [italics added]." (Meurier et al., 1997, p. 133)
>
> "*If there is general agreement that an actor, Z, should have done other than what Z did, Z has committed an error.*" (Senders & Moray, 1991, p. 81)

This social evaluation perspective takes into account the hierarchical nature of work organisations which implies that usually not one actor alone evaluates whether an action is an error, but a superordinate person or group participates in the judgement, or may impose it on the actor. There are multiple sources from which evaluative criteria may be obtained. National standards for an occupation may be applied that are codified in legal conventions, as well as rules and standards fixed by an organisation, or a community's shared values and ways of doing things (Wenger, 1998). This reflects the complex interplay of goals and norms of the sociocultural practice, the requirements of specific workplaces, and individual idiosyncrasies in interpreting and enacting the practice (Billett, 2001c). For example, nurses' work is largely shaped by local guidelines and standard procedures that are supposed to reflect national 'expert-standards' based on the state of the art in medical care (Büssing & Glaser, 2002; Deutsches Netzwerk für Qualitätsentwicklung in der Pflege, 2007). These standards provide transparent criteria for errors, with the underlying norm that a patient's health or healing process must not be affected in a negative way by medical mismanagement (Bogner, 1994; Kohn et al., 1999). They may be used by members of an organisation to evaluate the appropriateness of specific actions. Although discrepancies between the espoused values of the organisation and their individual interpretation may occur, it can be assumed that an organisation and individuals in a supervisory position have the power of definition (Heid, 1999).

The introduced social evaluation perspective on errors fills a gap in cognitive and action-oriented approaches to human error by enabling analyses of evaluation processes of specific error episodes. Whereas the human error approaches describe the general structure of errors in the context of human action in terms of an action-goal relationship, the social evaluation perspective can be used to explain how and why an action is judged to be an error in a given context. For the present discussion on a definition of error, I conclude that a specific case is an error for a given domain if it has been evaluated to be one by knowledgeable members. As a consequence, I propose that research on learning from errors should be grounded in specific error cases that are collected from a domain under study. Under the social evaluation perspective, it can be explained why a specific case is assumed to be an error, whereas the development of a general definition of error for a given domain seems hardly possible in the light of the problems raised above.

2.1.4. Summary: Definition of error for this thesis

Drawing together the discussion so far, I conceptualise errors for the purpose of this study as follows.

- An error is an individual action that is performed in such a way that (at least temporarily) a goal is not achieved and the achievement of higher-order goals is endan-

gered. Action in this sense also encompasses decisions and omissions. It is important to distinguish between the erroneous action and the outcome: the term 'error' concerns the erroneous action, regardless of whether an adverse outcome results. An inadequate action establishes a critical situation in which the achievement of the desired goal is endangered. From thereon the error may be detected and corrected, or defences in the environment may work so that no damage results ('near-miss'). Otherwise, an adverse event may occur, which comprises an undesirable negative outcome.

- Errors can be classified on basis of the underlying level of cognitive action regulation. Two error types are distinguished here: (a) slips and lapses and (b) knowledge- and rule-based errors. It is crucial for research on errors to specify in advance what type of error is in focus, because errors vary in the learning potential they provide. For the present study I decide to focus on knowledge- and rule-based errors, because this errors type can be assumed to be open to deliberate changes through learning activities.
- Error is a normative category that involves judgement on the basis of normative criteria. The problem that norms are not unequivocally valid in different socio-cultural contexts cannot be solved entirely. Based on a social evaluation perspective of errors, the position advanced here is to employ a pragmatic solution by relying on concrete error cases that are evaluated to be errors by knowledgeable members of the specific work domain under investigation.

2.2. Conceptualisation of learning from errors

In this section a conceptual framework for understanding learning through errors in the workplace is advanced. Although the issue of individual and team learning from errors at work is receiving growing attention in empirical research (Arndt, 1996; Edmondson, 1996; Meurier et al., 1997; Tjosvold et al., 2004; Tucker & Edmondson, 2003), the existing studies have not yet systematically elaborated a theoretical framework that explains individual learning through errors at work and guides its operationalisation for empirical research (Bauer & Mulder, in press). Most of the studies on errors and learning from errors focus either on the organisational level (e.g., Argote & Todocara, 2007; Argyris & Schön, 1996; Barach & Small, 2000; Dovey & Phillips, 2004; Kaufmann et al., 2002; Kriegesmann et al., 2005; Sitkin, 1992; Uribe, Schweikhart, Pathak, & Marsh, 2002) or on learning from errors in organised learning environments, such as training (e.g., Ellis & Davidi, 2005; Heimbeck et al., 2003; Keith & Frese, 2005, 2008; Klockmann, 2005; Van Lehn, 1988; Meyer et al., 2006; Oser & Spychiger, 2005). Therefore, they make only limited contributions to improve our understanding of individual learning from errors at work (cf. Ohlsson, 1996).

The position advanced here is to contextualise learning from errors in theories of experiential learning and learning through work ('workplace learning') (Billett, 2004b; Eraut et al., 1998; Gruber, 1999a; Kolb, 1984; Kolodner, 1983; Schank, 1999; Schön, 1983). Learning from errors at work implies the notion of constructing or modifying knowledge through the experience of an episodic event encountered during daily work. Therefore,

individual learning from errors can be conceptualised as a sub-category of experiential learning at work. This contextualisation allows us to integrate learning from errors with conceptions of professional development that emphasise the role of experiential learning (Billett, 2004a; Boshuizen, Bromme, & Gruber, 2004b; Eraut, 1994, 2000; Ericsson, 2006a; Gruber, 1999a; Gruber, Harteis, Mulder, & Rehrl, 2005; Kolb, 1984; Schön, 1983; Simons & Ruijters, 2004).

Below, the following steps for the development of a framework of individual learning from errors at work will be taken. Firstly, definitions of the concepts 'learning', 'experience', and 'experiential learning' in the context of professional learning and development are provided. Secondly, learning from errors will be conceptualised under two complementary perspectives on experiential learning. The cognitive perspective explains learning as the acquisition and modification of knowledge and focusses on the memory and knowledge structures involved (Kolodner, 1983; Schank, 1999; Schank & Abelson, 1977). The activity perspective understands learning as a self-directed and self-organised effort to improve performance and focusses on learning in terms of the engagement in deliberate overt or cognitive learning activities (Boshuizen, Bromme, & Gruber, 2004a; Eraut et al., 1998; Gruber, 1999a; Kolb, 1984; Schön, 1983; Van de Wiel, Szegedi, & Weggeman, 2004). The integration of both perspectives has the potential to deepen our understanding of learning through errors by explaining its processes on the basis of established learning theories and by providing possibilities for its operationalisation. In the conclusion of this section the discussion will be integrated to a definition of learning from errors for the purpose of this study. A framework of learning activities will be derived that builds the basis for operationalising learning from errors in the empirical studies presented later.

2.2.1. Learning, experience, and experiential learning

The goal of this paragraph is to elaborate definitions of the concepts of learning, experience, and experiential learning for the purpose of this study. These definitions are needed to contextualise learning from errors in conceptions of experiential learning at work.

Simons and Ruijters (2004) advance a definition of learning in the context of professional learning and development that is followed here.

> "Learning, in our view, refers to implicit or explicit mental and / or overt activities and processes leading to changes in knowledge, skills or attitudes or the ability to learn of individuals, groups or organisations. These can under certain conditions also lead to changes in work processes or work outcomes of individuals, groups or organisations." (Simons & Ruijters, 2004, p. 210)

This definition addresses three aspects of learning that are relevant for conceptualising learning from errors.

1. The learning process as well as its outcome may be explicit or implicit. Eraut (2000) distinguishes three modes of non-formal workplace learning according to their level of intentionality and consciousness: 'Deliberative learning' is basically intentional, with time being especially set aside for it. 'Reactive learning' is learning that follows

as immediate reaction to a specific event. It is nearly spontaneous, no time is specifically set aside for it, and the level of intentionality may vary. 'Implicit learning' is conceptualised as non-conscious and unintentional, and the learner may not even be aware of the outcome (cf. Simons, 2005). Because learning from errors occurs as a reaction to an unexpected event and is not part of the normal work process, learning from errors typically will take place in a deliberative mode or in a reactive mode. Eraut (2000) notes that practitioners will be most likely in a deliberative mode when they are reflecting on their experience. However, this does not necessarily imply awareness of the learning process in the sense that the focus of intention would be on learning or that the individual would call the process 'learning' (Simons, 2005).

2. The definition of learning indicates that learning processes involve cognitive as well as overt learning activities. Similarly, the outcome of learning can be analysed in terms of cognitive structures and changed performance. Learning from errors will be conceptualised below both in terms of cognitive processes and in terms of the engagement in learning activities, while the empirical part will focus on the latter. As Kwakman (2003) states, measuring learning in terms of learning activities is legitimate, but it has to be acknowledged that the engagement in learning activities and the cognitive learning process itself are not the same. Models of learning activities without an explanation of the cognitive processes that are assumed to be triggered by them, stay inherently normative. Therefore, the discussion both of a cognitive and an activity perspective is required for conceptualising learning from errors.
3. Finally, the definition indicates that learning can take place on the individual, group, or the organisational level. Although the focus here is on individual learning, the framework of learning through errors developed below can potentially be extended to the team level. Several scholars have elaborated on how theories of individual and group learning are linked through the common notion of adaptive processes through cycles of reflective, experiential learning (Cressey, Boud, & Docherty, 2006; Ellström, 2001; Hoeve & Nieuwenhuis, 2006; Järvinen & Poikela, 2001). In this understanding, team learning involves, but goes beyond, individual learning and comprises processes of re-negotiating and changing shared knowledge, routines, and practices. This perspective analyses work teams under a micro perspective (Bauer & Gruber, 2007) that integrates the individual and the group level (Edmondson, 1996). It contrasts with a macro-perspective on team and organisational learning that is mainly interested in learning in terms of organisational change. Hence, the framework of learning from errors developed below focusses on individual learning, but is potentially applicable to analyse links between individual and team learning.

Contextualising learning from errors in theories of experiential learning requires furthermore elaboration of the concepts of 'experience' and 'experiential learning'. Experience means encountering episodes that are personally relevant to a subject (Gruber, 1999a). The term 'episode' refers to a personally encountered event in a certain situation at a certain time (Gruber, 1999b; Tulving, 1993). Experiential learning means to construct new or to modify existing knowledge through the active participation in personally relevant

episodes in a natural context, e.g., a workplace (Gruber, 1999a; Kolb, 1984). Personally relevant implies that the subjective interpretation of the episode as well as its emotional and motivational valence play an important role for the initiation and the quality of learning processes.

As indicated above, experiential learning is regarded as crucial in the process of professional development (Billett, 2004a; Boshuizen et al., 2004b; Eraut, 1994, 2000; Ericsson, 2006a; Gruber, 1999a; Gruber et al., 2005; Kolb, 1984; Schön, 1983; Simons & Ruijters, 2004). Fundamental mechanisms of experiential learning are (a) the integration of new experiences into prior knowledge, (b) the generalisation over repeatedly encountered similar episodes, as well as (c) the indication and integration of deviant episodes, involving learning from errors (Gruber, 1999a; Kolodner, 1983; Schank, 1999). There is general agreement that reflection on an experience is a key learning activity in these processes (Boud, Keogh, & Walker, 1989a; Boud, 1999; Ellström, 2006; Gruber, 1999a; Kolb, 1984; Moon, 2004; Schön, 1983; Simons & Ruijters, 2004). Eraut (1994) conceives reflection as an essential element of experiential learning. The concept of reflection will be elaborated more deeply in the following sections (2.2.2 and 2.2.3). For the moment, reflection will be shortly defined as "(...) a generic term for those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations" (Boud et al., 1989a, p. 19).

The aspects of experiential learning can be summarised in the following definition of experiential learning for the purpose of this study. Learning from experience is a process of acquiring new or modifying existing knowledge and skills through the participation in personally relevant episodes in natural settings. The learning process may take place implicitly, be initiated as immediate reaction to an (unexpected) situation, or be initiated deliberately with the intention to learn with time especially set aside for it. For the latter two modes of learning, reflection is a key activity. Learning from experience is action oriented in a sense that it results from individuals' active engagement in given episodes and that its outcomes may contribute to improve the ability to act in a given context.

Experiential learning as defined above comprises learning from errors as a subcategory. Errors constitute unexpected situations and – if perceived as relevant – may evoke the intention to change one's behaviour or the underlying dispositions to which the error is attributed. The following two sections will address the question how learning from errors can be explained more precisely from a cognitive perspective that focusses on the acquisition and modification of knowledge, and from an activity perspective that focusses on learning in terms of the engagement in experiential learning activities. Both perspectives are linked through the shared assumption that learning is an adaptive process that is mediated by reflection.

2.2.2. The cognitive perspective: Modification of scripts in dynamic memory

The conceptualisation of learning from errors at work requires explaining how the experience of an error can lead to a modification of individuals' knowledge and how this may contribute to future improved action. For this purpose, a cognitive perspective on

learning from errors will be introduced below by drawing on theories of dynamic memory that model changes in episodic memory structures and describe processes of case-based reasoning (Kolodner, 1983; Schank, 1999; Schank & Abelson, 1977). Several scholars have argued that these concepts are particularly useful for the analysis of professional development and work related learning of individuals or teams (Bauer & Gruber, 2007; Eraut, 1994; Gruber, 1999a; Hoeve & Nieuwenhuis, 2006; Strasser & Gruber, 2004). The position advanced here is that learning from errors can be explained as the modification of scripts through the experience of deviant episodes, comprising error situations. Although the process of script modification cannot be measured directly for reasons given below, this discussion adds to our understanding of learning from errors by modelling the cognitive processes and structures underlying learning from errors. Furthermore, the cognitive perspective provides links between theories of experiential learning and the cognitive and action-oriented approaches to human error that were used above to conceptualise error (Frese & Zapf, 1994; Hacker, 1998; Rasmussen, 1987b; Reason, 1990; Senders & Moray, 1991; Volpert, 1992).

In the following paragraphs the cognitive perspective will be elaborated. Firstly the concepts of dynamic memory, scripts, and case-based reasoning are introduced. Secondly, experiential learning at work and learning from errors will be modelled as the establishment and modification of scripts. In the conclusion of this section the contribution made by the cognitive perspective will be critically discussed.

Dynamic memory, case-based reasoning, and scripts. Theories of dynamic memory and case-based reasoning are relevant for conceptualising learning from errors because they provide an explanation of how individuals can use knowledge about formerly experienced errors in new situations. These theories assume that individuals act in given situations on the basis of episodic knowledge structures that are derived from experience of specific episodes (Kolodner, 1993; Kolodner & Simpson, 1986; Schank, 1999). As indicated by the notion of a 'dynamic' memory, this knowledge is subject to continuous refinement and modification through the repeated experience of episodes. Theories of dynamic memory and case-based reasoning imply assumptions about an episodic memory that stores information about personally experienced events and that enables persons to remember and re-experience their own previous experiences (Tulving, 1972, 1993, 2002). In dynamic memory, cases – i.e., interpreted representations of formerly experienced episodes (Kolodner, 1997) – are organised in script-like episodic memory structures that are derived from the 'raw' experiences through reflection ('episodic memory organisation packets'; Kolodner, 1983; Kolodner & Simpson, 1986). The case-based reasoning approach describes how remembering cases is helpful to improve problem-solving and action in recurrences of similar episodes. For example, O'Hare and Wiggins (2004) analysed how former experiences of critical incidents during flights improved pilots' later responses to new critical flight events.

These conceptions of the acquisition, representation, and use of action-oriented knowledge are based on schema and script theories of conceptual knowledge representation (J. R. Anderson, 2005). Scripts are generalised episodic knowledge structures that are acquired

and modified through the experience of episodes and that serve as a framework for the accomplishment of similar recurring tasks (Schank, 1999; Schank & Abelson, 1977). They comprise information about sequences of events, appropriate actions and procedures, involved artefacts, and the division of social roles for a given class of situations. Scripts serve as a set of default rules that apply until challenged and that can be changed on the basis of experience (Hoeve & Nieuwenhuis, 2006; Kolodner, 1993). For application, scripts can be adjusted to meet the requirements of a specific situation at hand (Gruber, 1999b). These characteristics make scripts a powerful cognitive tool that allows for the efficient representation of action-oriented knowledge. However, a restriction of scripts is that they cannot account for action in novel situations, for which per definition no pre-existing set of procedures is available. In novel situations the quality of mental models and theoretical knowledge are important for developing effective action plans (cf. knowledge-based regulation) (Gruber, 1999a; Stark, Mandl, Gruber, & Renkl, 1998). Then again, by encountering once novel situations repeatedly, new scripts are established that can be modified and fine-tuned by further experiences (Kolodner, 1983; Schank, 1999).

The concept of scripts is particularly useful for analysing knowledge, practices, and changes of knowledge or practices in work settings (Boshuizen, 2004; Eraut, 1994; Hoeve & Nieuwenhuis, 2006; Gruber, 1999a; Strasser & Gruber, 2004). For the purpose of conceptualising learning through errors, the concept of scripts is helpful for two reasons. First, it provides links between theories of experiential learning and the action-oriented perspective on human error introduced above, because the concept of operative image systems as an action-oriented knowledge system that is acquired or revised through action is based on script theory (Hacker, 1998; Volpert, 1987; Wehner & Mehl, 2003; Zimolong, 1990). This provides a basis to integrate both lines of theory into a consistent framework of learning from errors. Secondly, learning from errors can be conceptualised as a process of script modification, as will be elaborated below.

Learning as the establishment and modification of scripts. Processes of experiential learning at work – and learning from errors as a special case of such learning – can be understood as the establishment and the modification of scripts (Bauer & Gruber, 2007). Hence, learning from errors involves changing the knowledge base that underlies action regulation during task performance. For learning from errors, the processes of script modification through the integration of deviant episodes in dynamic memory are particularly relevant (Gruber, 1999a; Kolodner, 1983; Schank, 1999). Through reflection on the deviant episode, a respective script can be enriched by an additional part (i.e., an index) that marks the deviant parts from the expected ones. The index assists the actor to remember the deviant episode in recurrences of similar situations and to chose alternative action strategies (i.e., case-based reasoning).

Indexing deviances from default scripts can be modelled in a process of six steps (Kolodner, 1983). (a) At first, an initial sequence of action is performed, or a decision is made, on the basis of the existing episodic memory contents ('initial decision'). In the next steps, (b) a resulting effect has to be noticed as a deviation ('noticing the failure') and (c) the erroneous action has to be identified ('assigning blame'). (d) Then the error may be

corrected ('correcting the failure'). This correction concerns the consequences resulting from the error, because 'The action itself is history the moment it is completed and cannot be corrected or otherwise edited' (Ohlsson, 1996, p. 247). (e) In order to learn from the error, reflection on why it occurred and how it could have been prevented is required ('explaining the failure'). (f) As a result, the experienced episode is integrated with prior knowledge ('memory update'). This is accomplished by adding indices to the original episode that refer to the explanation of the error. At the next occurrence of a similar episode the index serves as reference to the faulty episode and may help to prevent the same error. If the cause for a deviance cannot be identified or explained, at least the difference between the expected and the deviant episode is indicated, so that it is possible to search for a cause at the next occurrence of a similar episode.

Learning from errors plays a significant role for modifying and fine-tuning scripts (Gruber, 1999a; Kolodner, 1983; Schank, 1999). As Schank (1999, p. 130) puts it, "Failure is the root of change." Learning from errors implies improving future action by enriching the underlying knowledge base with conditions under which a script has proven inappropriate. This enrichment is accomplished by reflection on possible causes of the error (assigning blame) and explaining why it occurred and what might be done differently next time (explaining the error). Remembering such deviant cases in later similar situations helps to avoid repeating the same inappropriate application of (parts of) a script. However, the quality of the reflection process in terms of the correct identification of the erroneous action and finding an appropriate explanation is critical for improving future action.

Discussion of the cognitive perspective. So far, the position has been advanced that learning from errors can be modelled as the modification and enrichment of scripts. Experiences of error situations and reflection on them can contribute to extend scripts by parts that enable an actor to improve future action and problem solving through case-based reasoning processes. This cognitive perspective is able to explain processes and outcomes of learning from errors at work. However, one of its problems is that the described cognitive structures and processes are difficult to measure in applied empirical research. Case-based reasoning has been investigated mainly by employing computational modelling techniques (Kolodner, 1993). As Kolodner (1997) notes, the goal of case-based reasoning research is to provide plausible cognitive models that serve to derive hypotheses about cognition for empirical research. Therefore, empirical studies have to rely on the measurement of behaviour that is supposed to indicate the existence of the assumed knowledge structures, for example, through think-aloud protocols (outcome perspective), or through learning activities that are supposed to effect changes in knowledge (process perspective).

In the following section, the case will be made that conceptualising and operationalising learning from errors in terms of the engagement in experiential learning activities provides a fruitful approach. Despite of the focus on cognitive structures, the model of error-driven script modification implies concrete activities in which an individual has to engage in order to learn from an error (Kolodner, 1983). Furthermore, there are similarities between the model of script modification and experiential learning cycles that consist of experiential learning activities (Hoeve, Mittendorff, & Nieuwenhuis, 2003; Gruber, 1999a; Kolb, 1984;

Schön, 1983; Van de Wiel et al., 2004). The reason for these similarities is that models of script modification and models of experiential learning cycles both describe adaptive processes as a reaction to the experience of an episode. They start out with concrete experiences and model reflective activities that result in modified dispositions for future action. The engagement in reflective activities – such as identifying possible causes of an error, explaining why it occurred, and considering ways to prevent it in future – is potentially more promising for measuring learning from errors in empirical research than script modification. However, this activity perspective cannot replace the cognitive explanation of learning from errors or make it obsolete, because models of learning activities without an explanation of the cognitive processes that are assumed to be triggered by them stay inherently normative (Kwakman, 2003). In the next section the discussion about learning activities will be extended and a more systematic model of learning activities will be derived.

2.2.3. The activity perspective: Learning as the engagement in experiential learning activities

In this section the proposition is advanced that learning from errors can be conceptualised and operationalised in terms of the engagement in experiential learning activities. While the above section mainly relied on psychological theories that frame learning as change in memory structures, the activity perspective presented here is based on educational theories of adult and professional learning that understand learning as a self-directed and self-organised effort to improve performance through the engagement in learning activities (Boshuizen, 2004; Gruber, 1999a; Kolb, 1984; Schön, 1983; Van de Wiel et al., 2004). Learning activities are defined to consist of actions which are supposed to effect a change in the individual's knowledge or skills (Schiefele & Schiefele, 1997). In this perspective learning is closely linked to action and the boundary between both is not distinct (Billett, 2001c; Hager, 2004a). Taking such a perspective has been argued to be most appropriate for modelling learning at work (Hager, 2004a). The notion of modelling and measuring learning at work as the engagement in learning activities has been applied in several studies (e.g., Billett, 2000; Berings, Gelissen, & Poell, 2005; Eraut et al., 1998; Kwakman, 2003; Van Woerkom, 2003). However, so far there are no frameworks that systematically describe error-related learning activities. Therefore, the question is which kind of learning activities an individual has to engage in after the experience of a knowledge- and rule-based error.

This question will be addressed in the following paragraphs. Firstly, the notion of experiential learning cycles will be introduced, which provides a systematic framework for the identification of relevant learning activities. Secondly, two points of critique on the conception of experiential learning cycles are addressed that are relevant here: the neglect of the social dimension of learning (Fenwick, 2003) and the lack of elaboration on reflection (Boud, Keogh, & Walker, 1989b; Boud, 2006; Järvinen & Poikela, 2001; Van Woerkom, 2003). Thirdly, the concept of experiential learning cycles will be applied to learning from errors by identifying relevant error-related learning activities within the steps of the cycle. The results of this discussion will be integrated to build a framework of learning activities

that provides a basis for operationalising learning from errors (Bauer & Mulder, 2007, in press).

Experiential learning as action–reflection–action cycles. A general framework of learning activities can be derived from conceptions of experiential learning cycles (e.g., Boud et al., 1989a; Cseh et al., 2000; Gruber, 1999a; Kolb, 1984; Schön, 1983; Van de Wiel et al., 2004). Basically, these conceptions describe how an individual's 'theory of action', that is, the knowledge and the beliefs underlying action, is revised as a response to the experience of a concrete episode, mediated by reflection. This conceptualisation of experiential learning involves the notion of a cyclic – or more precisely of a spiral – progression starting and ending with action. According to Kolb (1984), an experiential learning cycle involves a progression of the following steps.

1. At first, a specific conflicting episode is encountered ('concrete experience'). 'Conflicting' means that the episode is perceived as subjectively salient and relevant by the subject, e.g., through recognising an unexpected dissonance between the current theory of action and the feedback resulting from the performance. This conflict creates the motivational basis for the engagement in reflection (Step 2). The conflict may emerge directly out of the situation, or be recognised later through feedback of any kind.
2. In order to learn, reflection on the experienced episode and the applied theory of action is required ('reflective observation'). This step involves a shift from the specific involvement in action towards observation and "general analytic detachment" (Kolb, 1984, p. 31). Reflection in Kolb's sense has an instrumental focus. Its purpose is to analyse the situation and the effectiveness of the action in order to draw conclusions for future action and problem-solving.
3. Reflective thinking may result in the derivation of a revised theory of action. This can take the form of defining general principles operating in the episode ('abstract conceptualisation') or developing rules of thumb which guide future action.
4. The resulting knowledge can be applied in subsequent episodes through actively experimenting with and evaluating the revised theory of action ('active experimentation'). At this point the cyclic progression enters action again, on the basis of a revised and enhanced understanding.

This notion of an experiential learning cycle is helpful for conceptualising learning from errors in two ways. Firstly, Kolb's (1984) model has been acknowledged in the human error and safety management literature (Glendon et al., 2006). A similar model has been introduced to describe processes of 'error recovery' (Zapf, Lang, & Wittmann, 1991). Error recovery starts with the detection of an error during an episode of action, followed by a phase of analysing and explaining the error, then planning a strategy for its correction, and finally implementing the developed strategy. Though this model of error recovery addresses processes of *error management* – i.e., correcting an error and preventing or reducing negative outcomes (Zapf et al., 1999) – and not of *learning* from errors, the similarity to an experiential learning cycle can be ascribed to the underlying notion of an

adaptive process. This similarity is not a matter of chance. Kolb conceives learning as the "major process of human adaption" (1984, p. 32). He thus considers learning to encompass other related concepts such as problem-solving or inquiry.

Secondly, Kolb's (1984) conception of experiential learning can be related to the model of script change in dynamic memory discussed above (Kolodner, 1983; Schank, 1999). The joint basic argument is that people learn continually by modifying their knowledge through their experiences. The experience of and reflection on deviant episodes are learning mechanisms of special relevance in both lines of theory. However, a difference is that though Kolb (1984) refers to the change of knowledge, he focusses more on the engagement in learning activities than on the underlying cognitive structures. Consequently, he argues that learning should be considered as a process, not in terms of outcomes. This position has also been advanced in constructivist theories and in research on professional development and learning at work for conceptual as well as for empirical reasons (Collins, 1990; Duffy, Lowyck, & Jonassen, 1993; Gruber, 1999a; Hager, 2004a, 2004b; Law & Wong, 1996). Several scholars have argued that for the empirical investigation of learning at work, it is desirable to operationalise the variables under investigation as much in terms of concrete workplace activities as possible, because these activities – in contrast to cognitive structures – may be either observed directly or may be easier articulated by the participants of a study (Eraut et al., 1998; Simons & Ruijters, 2004; Simons, 2005; Van Woerkom, 2003).

For the purpose of this study the decision is made to operationalise learning from errors in terms of the engagement in learning activities that are assumed to lead to the cognitive processes described above (Kolodner, 1983; Schank, 1999). Kolb's (1984) experiential learning cycle provides a systematic framework for this purpose by allowing us to identify relevant error-related learning activities in the steps of the cycle. However, several points of critique of Kolb's (1984) approach that are relevant here have to be addressed beforehand.

Critique and extensions. In particular, two points in Kolb's (1984) conception of experiential learning cycles have been subject to critique by other scholars: neglect of the social dimension of learning (Fenwick, 2003) and the lack of elaboration on reflection (Boud et al., 1989b; Boud, 2006; Järvinen & Poikela, 2001; Van Woerkom, 2003). Both points are relevant here, because learning from errors is investigated in the social context of the workplace and because the case has been made above that reflection plays an important part in learning from errors. Therefore, theories have to be introduced that compensate for the mentioned weaknesses of Kolb's (1984) approach.

Neglect of the social dimension. A point of concern is that Kolb's (1984) model neglects the social dimension of learning as a process of co-construction and negotiation of meaning (Fenwick, 2003). Although Kolb emphasises that learning involves transactions between the person and the environment, he hardly elaborates on the social dimension of learning. Particularly, the relevance of social exchange for learning has been stressed in socio-cultural and constructivist learning theories (Lave, 1991; Rogoff, 1984; Valisner & Van der Veer, 2000), and in conceptions of learning at work and professional development (Billett, 2004a;

Eraut et al., 1998; Felstead et al., 2005; Hakkarainen et al., 2004; Smith, 2003). For the individual, engagement in social learning activities delivers opportunities to co-construct knowledge and meaning from a situation. By including others' perspectives, the own, probably limited, perspective is extended. The effect is reciprocal: others involved have the opportunity to profit from the experience of an individual, and group-learning may be initiated in the form of changing established routines (Hoeve & Nieuwenhuis, 2006). As for learning from errors, it has been emphasised that especially those activities that go beyond finding a quick fix for an error in order to proceed with the original task, and that aim at exploring underlying causes, require communication and collaboration with others (Edmondson, 2004; Van Woerkom, 2003). Communication and exchange about errors support the development of shared knowledge and understanding, but also of solutions and strategies to handle errors and critical situations (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996; Meurier et al., 1997; Tjosvold et al., 2004; Tucker & Edmondson, 2003). Therefore, a framework of error-related learning activities needs to take into account that learning activities can involve individual as well as cooperative engagement (cf. Van Woerkom, 2003).

Lack of elaboration on reflection. Although Kolb's (1984) model assigns reflection a high value, it has been criticised in that he treats reflection as self-evident and neglects to elaborate on its processes and components (Boud et al., 1989b; Boud, 2006; Järvinen & Poikela, 2001; Van Woerkom, 2003). Conceptualising reflection on errors therefore requires drawing upon more comprehensive theories of reflection (e.g., Boud, Cressey, & Docherty, 2006; Fenwick, 2003; Moon, 2004; Van Woerkom, 2003). Boud (2006) summarises several common themes in the literature on reflection. These themes are discussed here and will be applied to learning from errors in the following paragraph.

(a) Reflection refers to cognitive and emotional processes as well as to actions which serve to examine experiences. Hence, reflection is not restricted to cognition but also involves overt activities. (b) Reflection is triggered by the experience of conflict, such as surprise, perplexity, hesitation, uncertainty, dissatisfaction, or discrepancy (cf. Kolb, 1984). Several authors have elaborated on how emerging problems and unexpected outcomes lead practitioners to leave a routinised and intuitive mode of action regulation and to enter a deliberate, knowledge-based, and analytical one (Ellström, 2006; Eraut, 2000; Schön, 1983). (c) Consequently, the third theme observed by Boud (2006) is that of reflection as a conscious, volitional process of interpreting and making sense of experiences (cf. Ellström, 2006). Reflection in this sense relates to the reactive and deliberative modes of learning, discussed above (Eraut, 2000). (d) Finally, reflection has been regarded mainly as an individual activity the benefits of which concern the individual. This notion has been subject to debate (Cressey et al., 2006; Høyrup & Elkjaer, 2006; Van Woerkom, 2003). First, individual reflective processes may profit from social exchange while at the same time reflection as a collectively shared practice has the potential to contribute to the competence development of others involved and may initiate processes of group or organisational learning (Järvinen & Poikela, 2001). Secondly, even if reflection is performed individually, its outcomes concern action in and relations with a social and technical-organisational environment and therefore are inherently social and contextual (Cressey et al., 2006; Hager,

2004a). Hence, the association of reflection with the metaphor of the 'brooding thinker' is inadequate and needs complementation by a social negotiation perspective.

In addition to Boud's summary, one more theme in the discourse on reflection is of importance. (e) Reflection has been analysed on a continuum between 'instrumental' and 'critical' reflection (Mezirow, 1990; Van Woerkom, 2003). "[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" (Mezirow, 1990, p. 1). Hence, instrumental reflection concerns the contents 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 underlying action.

The discussed themes of reflection will be picked up again in the following paragraph, when contextualising the notion of a learning cycle to learning from errors.

Application of the experiential learning cycle to error-related learning activities. In the previous paragraphs Kolb's (1984) model of an experiential learning cycle and extensions based on its critique have been discussed. Drawing together this discussion, the following conclusions for a framework of error-related learning activities can be made.

1. Learning from errors can be modelled as well as operationalised by the engagement in learning activities regarding the latter three steps of the learning cycle, after the experience of an error episode. Learning from errors through the engagement in learning activities implies intentional adaptive efforts as response to an encountered error episode that aim to change the causes to which the error is attributed. The steps of the learning cycle can be contextualised to learning from errors, as follows.
   (a) *Concrete experience.* In learning from errors, a concrete experience means the detection that an error has occurred. The starting point for the experiential learning process is that an actor has detected the occurrence of an error, either by him- or herself, or through feedback provided by others involved, technical systems, or the functioning of the work system itself (Glendon et al., 2006; Zhao & Olivera, 2006). After the detection, an actor may elect to engage in error-related learning activities, or not. The decision to engage in learning may depend on the actor's interpretation of the error situation and the perception of supportive contextual conditions, as will be elaborated later (Chapter 2.3).
   (b) *Reflection and analysis.* Reflection on errors involves performing a root-cause-analysis in order to identify probable causes of an error and to explain why it occurred (Kolb, 1984; Kolodner, 1983). Reflection on errors can be contextualised in the discussed themes in the discourse on reflection as follows. Reflection on an error 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 elect to engage in cognitive or overt reflective activities (Theme a), as a response to a conflict induced by the detection of an error (Theme b), with the aim to analyse its causes (Theme c). Reflection on

errors has a social dimension in that it may be performed cooperatively, and its outcomes concern action which cannot be thought of as separate from the socio-cultural context in which it occurs (Theme d). Locating reflection on errors on the continuum between instrumental and critical reflection (Theme e) is more difficult. The focus of reflection on errors as discussed so far is an instrumental one, that is, reflection is preformed in order 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 required in order to achieve a change (Arndt, 1996; Aspden et al., 2004; Bogner, 1994; Feldman & Roblin, 2000; Harteis, Bauer, & Haltia, 2007; Van Woerkom, 2003). Secondly, errors can also bear the potential to initiate critical reflection by asking for an in depth inquiry about underlying values and presuppositions of the practice. Learning from errors is not limited to mere adaption and can result in breaking up existing practices ('developmental learning'; Ellström, 2006). Hence, reflection on errors comprises facets of instrumental as well as of critical reflection.

(c) *Development of a new action strategy.* Based on the outcomes of the reflective process a revised or new strategy for action has to be developed. While the search for causes describes an analysis of the discrepancy between the actual and the desired state, a thorough analysis of alternative action strategies is necessary in order to develop adequate new options for action (Stiensmeier-Pelster & Heckhausen, 2006). Concrete activities may involve considering strategies to change the presumed cause of the error, identifying and reasoning about possible alternatives for future acting, allocating required information and resources, and planning the implementation. The boundary between reflection and the development of a new strategy is not as distinct as the separation in two subsequent steps, linearly following each other, may suggest. Phases of reflective examination and developmental planning may be intertwined and the focus of activity may move to and fro, especially when social negotiation is involved.

(d) *Implementation of the new strategy.* The last step concerns the implementation of the revised action strategy through experimenting and evaluating it after experiences in similar situations. Experimenting means intentional efforts in order to try out and test the new action strategy within the work context (Cannon & Edmondson, 2005; Ellström, 2001; Kwakman, 2003; Sitkin, 1992; Van Woerkom, 2003). This may involve formulating hypotheses, performing mental as well as overt trials, and to tune, reconsider, or reject the new action strategy based on implicit or explicit evaluations of the outcomes. Again, phases of experimentation are likely to be intertwined with phases of reflection and planning. If the strategy is evaluated as ineffective, re-entering phases of reflection and deliberate planning is required. If the new strategy proves to be effective, it becomes part of the standard repertoire for action in the given class of situations. In terms of

Table 1: Framework of learning activities

Activity	*Performed individually or socially shared*
Reflection	Cause analysis
Development of a new action strategy	Considering ways to change the cause Considering alternatives for future acting Allocation of information and resources Planning the implementation
Implementation of the new strategy	Experimenting with the new strategy Evaluating the new strategy

scripts and routines, a new 'dominant design' is established, after it is applied several times in relevant episodes (Hoeve et al., 2003).

2. Each of these learning activities may be performed individually or in cooperation with others through social exchange and negotiation in informal or formal situations (Van Woerkom, 2003). Concrete social learning activities may involve asking experienced colleagues for help and advice, jointly discussing and analysing the episode, considering ways of preventing the error from happening again, planning and implementing the new strategy, and providing mutual control and critique in future situations (Bauer & Mulder, 2007; Cannon & Edmondson, 2001; Meurier et al., 1997; Tucker & Edmondson, 2003).

The discussion of learning activities can be summarised to build a conceptual framework of error-related learning activities, as presented in Table 1 (Bauer & Mulder, 2007). For the purpose of this study, this framework serves a heuristic to guide the operationalisation of error-related learning activities. The idealised notion of a cyclic process starting out with experience is only one special possibility of a sequence of learning from errors. Phases of reflection, planning, and experimentation can be intertwined and may follow each other rapidly in a non-linear process. However, the notion of a complete learning cycle is helpful here, because it enables the systematic construction of a framework of relevant error-related learning activities. In saying that the framework is conceived as a heuristic, it is acknowledged that it does not yet represent the final operationalisation of learning activities to be applied in the empirical part of this study. The framework represents an experiential learning cycle that has been applied to learning from errors, but still needs contextualisation to the requirements of the specific domain under study (i.e., nursing). This contextualisation cannot be accomplished theoretically but requires exploratory research (Chapter 4).

2.2.4. Summary and definition of learning from errors at work

The goal of this section has been the development of a theoretical framework that explains individual learning from errors at work and that provides a basis for operationalising learning from errors (Research Question 1). Learning from errors has been explained under

a cognitive and an activity perspective on experiential learning (Boshuizen et al., 2004b; Eraut et al., 1998; Gruber, 1999a; Kolb, 1984; Kolodner, 1983; Schank, 1999; Schön, 1983; Van de Wiel et al., 2004). The integration of both perspectives contributes to deepen our understanding of learning from errors and to base it upon established conceptions of experiential learning and learning at work. By modelling the underlying cognitive processes and structures, the cognitive perspective explains why errors provide learning chances that can contribute to the improvement of individual dispositions underlying action at work. The activity perspective places the learning process and its outcomes in the socio-cultural context of a workplace and provides possibilities for operationalising learning from errors by identifying learning activities that lead to the learning processes and outcomes described by the cognitive perspective. On the basis of the results of this discussion, a framework of learning activities has been developed that is consistent with the theoretical perspectives of existing empirical studies on learning from errors (Arndt, 1994; Cannon & Edmondson, 2001; Edmondson, 1996; Meurier et al., 1997; Tjosvold et al., 2004; Tucker & Edmondson, 2003) in so far as these studies take an activity perspective on learning (Bauer & Mulder, in press). However, the framework goes beyond these studies, in that it is systematically derived from learning theory.

In conclusion, learning from errors at work is defined for the purpose of this study as follows.

> Learning from errors at work is a process of acquiring new or modifying existing knowledge and skills through the experience of personally relevant error episodes in a work setting. Learning from errors is intentional and action oriented, though the focus of intention does not need to be on 'learning' in an explicit sense. The change of knowledge involves the enrichment of scripts by adding indices that assist to remind of the deviant episode in future occasions and to avoid committing the same error. These cognitive processes can be triggered through the engagement in learning activities. Learning activities can be modelled in the form of an experiential learning cycle, though the learning subject will not always walk the shortest way through this cycle. The detection of an error, or receiving feedback about its occurrence, forms the starting point from which a subject may elect to engage in individually or cooperatively performed learning activities. Reflection on the episode is required in order to learn. Reflection involves identifying causes and explaining why the error occurred. The results of reflection provide a basis for the development of new action strategies, and for experimenting with and evaluating these strategies. The short term outcomes of learning from errors concern a renewed, corrected, and deeper understanding on the knowledge level, and the subject's ability to avoid the error in future on the action level. The latter involves a change in practice that may require breaking up underlying presuppositions through critical reflection. In the long run, the experience of error episodes can contribute to the development of a rich knowledge base that enables action at work.

A consequence resulting from the conceptualisation of learning from errors as an inten-

tional, goal-directed process of the engagement in learning activities is that learning from errors cannot be assumed to happen automatically. The decision to engage in learning activities belongs to the individual's agency (Billett, 2001c, 2004b). Therefore, both individual variables as well as the individual's interpretation of the conditions at a workplace must be taken into account as either supporting or constraining individual agency. A discussion of this proposition and of the individual and contextual conditions that can be assumed to relate to the engagement in error-related learning activities will be provided in the following section.

2.3. Individual and contextual conditions for learning from errors

This section provides a discussion of individual and contextual conditions that are potentially relevant for the individual engagement in error-related learning at work. From this discussion hypotheses will be derived that are subject to investigation in the empirical part of this study (Research Questions 2—4).

The discussion starts with the consideration that in research on learning at work individual subjectivity has to be taken into account (Billett, 2006). Hence, errors as well as the contextual affordances and constraints through which a workplace may shape responses to errors are relevant for learning in terms of their individual interpretation, not as quasi-objective environmental entities (Billett, 2001b, 2004b; Ellström, 2001; Jørgensen & Warring, 2002). On the basis of a summary of existing studies on learning from errors at work (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996, 1999; Meurier et al., 1997; Tjosvold et al., 2004; Tucker & Edmondson, 2003; Van Woerkom, 2003) it will be concluded in particular that (a) the individual interpretation of an error, and (b) the perception of a safe social context at work are important for learning from errors. However, the existing studies are too heterogeneous to provide strong, cumulative evidence for these assumptions (Bauer & Mulder, in press). Therefore further inquiry is required. The assumptions that the interpretation of errors and the perception of a safe social context are related to learning from errors are elaborated upon by drawing on the concepts of individual 'error orientation' (Rybowiak et al., 1999) and a safe team climate (Edmondson, 1999), respectively. From this discussion, a research model for individual learning from errors at work will be derived that comprises hypotheses about how the interplay of these variables fosters or constrains learning from errors at work.

2.3.1. The importance of subjectivity

Variables that either foster or constrain experiential workplace learning – and learning from errors as a specific case of such learning – have been classified into individual and contextual influences (e.g., Billett, 2001c, 2004b). As Billett (2004b) notes, workplace learning is dually dependent, on the one hand on the affordances and constraints a workplace provides, on the other hand on the individual's interpretation of and decision to engage in such affordances. Hence, these affordances and constraints a workplace provides are not quasi-objective learning potentials that exist independent of individual subjectivity and agency

(Billett, 2004b, 2006). Although possibilities to participate in workplace practices may be highly structured, the recognition and the use of learning possibilities cannot be taken for granted (Bauer & Gruber, 2007; Billett, 2001b; Ellström, 2001). Individuals subjectively evaluate their environment and act on the basis of their idiosyncratic construction of reality. As Jørgensen and Warring (2002) put it:

> "Analysis of the technical-organisational and the socio-cultural environments conveys knowledge about the learning potentials in the learning environments of the workplace. But it is how these potentials (and constraints) are perceived by the employees and how they interact with their subjective motivation that determines what kinds of learning occurs." (Jørgensen & Warring, 2002, p. 9)

Hence, employees may regard learning potentials at a workplace as irrelevant or fail to recognise them while they are salient for external observers, and vice versa. This is especially relevant for deliberate and reactive forms of learning, like learning from errors. Ellström (2001) states that even if a work situation offers a high degree of seemingly objective learning potentials, an individual may not be able to take advantage of them because he or she lacks the knowledge or self-confidence to do so. He concludes that beyond objective job characteristics the individual subjective interpretation of workplace features and events must receive attention.

Similar arguments come from research on human error. In their framework on error reporting, Zhao and Olivera (2006) argue that individuals elect to report or not to report errors on the basis of a calculation of potential costs (e.g., efforts, fear of losing face, repercussions, or disciplinary proceedings) and benefits (e.g., learning, preventing further consequences, maintaining one's self-concept as a good employee). The authors emphasise that contextual conditions affect individual cognitions and perceptions regarding this evaluation, rather than being direct determinants of actual error reporting.

In summary, analyses of how individuals do or do not use errors at work as learning opportunities have to consider the individuals' idiosyncratic interpretation of an error situation as well as the individual interpretation of contextual conditions that provide affordances or constraints for learning. This concerns also the selection of variables under investigation in this study. While this conclusion is drawn here on the basis of conceptions of learning at work, it also receives initial support from the few existing empirical studies on learning from errors at work. An overview of these studies will be provided in the next paragraph.

2.3.2. Identifying relevant conditions for learning from errors at work

The current state of the literature on conditions that foster or constrain learning from errors at work can be summarised as follows. Errors have to be taken as a reason to start an inquiry about underlying causes, which requires an actor to develop a learning orientation, even if his or her natural inclination may be otherwise (Argyris & Schön, 1996; Edmondson, 2004; Sitkin, 1992; Tucker & Edmondson, 2003). Negative emotions, stress, and increased time pressure have to be regulated (Keith & Frese, 2005; Rybowiak

et al., 1999; Zapf, 1991). A positive cost-benefit-balance must be perceived in return for taking the effort to engage in learning activities and to overcome possible tendencies to ignore or conceal the error (Rybowiak et al., 1999; Zhao & Olivera, 2006). Furthermore, the engagement in learning activities will typically involve conceding the error to others (if it has not been discovered by others anyway). This involves taking interpersonal risks like losing face and appearing incompetent as well as more tangible risks like disciplinary proceedings or prosecution. Therefore the individual perception of the social environment as safe for taking interpersonal risks as well as the expectation whether errors are dealt with under a blame- versus a problem-solving or learning orientation will have a strong weight in the balance (Cannon & Edmondson, 2001; Edmondson, 1996, 1999; Tjosvold et al., 2004).

Unfortunately, only few of these propositions are based on systematic empirical evidence. In a literature review (Bauer & Mulder, in press), only five studies could be found that focus directly on individual or team learning from errors at work (i.e., Arndt, 1996; Edmondson, 1996; Meurier et al., 1997; Tjosvold et al., 2004; Tucker & Edmondson, 2003). Three more studies were identified that treat learning from errors as part of a more complex dependent variable, i.e., 'team learning behaviour' (Cannon & Edmondson, 2001; Edmondson, 1999) or 'critically reflective work behaviour' (Van Woerkom, 2003). One last study focusses on the development of a questionnaire on individual 'error orientation', a multidimensional construct involving beliefs and attitudes towards errors as well as ways of dealing with them (Rybowiak et al., 1999). Whereas error orientation might be a promising independent variable for learning from errors, the study does not investigate this relation.

Table 2 contains a summary of the variables that have been found to be related to learning from errors in the mentioned studies[4]. In the left column, each study is referred to by a numerical code, which is linked to a listing of the studies below the table. The right hand column presents the variables identified from the studies. However, obtaining evidence about predictors for learning from errors from these studies is difficult, because there is a large variability concerning the empirical approach, the level of learning (individual—group), and the operationalisation of learning from errors (Bauer & Mulder, in press). Some of them operationalise learning in terms of learning activities, as suggested above (Cannon & Edmondson, 2001; Edmondson, 1999; Meurier et al., 1997; Tucker & Edmondson, 2003). However, none of the studies provided a systematic theoretical rationale for its specific selection of learning activities. Other studies focussed on beliefs, attitudes, or emotions about errors – e.g., that errors provide useful sources of learning or that people in one's organisation learn a lot from their errors (Rybowiak et al., 1999; Tjosvold et al., 2004; Van Woerkom, 2003) – or on seemingly objective indicators for learning from errors, i.e., detected error rates and the difference between reported and occurring errors (Edmondson, 1996). Regardless of whether these operationalisations are valid for measuring learning, the variability in them inhibits the accumulation of evidence, because even if similar predictors are used in different studies they hardly predict the same thing. Therefore, it is difficult to compare the studies and to integrate their findings.

[4]Only studies dealing directly with learning from errors or with learning from errors as part of a more complex dependent variable are included.

Table 2: Overview of variables related to learning from errors at work from a review of empirical studies

Study	*Variables*
(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).

In summary, Table 2 must be interpreted as a collection of potentially relevant variables, not as accumulated evidence. Therefore, Sitkin's (1992, p. 260 f.) lament that "Although there has been a substantial amount of attention to the benefits of failure, that work has been non-cumulative, largely anecdotal or normative, and has not been subject to systematic empirical testing" still has to be regarded as valid. Nevertheless, the selection of variables made in the studies underpins the proposition advanced above, that relevant determinants for learning from errors may be searched for in the interpretation of errors and in the perception of a safe context for learning from errors. Therefore, this study aims to investigate the relation of these variables with the engagement in learning activities after an error at work, in order to contribute to the accumulation of evidence about what individual and contextual variables foster or constrain employees' learning from errors. For deriving hypotheses, the following three paragraphs elaborate how (a) the individual interpretation of errors and (b) the perception of a safe context may relate to the engagement in learning activities after an error (Research Questions 2 and 3), and (c) how the interpretation of errors and the perception of a safe context may be interrelated (Research Question 4).

2.3.3. Individual interpretation of errors and the error situation

Engaging in workplace learning activities belongs to the individual's agency and therefore is based on his or her personal history, knowledge, values, and beliefs (Billett, 2001b). The accumulated experiences an individual has gathered with errors in general and at a specific workplace in particular, may lead to a generalised appraisal of errors and what kind of coping strategies are preferred. This appraisal will have an impact on how the individual interprets a newly encountered error situation and whether and how action is taken. Rybowiak et al. (1999) proposed individual 'error orientation' as a multi-dimensional construct that reflects this relationship. Error orientation subsumes individual attitudes and emotions concerning errors as well as related strategies to deal with them. Although the concept of error orientation as suggested by Rybowiak et al. (1999) suffers from several

problems, as will be discussed below, its sub-dimensions contain potentially relevant variables that may have an impact on learning from errors. In this study particularly (a) the estimation of an error situation as a chance for learning, (b) the degree to which negative emotions are evoked by an error, and (c) the tendency to cover up an error are investigated as predictors for learning from errors. Below, a critical discussion of the error orientation construct as well as a rationale for this selection of error orientation variables are provided.

Problems of the construct 'error orientation'. Problems of the construct error orientation that are relevant here can be classified as conceptual and empirical problems. These problems are discussed here, before elaborating the application of the concept in the context of this thesis.

The first conceptual flaw is that Rybowiak et al. (1999) provide no overarching theoretical framework from which the eight proposed dimensions of error orientation (i.e, error competence, learning from errors[5], error risk taking, error strain, error anticipation, covering up errors, error communication, thinking about errors) are derived or that could provide a rationale that these dimensions form a conceptually complete model. Although the dimensions (and the scales built on their basis) have some face validity regarding the goal of measuring individual orientations towards errors, no systematic efforts have been made to establish content validity. Therefore, the composition of the error orientation dimensions seems somewhat arbitrary. A related issue is whether the complex structure of the construct in eight dimensions is necessary or whether it could possibly be reduced (Bauer, Festner, Harteis, Heid, & Gruber, 2004). Rybowiak et al. (1999) present supportive data from confirmatory factor analyses. However, they themselves assume that the structure could possibly be reduced to a few higher order constructs. A problem of the complex structure is that for a given dependent variable probably not all error orientation dimensions will be equally relevant. Therefore a selection from these dimensions has to be made for the purpose of a given study (e.g., Keith & Frese, 2005). This problem might cast doubt on the usefulness of the composite construct 'error orientation'.

A related problem is that the error orientation construct consists of a mix of attitudes, beliefs, emotions, and behavioural components. On the one hand, a combination of cognition, emotion and behaviour is appealing because it presents a holistic picture of the phenomenon. On the other hand, it evokes the impression that all error orientation dimensions are on the same level, whereas in fact hypotheses about dependencies between the variables are possible. In particular, dependencies between variables expressing beliefs or emotions concerning errors, and the behaviour in error situations (e.g., the engagement in reflection or communication about errors) can be hypothesised (cf. Cannon & Edmondson, 2001).

A last conceptual problem is that Rybowiak et al. (1999) omit to elaborate whether they consider error orientation to be a stable trait or a situational construct. The items are

[5] 'Learning from errors' is a scale of the Error Orientation Questionnaire, that comprises beliefs that errors are useful chances for learning. Therefore, it is referred to as the estimation of errors as chance for learning, below.

formulated in a general manner, thus evoking the impression of a trait perspective. However, the existence of a stable orientation towards errors, regardless of the type of error and the context in which it occurs, has not yet been demonstrated empirically.

Turning to empirical issues, so far there is hardly any evidence about the validity of error orientation. Rybowiak et al. (1999) made efforts to establish construct validity by placing the error orientation variables into a nomological net of relationships with variables such as self-efficacy, self-esteem, plan- and action-orientation, readiness for change, control rejection, initiative, etc. Unfortunately, no criterion-related evidence about error orientation exists, either from their study or from others. Despite the broad reception of this contribution in the literature on errors, the construct has hardly been applied to a learning context in empirical studies. Even those studies which place error orientation in a learning context deliver no evidence for its relation with the engagement in learning activities, because they focus on beliefs and attitudes about errors (Tjosvold et al., 2004) or learning in a training environment (Keith & Frese, 2005). Other authors who have used the error orientation construct have focussed mainly on the organisational level and have, for instance, applied it to firm economic performance and firm goal achievement (Van Dyck et al., 2005), or have constructed related instruments to assess error orientation in the context of organisational (learning) culture (Putz, Schilling, Kluge, & Stangenberg, in press; Stangenberg, 2005) or leadership and management (Korsten, 2003).

Despite these problems, error orientation variables seem to be relevant predictors for the engagement in error-related learning, because they address a number of theoretically important aspects, as discussed below. However, for the purpose of this study these problems require explicit decisions about (a) whether error orientation is treated as a personal trait or as a situational construct, (b) which error orientation variables are focussed upon (rather than using the instrument as it stands, or building a composite index for the whole construct), and (c) what kind of relationships are assumed between the subsets. The following paragraph will elaborate hypothesised relations of selected error orientation variables that are investigated in this study.

Hypothesised relations between error orientation variables and the engagement in learning from errors. For the purpose of answering the question how the individual interpretation of an error relates to the engagement in learning activities after an error (Research Question 2), three error orientation variables are investigated that cover cognitive, emotional, and motivational aspects of the interpretation of an error situation: (a) the estimation of an error situation as a chance for learning, (b) the degree to which negative emotions are evoked by an error, and (c) the tendency to cover up an error. These variables are conceived as situationally dependent here, that is, they relate to the specific error situation at hand and are not stable traits. In the following paragraphs, the variables and their hypothesised relationship to the engagement in learning activities are described.

Firstly, the *estimation of an error situation as a chance for learning* is selected, because it has been argued that errors need to be interpreted as relevant learning opportunities in order to make the effort of engaging in learning activities (Argyris & Schön, 1996;

Edmondson, 2004; Sitkin, 1992; Tucker & Edmondson, 2003; Zhao & Olivera, 2006). This position receives support from experiential learning theory, according to which only those episodes become learning experiences which are perceived as relevant for the engagement in learning activities (Gruber, 1999a). Furthermore, it has been argued that learning from errors requires employees to adopt a learning orientation when their natural inclination may be otherwise (Cannon & Edmondson, 2001). A learning orientation cannot be taken for granted because in work performance typically an achievement orientation – in contrast to a learning orientation – will be dominant, under which an error is likely to be perceived as a threat (Kleinbeck, 2006; F. E. Weinert, 1999). Therefore, a deliberate shift to a learning orientation is required, under which an error is interpreted as a provider of learning relevant information. Rybowiak et al. (1999) found the estimation of errors as chances for learning positively related to plan orientation, and action orientation after an error, as well as with initiative. Therefore, it is hypothesised here that the estimation of errors as chances for learning is a positive predictor for the engagement in learning activities.

Hypothesis 1. *The estimation of an error as chance for learning predicts the engagement in learning activities positively.*

Secondly, *error strain* (i.e., negative emotions resulting from having committed an error) is investigated as a predictor for the engagement in learning activities. The notion that errors are stressful and related to negative emotions, such as fear, anger, guilt, or shame is ubiquitous in the literature on errors (e.g., Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996; Keith & Frese, 2005; Mehl, 1993; Meurier et al., 1997; Oser & Spychiger, 2005; Rybowiak et al., 1999; Zapf, 1991; Zhao & Olivera, 2006). However, the impact of negative emotions on learning from errors is conceptually ambiguous and has not yet been investigated systematically. Scholars have claimed both fostering and inhibiting effects of negative emotions on learning from errors.

Two points for a fostering effect of negative emotions can be made. Firstly, negative emotions can lead to conditioning insofar as the error situation is associated with this emotional experience (Thorndike, 1913). Therefore, the negative emotions will be remembered when encountering a similar situation and thus have an alerting function. However, learning in the sense of being able reliably to avoid the same error in future requires the identification of its cause(s). Therefore the learning process cannot be explained only by conditioning. Secondly, Oser and Spychiger (2005) (focussing on the moral dimension of errors and on school children) argued that negative emotions may create a feeling of relevance that causes the actor to engage in reflection. This is consistent with the assumption of experiential learning theories that the personal relevance of an episode is important to interpret the situation as an opportunity for learning (Gruber, 1999a). Nevertheless, Oser and Spychiger (2005) assume no straightforward positive effect of negative emotions. They distinguish between positive and negative 'embarrassers' (*Beschämer*) that are either conductive or obstructive to learning. A positive embarrassment is assumed to be driven internally by the actor's self-indignation, while a negative one is induced externally by unsympathetic, mortifying, or cynical reactions from others.

In contrast, several other scholars have made a case for inhibiting effects of negative emo-

tions on learning from errors for several reasons (e.g., Edmondson, 1999; Greif, 1996; Keith & Frese, 2005; Rybowiak et al., 1999). Firstly, negative emotions can lead to resignation and brooding and thus inhibit taking an action-orientation after an error. For example, Rybowiak et al. (1999) report medium negative correlations of error strain to action orientation and initiative after an error. Secondly, negative emotions can interfere with cognitive processes such as planning and reflection. The occurrence of errors results in emotional pressure which induces stress and rigid thinking (Zapf, 1991). If the negative emotions cannot be regulated effectively, they distract attentional resources away from the task (and handling the error) towards the self (Keith & Frese, 2005). This can influence judgement and decision making, especially in the 'hot' phase directly after an error (Greif, 1996; Zhao & Olivera, 2006). Follow-up errors may occur due to rash and poorly planned action. Thirdly, negative emotions may prevent individuals from the engagement in learning activities. Boud (1999) considers feelings of inadequacy and embarrassment as the greatest barriers to taking action in a potential learning situation. Zhao and Olivera (2006) cite evidence that individuals who feel negative emotions are more likely to attend to the perceived costs and threats of making an error public (cf. Edmondson, 1999). They assume that especially fear, shame, and embarrassment have negative effects on error reporting, whereas guilt may also support it because it can act to motivate reparative actions.

Drawn together, scholars agree upon that errors go along with negative emotions. However, there is disagreement about their effects on learning. Nevertheless, in the discussion so far there is a stronger basis for the assumption of negative effects on cognition and learning activities. Hypotheses about differential effects of specific emotions are still at an early stage. In particular, individual cognitive activities like reflection and planning may be hampered through these emotions. Furthermore, individuals who are feeling strong negative emotions may fear the risk of making an error public through the engagement in social learning activities. Therefore, it is hypothesised here that the experience of the negative emotions fear, worry, anger, and embarrassment (as conceptualised in the EOQ scale 'error strain') inhibits the engagement in learning activities.

Hypothesis 2. *Error strain predicts the engagement in learning activities negatively.*

Finally, the motivational tendency to cover up errors, because one expects disadvantages from communicating it, is investigated as a predictor for engagement in learning activities. This variable is relevant here, because social learning strategies in particular involve making an error public (cf. Edmondson, 1999). Since error orientation variables are conceptualised as situationally dependent here, the term 'tendency' does refer to a perceived negative cost-benefit-balance regarding a specific error episode (Zhao & Olivera, 2006), not to a general stable disposition. Whereas the estimation of an error as a chance for learning focusses on potential benefits that can be gained from an error, the tendency to cover up an error focusses on potential costs. Such a tendency may result from the interpretation of an error as a threat, as well as from the anticipation that the social and organisational context will react with accusations and negative sanctions (Barach & Small, 2000; Edmondson, 1999). Rybowiak et al. (1999) found covering up errors to be

negatively related to action orientation and initiative. Meurier et al. (1997) indicate that nurses who tend not to report errors are less likely to seek social support and plan a course of action. Therefore, it is hypothesised here that the tendency to cover up errors inhibits the engagement in learning activities after an error.

Hypothesis 3. *The tendency to cover up errors predicts the engagement in learning activities negatively.*

These three variables cover cognitive, emotional, and motivational facets of the interpretation of an error situation. The derived hypotheses are investigated in the empirical part of this study in order to answer the question how the interpretation of an error situation may shape the engagement in learning activities (Research Question 2). This reflects the first assumption made in the literature on learning from errors that has been identified above. In the following paragraphs the second assumption, namely that the perception of a safe context relates to the engagement in learning activities after an error, is elaborated and hypotheses are derived.

2.3.4. Perception of a safe social context

The second proposition identified from the literature on learning from errors is that taking a learning orientation towards errors and engaging in learning activities requires the perception of a supportive social context (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996, 1999; Tjosvold et al., 2004; Tucker & Edmondson, 2003). Previous research indicates that learning at work is a social process that is shaped by the quality of social interactions at the workplace (Billett, 2004a; Boud & Middleton, 2003; Eraut, Alderton, Cole, & Senker, 2002; Palonen, Hakkarainen, Talvitie, & Lehtinen, 2004; Rehrl, Gruber, & Palonen, 2006). In particular, a social climate of mutual trust is supposed to support individual learning and learning in social exchange (Bauer, Rehrl, & Harteis, 2007; Edmondson, 1999; Thompson & Kahnweiler, 2002). Applied works on errors and safety management have claimed that learning from errors requires the establishment of a learning oriented "error culture" in organisations (e.g., Glazinski & Wiedensohler, 2004; Glendon et al., 2006; Holzer et al., 2005). Because contextual characteristics work primarily through their effects on individual cognition (Billett, 2006; Zhao & Olivera, 2006), a supportive context concerns the individual perception of whether it is possible and safe to admit an error to colleagues or to a supervisor and to analyse potential causes and prevention strategies. Therefore, this study investigates whether the perception of a safe team climate predicts the engagement in error-related learning activities (Research Question 3). Below, the conception of a safe team climate and its hypothesised relation with the engagement in learning are elaborated.

A safe team climate. Edmondson (1999) investigated how a safe and trustful team climate ('psychological safety') supports sharing knowledge and engaging in learning behaviour (including learning from errors) in organisations. The term 'safety' refers to the belief that a team is safe for interpersonal risk taking (cf. N. R. Anderson & West, 1994).

Hence, a safe team climate is characterised by interpersonal trust, mutual respect and support, the possibility to come up with critical problems, and to openly address errors (Edmondson, 1999). Trust can be defined as a psychological state concerning "... one's expectations, assumptions, or beliefs about the likelihood that another's future actions will be beneficial, favorable, or at least not detrimental to one's interests." (Robinson, 1996, p. 576). Hence, trust implies the willingness of a party to take the risk to be vulnerable to the actions of another party, based on positive expectations of the other party's collaboration (Kramer, 2006; Mayer, Davis, & Schoorman, 1995; Palonen, 2003). However, a safe team climate goes beyond trust in that a safe climate includes concrete instants of trust, such as the perception of a fair handling of errors that is oriented towards problem-solving and learning instead of focussing on blame assignment and prosecution (Edmondson, 1999). Other authors conceptualised this as a problem solving or learning orientation towards errors versus a blame or error-aversion orientation (Kriegesmann et al., 2005; Tjosvold et al., 2004; Van Dyck et al., 2005).

Hence, a safe team climate is conceptualised here as an individual perception of the social context of a team – including both peers and supervisors – that comprises two related facets: the perceived trustworthiness of team members and the perception of a non-punitive orientation towards errors within the team. Whereas Edmondson (1999) conceptualises psychological safety on the team level, the focus here is on the individual's interpretation of the social context because this study aims to identify conditions that motivate individuals to engage in learning activities. Hence, interindividual differences are in focus, not intergroup differences. This focus is conceptually legitimate because trust as well as climate variables are meaningful on both the individual and the collective level (Kramer, 1999; A. B. Weinert, 2004). Below the hypothesised relation of a safe team climate with the engagement in learning activities after an error is discussed.

Hypothesised relations between the perception of a safe team climate and the engagement in learning from errors. One of the primary effects of a trustful climate in organisations is the provision of an 'expectational backdrop' that fosters manifold forms of sociability and cooperative activities among organisational members (Kramer, 1999, 2006). For example, trust has been found to be a determinant of sharing knowledge in organisations (Palonen, 2003). Edmondson (1999) assumes that initiating learning behaviour within a team – such as seeking feedback, asking for help, or talking about errors – may be constrained by the fear of appearing incompetent or losing face. Also other authors have argued that people in organisations will tend to defensive behaviour if they perceive the danger of losing face or getting embarrassed, and thus relevant learning opportunities are missed (Argyris, 1982; Argyris & Schön, 1996; Van Dyck et al., 2005). The perception of psychological safety should alleviate such concerns about potential embarrassment. Indeed, Edmondson (1999) found psychological safety to be positively related to team learning and the readiness to ask for help.

If a safe team climate has an effect on learning and knowledge exchange in teams in general, then this should be particularly valid for communicating about errors. As mentioned above, learning from errors is part of Edmondson's (1999) operationalisation of

team learning behaviour. Furthermore, this line of argument is consistent with Zhao and Olivera's (2006) cost-benefit-calculation framework of error-reporting: whereas fear concerning reprisal, loss of personal image, blame, or embarrassment are costs that may hinder an actor from communicating an error to others, the perception of a safe team climate may be a resource that mitigates these fears and reduces the anticipated costs. Especially the engagement in social learning activities should depend on the overall level of trust in the team and on the generalised perception of non-punitive reactions of the team members towards admitting errors.

There is some evidence for these assumed relations. In studies on error reporting and the use of reporting systems in medical professions it was found that scepticism, lack of trust, fear of reprisals, and a potential loss of professional image were disincentives to error reporting (Barach & Small, 2000; Uribe et al., 2002). Edmondson (1996) found positive correlations between unit characteristics (i.e., supervisors leading qualities and quality of unit relationships) and detected medication error rates. Studies in nursing found that when others' reactions to errors were perceived as insensitive, unsupportive, or unjust, nurses would be more likely not to communicate errors (Arndt, 1996; Meurier et al., 1997). Conversely, nurses took a learning oriented orientation, if supervisors tended to treat incidents openly in the team and protected the nurse in charge. In non-medical work domains, Harteis et al. (2007) found that employees from different types of enterprises consistently named a lack of trust and a prevailing intolerance for errors to inhibit learning from errors. A problem of these studies is that they either focus primarily on error reporting – which itself is a helpful but not sufficient condition for learning – or do not relate the perception of the context systematically to learning activities derived from a theoretical framework. Although there is some evidence that psychological safety predicts error reporting, there is hardly any about the degree to which it affects other learning activities.

Drawn together, for the purpose of this study the perception of a perceived safe climate in the work team is assumed to be a facilitating condition for the engagement in learning activities.

Hypothesis 4. *The perception of a safe team climate predicts the engagement in learning activities positively.*

Interrelation between the interpretation of errors and the perception of a safe team climate. The hypotheses stated above addressed the main focus of this study, namely to answer the questions how the individual interpretation of errors and the perception of the social context at work predict learning from errors (Research Questions 2 and 3). However, individual and contextual variables that provide a framework for learning at work are typically assumed to be intertwined (Billett, 2001c; Eraut et al., 1998). Therefore the question how the three error orientation variables and the perception of a safe team climate are interrelated must be addressed (Research Question 4).

Concerning the interrelation of the error orientation variables, initial evidence exists for their interrelation from Rybowiak et al. (1999). However, it has to be checked, whether these findings replicate under the situational interpretation of the error orientation vari-

ables proposed above and in the domain of nursing. Rybowiak et al. (1999) found a medium positive correlation between covering up errors and error strain, and a small negative correlation between covering up errors and the estimation of errors as a chance for learning. Furthermore, small to medium negative correlations between the estimation of errors as chance for learning and error strain have been found (Keith & Frese, 2005; Rybowiak et al., 1999). These results are consistent with the argument above that the tendency to cover up an error may be associated to feelings of being inadequate or fear of reprisals and prevent a subject from taking a learning orientation towards an error. Similar relations are expected for this study.

Hypothesis 5. *The estimation of errors as chance for learning is negatively correlated with the tendency to cover up errors.*

Hypothesis 6. *The estimation of errors as chance for learning is negatively correlated with error strain.*

Hypothesis 7. *The tendency to cover up errors is positively correlated with error strain.*

Whereas the error orientation variables have been conceptualised as situationally dependent here, the perception of the social context is the result of a cumulated experience, that is, it is built through individual codings of a common interaction history (Kramer, 2006). Hence, it is assumed that the perception of the social context is related to the situational interpretation of errors within this context as well as resulting emotions and the tendency to cover up errors. This implies that there may be also an indirect effect of the perception of a safe team climate on the engagement in learning activities, mediated by error orientation variables. The following relations are expected between the error orientation variables and the psychological safety variables.

If an individual generally perceives a safe climate for communicating about errors and a non-punitive, learning oriented way of handling them, there may be an increased likelihood that an error episode is interpreted as a chance for learning. Cannon and Edmondson (2001) found team members to share beliefs and attitudes towards errors, that is, there seems to be a socialisation effect between team and individual reactions and attitudes towards errors. Therefore, a positive relation between the perception of a safe team climate and the estimation of an error as a chance for learning is hypothesised, here. Furthermore a safe team climate should mitigate potential fears of having committed an error and anticipated risks of admitting the error to others (cf. Edmondson, 1999). Therefore a safe team climate should reduce negative emotions related with errors as well as the individual tendency to cover up an error.

Hypothesis 8. *The perception of a safe team climate is positively correlated with the individual estimation of errors as a chance for learning.*

Hypothesis 9. *The perception of a safe team climate is team negatively correlated with the individual tendency to cover up errors.*

Hypothesis 10. *The perception of a safe team climate is negatively correlated with error strain.*

2.4. Summary of the theoretical framework

In this chapter a theoretical framework of individual learning from errors at work has been developed that is based on established learning theories and that can guide further empirical analyses. The framework addressed the questions (a) how 'error' can be conceptualised, (b) how errors that emerge in daily work processes can contribute to individual learning, and (c) what individual and contextual variables may foster or constrain learning from errors at work. These three components of the conceptual framework build the basis for answering the stated research questions. The conceptualisations of 'error' and 'learning from errors at work' are required for operationalising learning from errors (Research Question 1). The discussion of individual and contextual variables that are hypothesised to affect learning from errors guides the investigations to answer Research Questions 2—4. This section provides a summary of the conceptual positions taken so far and gives an outlook on tasks for the empirical part.

Errors have been defined as individual actions that fail to reach a goal and endanger the attainment of higher order goals (Frese & Zapf, 1994; Rasmussen, 1987b; Reason, 1990; Senders & Moray, 1991). The evaluation of actions as errors implies judgements of knowledgeable members of a community on the basis of socially negotiated norms (Meurier et al., 1997; Senders & Moray, 1991; Wehner & Mehl, 2003). It has been argued that especially knowledge- and rule-based errors bear a potential for individual experiential learning (Bauer & Mulder, 2007; Glendon et al., 2006; Keith & Frese, 2005). Therefore, this study will focus on the engagement in learning activities that are grounded in concrete situations of this type of error. This proposition involves the task to develop research instruments that achieve such a grounding in authentic error cases for the domain of nursing.

While learning from errors has been explained by drawing on cognitive theories of dynamic memory and case based reasoning (Kolodner, 1983, 1997; Schank, 1999; Schank & Abelson, 1977), the case has been made that learning from errors can be operationalised and measured in terms of the process of engagement in learning activities. The rationale behind this proposition is that in contrast to cognitive structures, concrete activities can either be observed directly or are easier for participants to explicate (Eraut et al., 1998; Simons & Ruijters, 2004). A framework of learning activities has been derived from conceptions of experiential learning cycles and learning at work (Billett, 2004a; Eraut et al., 1998; Gruber, 1999a; Kolb, 1984). Whereas this framework provides a systematic heuristic for operationalising learning from errors, yet a concrete operationalisation must be developed that is contextualised to the requirements of the specific domain of nursing. This implies identifying which learning activities from the framework are particularly relevant for this domain. Hence, a further selection of learning activities has to be made that will be focussed upon in the empirical investigations, because different kinds of learning activities may be of different relevance for nursing and for specific error situations. A further reason for making a selection of learning activities is that a given set of predictors may not be equally relevant for all kinds of learning activities . Hence, a task of exploratory research

as precursor to further studies will be to contextualise the framework of learning activities and to select those learning activities that will be focussed upon in further studies.

Concerning the conditions that may foster or constrain learning from errors at work, the position has been advanced that learning from errors results from an interaction of individual and contextual variables (cf. Billett, 2001c, 2004b). An error situation as well as contextual factors that may shape responses to errors are primarily relevant in terms of their individual perception, because these perceptions affect the motivation for engaging in learning activities through a cost-benefit-evaluation (Billett, 2004b, 2006; Ellström, 2001; Jørgensen & Warring, 2002; Zhao & Olivera, 2006). In existing studies, the interpretation of an error situation as a chance for learning and the perception of a safe and learning oriented climate in the social context have been especially emphasised as relevant for learning from errors (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996, 1999; Meurier et al., 1997; Tjosvold et al., 2004; Tucker & Edmondson, 2003; Van Woerkom, 2003). However, there is a need for more evidence about these assumptions (Bauer & Mulder, in press). For this purpose, a theoretical framework about the potential interplay of (a) the cognitive, emotional, and motivational interpretation of an error situation (i.e., error as a chance for learning, negative emotions resulting from an error, tendency to cover up an error; Rybowiak et al., 1999), (b) the perception of a safe team climate (Edmondson, 1999), and (c) learning from errors has been derived. From this theoretical framework, the research model shown in Figure 1 can be build. This model comprises the three variables concerning the interpretation of an error and the perception of a safe team climate as predictors for the engagement in learning activities (Hypotheses 1—4). These predictors are assumed to be interrelated with each other (Hypotheses 5—10). In the empirical studies, this model will be tested and advanced in order to answer Research Questions 2—4. The following chapter will provide an overview of the empirical procedure.

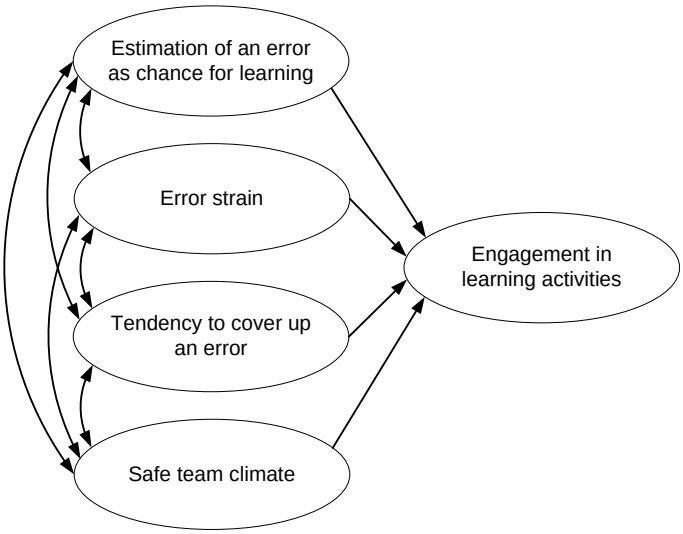


Figure 1: Research model

3. Overview of the empirical studies

In the empirical part of this thesis, the developed framework of learning from errors is applied in order to answer the research questions that were stated in the introduction. For this purpose, a research model has been derived in the previous chapter, that implies hypotheses about the relations among the individual interpretation of an error, the perception of a safe team climate, and the engagement in learning activities after an error. This chapter will summarise the developed hypotheses and provide an overview of how the research questions are answered in the empirical studies. This overview will pick up the discussion of the studies from the introduction and elaborate on them in more detail.

3.1. Summary of the hypotheses

Below, the hypotheses about the relations among the individual interpretation of an error, the perception of a safe team climate, and the engagement in learning activities after an error are summarised in relation to the stated Research Questions 2—4. (For Research Question 1 there are no hypotheses, because it concerns the conceptualisation and measurement of learning from errors as precondition for answering the other research questions.)

Research Question 2: To what degree does the individual interpretation of an error situation foster or constrain the engagement in learning from errors at work?

> **Hypothesis 1.** *The estimation of an error as a chance for learning predicts the engagement in learning activities positively.*
> **Hypothesis 2.** *Error strain predicts the engagement in learning activities negatively.*
> **Hypothesis 3.** *The tendency to cover up errors predicts the engagement in learning activities negatively.*

Research Question 3: To what degree does the perception of the social context at work foster or constrain the engagement in learning from errors at work?

> **Hypothesis 4.** *The perception of a safe team climate predicts the engagement in learning activities positively.*

Research Question 4: How are the variables regarding the individual interpretation of an error and the perception of the social context at work interrelated?

> **Hypothesis 5.** *The estimation of errors as a chance for learning is negatively correlated with the tendency to cover up errors.*

Hypothesis 6. *The estimation of errors as a chance for learning is negatively correlated with error strain.*
Hypothesis 7. *The tendency to cover up errors is positively correlated with error strain.*
Hypothesis 8. *The perception of a safe team climate is positively correlated with the individual estimation of errors as a chance for learning.*
Hypothesis 9. *The perception of a safe team climate is team negatively correlated with the individual tendency to cover up errors.*
Hypothesis 10. *The perception of a safe team climate is negatively correlated with error strain.*

3.2. Procedure and overview of the studies

This section provides an overview of the empirical process that addresses the research questions. Firstly, it will be argued that hospital nursing is an adequate domain for conducting research on learning from errors. Secondly, an overview of the empirical studies and their contribution to answering the research questions will be given.

Domain of work under study. All studies are conducted in the domain of hospital nursing. This domain is selected for two reasons. Firstly, learning from errors is particularly relevant in nursing. Quality management and patient safety are key issues in health care, because services in health care are supposed to be delivered by upholding the highest degree of quality and professional state of the art (Bogner, 1994; Kela & Kela, 2006; Kohn et al., 1999; Meurier et al., 1997; Meurier, 2000; Tucker & Edmondson, 2003). Errors are a delicate issue in this context because they may lead to serious adverse effects on a patient's health (Bogner, 1994; Kohn et al., 1999). On the other hand, nurses are faced with a dynamic field of work, thus having to adapt continuously to frequent changes in relevant knowledge, procedures, and methods that are driven by developments in medical science, technology, and policy (Büssing & Glaser, 2003; Eraut et al., 1998). Under such conditions, there is an increased likelihood of errors occurring (Rybowiak et al., 1999; Wehner & Mehl, 2003; Zapf et al., 1999), making error management and learning from errors particularly relevant. Hence, there is a strong tradition of research and applied works on human factors, safety, and risk management in health care (Bogner, 1994; Kohn et al., 1999). Recently, the politically driven demand has been advanced to create a learning oriented 'error culture' in hospitals that allows for open discussions and analyses of occurring errors (Glazinski & Wiedensohler, 2004; Holzer et al., 2005; Kela & Kela, 2006). These conditions make nursing to a relevant domain for conducting research on learning from errors and should ensure the field's interest in the findings.

A second reason for focussing on nursing is that the highly standardised nature of work processes in nursing facilitates the identification of errors and provides transparent criteria for judging actions as errors. In research on learning from errors it is helpful to select a domain in which the criteria for error judgements are as transparent, codified, and ac-

cepted inter-subjectively as possible. As mentioned before, nurses' work is shaped largely by guidelines and standardised procedures that are supposed to reflect national 'expert-standards' based on the state of the art in medical care (Büssing & Glaser, 2002; Deutsches Netzwerk für Qualitätsentwicklung in der Pflege, 2007). These standards provide transparent criteria for errors with the underlying norm that a patient's health or healing process must not be affected in a negative way by medical mismanagement (Bogner, 1994; Kohn et al., 1999).

For these reasons nursing is a domain that provides adequate conditions for answering the stated research questions. Learning from errors is relevant in this domain and its characteristics facilitate research on learning from errors.

Overview of the studies. The research questions stated in the introduction are addressed in a series of three studies. The first two studies aim to develop an operationalisation and a research instrument for measuring learning from errors in nursing (Research Question 1). These studies build the basis for testing and advancing the hypothesised model for learning from errors in a third study (Research Questions 2—4). A short overview of these studies and their contribution to answer the research questions is provided here, before presenting each study in detail in the following sections.

Research Question 1 concerns the development of a measurement instrument for learning from errors that is based on the conceptual framework of learning from errors developed above. In this framework, two propositions have been advanced: first, to conceptualise and operationalise learning from errors as engagement in experiential learning activities after a given episode of a knowledge- and rule-based error. This learning activity approach provides a fruitful perspective because it focusses on concrete behaviour in everyday work (Simons & Ruijters, 2004) and is consistent with theories of experiential and workplace learning (Gruber, 1999a; Kolb, 1984; Kolodner, 1983; Schank, 1999). Secondly, the measurement of error-related learning activities should be grounded in concrete error episodes that represent a specific type of error. Asking questions about whether subjects engage in learning activities after errors in general is inappropriate, because this requires the subjects to generalise over a number of situations that may not be comparable (cf. Ericsson, 2006b). As indicated above, errors differ in the underlying level of action regulation (Reason, 1995) and in the learning potential they imply (Glendon et al., 2006; Keith & Frese, 2005). Furthermore, it remains uncertain what kind of situations and errors the subjects refer to (Harteis et al., 2007) so that it is impossible to argue why these errors are relevant for learning, what can be learned from them, and what kind of learning activities are relevant. Both problems can be addressed by grounding questions on learning activities in concrete error episodes.

Translating these propositions in a research instrument requires performing the following tasks.

1. To decide on a data gathering technique.
2. To develop a way to ground questions on learning activities in concrete episodes of knowledge- and rule-based errors.

3. To adjust the framework of learning activities (Tab. 1) to the domain of nursing, to select relevant learning activities for the further research process, and to develop a instrument on this basis.

Concerning the data gathering technique, a decision between observations and self-reports has to be made. Given that errors are rare and unpredictable events at work (Wehner & Stadler, 1996; Wehner & Mehl, 2001), participating observations are impractical over a number of workplaces and extended periods of time (cf. Billett, 2000). Instead, self-reports can be used, if two already mentioned precautions are taken to enhance their validity. Firstly, the term 'learning' should be avoided in the questions because employees have been found to react strongly to the notion of formalised, classroom based learning if they are asked for 'learning' at work (Simons & Ruijters, 2004). Secondly, it has been indicated that employees are better able to explicate knowledge or learning activities when questions refer to concrete events at work (Billett, 2000; Eraut et al., 1998; Ericsson, 2006b; Ericsson & Simon, 1984; Simons, 2005). Hence, in order to enhance the validity of self-reports about learning at work, questions on activities in concrete workplace episodes have to be asked. This is accomplished here by grounding questions on learning activities in concrete error cases that are judged as errors, either by the participants themselves or by knowledgeable members of their domain. Because testing and advancing the research model requires a large sample, as discussed below (Study 3), a questionnaire is an adequate and efficient research instrument for measuring self-reports about the engagement in learning activities (Bortz & Döring, 2006).

Grounding questions on the engagement in learning activities in concrete error situations can be accomplished by two approaches: first, by applying the Critical Incident Technique (CIT; Flanagan, 1954; Fivars & Fitzpatrick, 2001). Essentially, the CIT aims to identify what people do or have done in order to respond to a specific situation. The CIT can be applied to measure learning from errors by asking subjects to describe a concrete error situation and the subsequent engagement in learning activities (Meurier et al., 1997). The second approach is to present vignettes of authentic error cases to the subjects and to ask them to identify with these cases. Subsequently, the subjects are asked about their anticipated engagement in learning activities in such a situation (Cases Approach). For this approach, authentic cases for knowledge- and rule based errors have to be developed. Authenticity concerns the case-domain relationship as well as the subjects' interpretation of the cases (Honebein, Duffy, & Fishman, 1993). Both approaches have their particular strengths and weaknesses.

CIT. Advantages of the CIT are that the participants' experience is directly involved and that real cases are used so that the participants can be asked how they actually reacted to the given incident. The problems are (a) that it is more demanding for the subjects and requires more disclosure, (b) that the researcher depends on the participants' readiness and ability to provide relevant error examples, and (c) that the incident may have happened a long time ago, making reconstruction difficult and leaving an opportunity for self-serving biases.

Cases Approach. Advantages of the Cases Approach are that it requires less disclosure

from the participants and thus should facilitate their readiness to participate. In addition, the used cases are standardised, ensuring that the chosen type of error is met. This increases the comparability of the answers. Problems are (a) that valid cases have to be constructed, (b) that the subjects need to be able to identify with the case, and (c) that it is unsure whether the answers about the engagement in learning activities are valid for actual behaviour.

Hence, it is inadvisable to decide on one on the basis of theoretical arguments. Both approaches will be explored in practical application and checked for their psychometric quality in order to make an informed decision.

The contextualisation of the framework of learning activities to the domain of hospital nursing requires to identify which learning activities are particularly relevant for this domain and to make a selection of those learning activities that will be further investigated. As mentioned above, this selection is necessary because different kinds of learning activities may be of different relevance for nursing and for specific error situations. On this basis, the selected learning activities can be operationalised and scales for a questionnaire can be developed and tested.

The described tasks for the development of a measurement method for learning from errors are addressed in two studies:

Study 1. In an exploratory study, experts in nursing (extensive work experience, supervisory position) are interviewed about concrete knowledge- and rule-based errors that occur in nurses' everyday work and about learning activities that enable nurses to learn from these errors. This study contributes to attaining the tasks of collecting concrete examples of errors from which authentic cases can be constructed as stimulus material (Cases Approach), to contextualise the framework of learning activities to the domain of nursing, and to select concrete learning activities for an operationalisation of learning from errors for the further studies.

Study 2. In a cross-sectional field study, two questionnaires for measuring learning from errors at work are developed on the basis of the findings from Study 1, applied, and compared. The questionnaires differ in the way in which they ground the questions on error-related learning activities in concrete error episodes. The first instrument applies the Cases Approach and presents vignettes of error cases that are developed from the interviews. In the second instrument, the CIT is applied by asking the participants to describe self-experienced error episodes. Study 2 provides an initial test of the psychometric properties of the developed operationalisation (i.e., questionnaire scales on error-related learning activities) and informs the decision to apply either the CIT or the Cases Approach for testing the research model in Study 3.

Research Questions 2—4 concern the relations among the individual interpretation of an error, the perception of a safe team climate, and the engagement in learning activities after an error. These questions are addressed in combination, because they are integrated in the research model presented above (Fig. 1). For the purpose of answering them, firstly, measures for the three variables concerning the interpretation of an error (i.e., the estimation of an error as chance for learning, error strain, and the tendency to cover up

an error) as well as the perception of a safe team climate have to be selected or developed. This task is performed in Study 2. Secondly, the research questions are addressed in a third study, by (a) testing the research model, and (b) advancing this model on the basis of the data in order to create more differentiated hypotheses for further research. Both steps are required to address the research questions adequately. In the first step the hypotheses are tested that were stated above on the basis of current theory and evidence in research on individual learning from errors at work. The second exploratory step is appropriate for fields of research where only tentative models can be specified due to a lack of cumulative prior research (Jöreskog, 1993). As has been argued above, this characterises the existing research on individual learning from errors at work, which has largely been conducted in a non-cumulative or normative fashion (Bauer & Mulder, in press; Ohlsson, 1996; Sitkin, 1992). As a consequence, the current state of theory has a rough grain size, that is, it allows us to identify potentially relevant conditions for learning from errors, but provides little information about how the interplay of the respective variables fosters or constrains such learning. Therefore, to explore how the stated model may be advanced or differentiated on the basis of the findings contributes to answering the research questions regarding the nature of the relation between the investigated variables and provides an improved basis for conducting further research. These steps are performed in Study 3 as follows.

Study 3. In a cross-sectional field study nurses from several hospitals are surveyed with the research instrument developed from Studies 1 and 2. In order to test and advance the model, the gathered data are analysed in a model generating structural equation modelling process (Jöreskog, 1993) in which an initial model is specified on the basis of substantive hypotheses, tested, and advanced both on the basis of the findings and substantive considerations.

The decision for a field-study design results from the objective to investigate under what conditions individual learning from errors occurs in a natural work context. For attaining this goal, the field study design is prone to deliver ecologically valid findings about learning behaviour in real organisations (cf. Edmondson, 1999). It is acknowledged that the conclusiveness of the study is limited because no causal inferences can be made from non-experimental, cross-sectional data. However, introducing a longitudinal component is beyond the scope of this thesis, because of the required amount of exploratory research (Studies 1 and 2) and the prerequisite to test the hypotheses in a large sample drawn from multiple hospitals. In the present design, statements about the direction of causality between predictors and criterion variable are made solely on the basis of the theoretical considerations presented above and have to be interpreted as such. Still, the study provides evidence about the association between the investigated variables as a elementary precondition for causality (Bollen, 1989; Hoyle, 1995; Urban & Mayerl, 2006) and contributes to answering the research questions about the relations between these variables. The findings of this study can guide the selection of variables for more in-depth investigations in experimental studies.

The three described studies build upon each other: An initial, theoretically founded conceptualisation of learning from errors is contextualised to the domain of nursing and op-

erationalised (Study 1). Research instruments are developed, tested, and improved on this basis (Study 2). The developed instrument is applied in order to test and advance hypotheses about learning from errors that are derived from theory and existing findings (Study 3). Together, the studies enhance our understanding of how learning from errors at work can be conceptualised and investigated (Research Question 1), and of how the individual interpretation of an error situation as well as the perception of the social context at work are related to the engagement in learning after an error (Research Question 2—4). In combination, the studies begin a process of answering the broader question of what individual and contextual variables foster or constrain nurses' engagement in learning after the experience of an error at work, and help to ask more precise questions about learning from errors in further research.

4. Study 1: Collecting error cases and contextualising the framework of learning activities

The study presented in this chapter[6] contributes to the development of an operationalisation and a measurement instrument for learning from errors in nursing (Research Question 1) by addressing two goals. (a) Since the case has been made above that the measurement of learning from errors should be grounded in concrete error cases, the first goal of Study 1 is to collect exemplary knowledge- and rule-based errors for the domain of nursing. These examples are needed for the development of authentic cases that can be used as stimulus material for the implementation of the Cases Approach. The term 'authentic' refers to the fact that the cases are based on actual incidents collected from the field. Furthermore, the cases should be subjectively relevant to the subjects (Honebein et al., 1993), and refer to the category of error which is in the focus of the research. (b) The second goal is to contextualise the framework of learning activities to the domain of nursing. This implies finding out which kind of learning activities are particularly relevant and to make a selection of learning activities for further studies. It is assumed that the learning activities identified in the developed framework (cf. Tab. 1; reflection and analysis, development of a new action strategy, experimenting with and implementing the new strategy) are of importance, and that these activities can be performed both individually and cooperatively.

To attain these goals, an exploratory interview study with experts in nursing (extensive work experience, supervisory position) was conducted. Below, firstly a description of the sample, the interview procedure, and the analysis of the interviews is provided. Secondly, the findings regarding the error cases and the learning activities are presented and discussed. The final discussion summarises the results and elaborates conclusions for the further research process in Studies 2 and 3.

[6] This chapter is based on the article: Bauer, J., & Mulder, R. H. (2007). Modelling learning from errors in daily work. *Learning in Health and Social Care, 6*, 121–133.

4.1. Method

4.1.1. Sample

Eleven experts from three hospitals were approached to participate in the study. The procedure focussed more on finding experienced people than on a large number of subjects. In this perspective experts are defined as professionals with a longtime professional experience who achieve at least a moderate degree of success in their occupation (Boshuizen et al., 2004a). The applied criteria for expertise were that the participants had substantial and broad professional experience in nursing (longtime experience, experiences from different types of wards) and a supervisory function. The supervisory function was chosen, first, because it is part of supervisors' role to have a critical perspective and distance towards their department. Secondly, a supervisory role often implies a central and powerful position, including an increased power to define what constitutes an acceptable practice (Hakkarainen et al., 2004; Heid, 1999). Hence, this group can be assumed to be able to provide valid answers about what constitutes an error in nursing and where errors appear.

Ten out of the eleven addressed experts agreed to participate in the study (5 female; 5 male). The subjects had a supervisory function at different levels: five subjects were supervisors in their wards. Another five were either at the CEO level for nursing in their hospital, or worked in quality management and vocational education and training. The average occupational experience was 27 years ($SD = 4$ years). All had started their career as nurses and participated in continuing professional development. In addition, all subjects had experience in different kinds of wards or specific domains of the hospital. Thus, they had substantial knowledge about the conditions in different units of a hospital.

4.1.2. Interview procedure

The interviews were conducted by the author in the period from September to October 2005. They took about one hour's time on average and were conducted at the subjects' workplaces. A semistructured interview guideline was used. It started with several opening questions about the subject's experiences as a nurse. Next, the subjects were introduced to the distinction between knowledge- and rule-based errors (KRE) and slips and lapses (SL). They were provided with a definition in everyday terms and some generic examples (e.g., SL: 'mixing things up', 'forgetting things'; KRE 'applying an inappropriate procedure'). All subjects could give short, concrete examples for either type of errors, as a test that they understood the distinction. In the following part of the interview, the subjects were asked to describe concrete cases for KRE which occur in nursing practice according to their experience. This part of the interview was mostly non-directive and narrative. No constraints were set concerning the frequency in which these errors occur or the severity of the consequences they imply. Next, the subjects were asked to identify activities that a nurse would have to engage in after an error episode, such as the one(s) they had just described, in order not to repeat a similar error again. Although it was impossible to avoid the term 'learning' completely in the interviews, the question was explicitly *not* what a person would have to do in order to *learn* from the error (cf. Simons & Ruijters, 2004).

4.1.3. Analysis

The interviews were recorded, transcribed verbatim, and analysed. For the error examples, a deductive strategy to categorisation was followed, using Reason's (1995) subcategories of KRE 'wrong application of a good rule', 'non-application of a good rule', 'application of a bad rule', 'wrong interpretation of a situation' and 'deficiencies in knowledge' as an initial category system. Firstly, all verbatim error examples provided by a subject were classified in SL and KRE. Only KRE were further analysed. Secondly, the KRE were allocated to the respective subcategory while keeping the information about which subject had provided the example. Thirdly, examples with common themes were grouped together within the categories while keeping the information about how many subjects had provided examples grouped to a theme. During this process, the categories were re-labelled in a more concrete way (e.g., 'deficiencies in knowledge' was re-labelled to 'lack of knowledge about current guidelines and standards'). Furthermore, three new categories were introduced for themes that could not be integrated in the existing system. For each category, the descriptive information was saved about how many subjects had provided examples within it and how many examples it contained. These data provide information about the degree to which errors from a given category are salient and subjectively relevant for the subjects. This is a relevant indicator for the development of authentic cases. In a last step of the analysis, the codings and categorisation were re-analysed systematically with a second researcher, and discussed until inter-subjective agreement was achieved. The classifications could be made clearly and no severe disagreements were encountered during this process.

For the learning activities, it was planned to use the framework in Table 1 as a category system. However, during the interviews, it became apparent that the subjects did not answer according to the notion of a sequential process, but named different possible learning activities. Thus, it was decided to employ an inductive mode of analysis by developing the categories from the data. Firstly, all expressions concerning learning from an error or steps to avoid it in future were collected verbatim per subject. Secondly, common themes were identified, coded, and grouped together. Thirdly, the resulting categories were grouped together to higher stratum constructs by focusing on the kinds of activity encompassed (e.g., social exchange). Here, the data-driven approach was broken up and theory-related constructs from the framework and from research on learning at work entered the analysis (e.g., 'reflection', 'self-regulated learning'). Most of these constructs could again be grouped on a third stratum in the distinction between formal and non-formal learning (Eraut, 2000). In learning from errors, non-formal learning activities mean self-initiated and self-regulated learning activities in which a subject engages either intentionally, with time being especially set aside for it (i.e., deliberative) or as immediate reaction to an error (i.e., reactive) (cf. Chapter 2.2). In contrast, formal learning refers to learning in externally organised learning environments with a prescribed learning framework (Eraut, 2000). As in the analysis of the error examples, information was saved about how many subjects had given examples within the categories (only valid for the first stratum), how many subjects had named a common theme, and how many examples a category contains (valid

for all three strata). Since the given learning activities were related to the error situations presented by the subjects, these frequencies can be interpreted as indicators of the degree to which the learning activities are perceived as relevant by the sample in a variety of error situations. After this preliminary analysis, the codings and categorisation were re-analysed systematically with the second researcher and discussed until inter-subjective agreement was achieved. The classifications were mostly unequivocal and no severe disagreements were encountered.

4.2. Findings and discussion

The following paragraphs report on the findings regarding the collection of examples for knowledge- and rule-based errors and relevant learning activities.

4.2.1. Examples of knowledge- and rule-based errors

The goal was to work out concrete, authentic cases, and to check whether the differentiation in different types of KRE can serve as a heuristic to structure the cases. Nine out of ten subjects gave one or more examples. One person claimed to have too little recent experience, because the focus of work was now on the organisation of nurses' vocational education and training.

The findings can be obtained from Table 3. The left hand column of Table 3 contains the categorised cases. Numbers in parentheses indicate that an example was named unanimously by several subjects. The frequencies in the right hand column refer to the number of subjects who named a case within the specific category (n) and the number of examples within the category (ex). Since each person could give more than one example, the number of examples can be larger than the number of subjects. Where adequate, Reason's (1995) subcategories are indicated.

Although the cases described by the subjects vary in their level of abstraction, they provide a rich picture of concrete errors in nursing. Most of them address professional issues of nursing. The category 'inadequate interpretation of a situation' was the largest one. The categories 'non-application of a new or up-to-date method', 'application of out-of-date methods' and 'lack of knowledge about current guidelines and standards' mirror the problem of adapting to continuous changes (Büssing & Glaser, 2003; Eraut et al., 1998). The subjects named frequency of changes and lack of motivation as barriers for adapting to changes and adopting innovations. Another category addressing professional issues is the wrong application of nursing methods, which was attributed to a lack of knowledge, competence and experience by the subjects. Also 'not asking experienced colleagues for help' in case of an uncertain situation was related to a lack of experience. Such errors were associated especially with younger colleagues. A related issue is 'not to challenge orders from supervisors' on the basis of one's knowledge and experience. Both issues address the topic of low confidence and self-efficacy. Two subjects mentioned errors that address social relationships at the workplace. This is noteworthy, as typologies of errors like the one of

Table 3: Examples of knowledge- and rule-based errors in nursing.

Category and examples	*n/ex*
Inadequate interpretation of a situation	6/7
Critical values on a medical instrument are misinterpreted or not cross-checked with the overall physical state of the patient, so that a required intervention is omitted or an inadequate or unnecessary intervention is applied. (2)	
The risk of bedsore is inadequately evaluated, so that prophylaxis is applied too late or insufficiently. (2)	
Complications are not recognised, misjudged, or wrong conclusions are drawn. (2)	
Relying too heavily on one's own judgement about a patient's level of pain or about how much a pain a patient can bear, and paying too little attention to what the patient says.	
Non-application of a new or up-to-date method (i.e., non-application of a good rule)	4/4
Not applying the Braden-Scales for evaluating the risk of bedsore. (2)	
Instead of a new or up-to-date method an old one is applied, because the nurse is not used to the new one, or does not feel confident enough in the application, and also does not dare to ask.	
Not applying the expert-standard for the administration of analgesics.	
Application of out-of-date 'rituals' and methods, although they have been proven to have adverse effects (i.e., application of a bad rule)	3/5
Wrong treatment of bedsore: applying ice and blowing dry. (2)	
Application of rubbing alcohol. (2)	
Application of an outdated disinfectant.	
Lack of knowledge about current guidelines and standards (i.e., deficient knowledge)	3/4
Lack of knowledge that there are standards for certain treatments or procedures. (2)	
Wrong preparation of a patient for an operation because the nurse has insufficient knowledge about current standards.	
Deficient knowledge about standard methods for the evaluation and prophylaxis of bedsore.	
Wrong application of a method because of lack of knowledge (i.e., wrong application of a good rule)	3/5
A patient falls down, because the nurse has insufficient knowledge and skills about mobilisation or supporting techniques and applies them deficiently. (2)	
Errors in the preparation of a colonoscopy may mean that the patient's bowel is not entirely empty and the examination cannot take place. This results from a lack of knowledge in the individual dosage of laxative for a specific patient.	
A patient gets an infection after the application of a catheter because the nurse has insufficient knowledge about how to apply it under sterile conditions.	
Getting out of the prescribed routine in an emergency situation, because one has too little experience with it.	
Not asking someone experienced in case of uncertainness	3/3
Wrong estimation of the danger of a situation and not asking more experienced colleagues for help. (3)	
Errors in interpersonal relationships	2/2
Giving up the professional distance from patients. (2)	
Not to challenge orders from a supervisor or a physician	1/1

Note. n = number of subjects; ex = number of given examples.

Reason (1995) do not take social aspects into account but focus only on professional and task issues.

Concerning the differentiation, the categories derived from Reason (1995) proved to be useful, although the framework was extended in certain respects (e.g., 'not asking'; 'errors in interpersonal relations'). One constraint is that Reason's (1995) category 'deficiencies in knowledge' could not be separated consequently from the other forms of KRE. This was to be expected, because all rule-based decisions and actions are performed on the basis of

relevant knowledge. Additionally, sometimes multiple causes were present. In these cases, the procedure of analysis was to stick as closely as possible to the subjects' interpretation of the cause.

From the error examples, authentic cases can be developed which can be located to an error category or theme (e.g., treatment of a bedsore) under interest. It is important to note that authenticity is not a general feature of a case but depends on the specific sample under study. Thus, if cases are used, whether the subjects regard them as authentic or are able to identify with them needs to be checked.

4.2.2. Learning Activities

A second goal of the interviews was to adjust the model of learning activities to the domain of hospital nursing. The experts were asked what a nurse could or should do after a KRE, in order to avoid a similar error in future. The left column of Table 4 depicts the categorised learning activities named by the subjects (numbers in parentheses indicate that the specific activity was named unanimously by several subjects). The frequencies in the right hand column refer to the number of subjects who named a case within the specific category (n) and the number of examples within the category (ex). (For the higher order categories, n is not meaningful because the contributions of the subjects in the lower order categories, from which the higher order categories are aggregated, are not independent from each other.)

The answers were categorised under three major headings: (a) The first category contains deliberative and reactive non-formal learning activities (Eraut, 2000). These activities appear here in three subcategories: (i) Most answers concerned socially orientated learning activities, like exchange with more experienced persons, joint root cause analysis and search for a new solution. The subjects emphasised the exchange with colleagues and supervisors, as well as open discussions in team meetings. (ii) On an individual level, reflection on possible causes was mentioned. As examples, deficiencies in the knowledge and action process of the responsible person, contextual issues at the workplace, and available resources were considered. Furthermore, reflection on alternative strategies for future action was mentioned. (iii) The underlying goal of the activities under the first two subcategories is not explicitly learning, but dealing with the error and on finding strategies to prevent its future occurrence. In contrast, the third subcategory explicitly deals with deliberative, self-regulated learning (Eraut, 2000). In this category, professional learning activities were mentioned such as reading professional journals and recent documented standards (cf. Berings et al., 2005; Eraut et al., 1998; Kwakman, 2003). They involve the goal of updating one's own professional knowledge. The categorisation of self-regulated learning into non-formal learning activities might be debatable, because it shares common features with formal learning (e.g., intentionality, time being especially set aside for it). It was categorised this way, because the subjects clearly indicated the self-initiated, -motivated and -regulated nature of these activities, which according to them should be performed at home and in spare time.

(b) The second main category concerns formal learning in externally organised learning

Table 4: Learning activities

Category and examples	*n/ex*
(1) Non-formal learning	n.a./28
(a) Learning in social exchange	n.a./16
Exchange with colleagues	7/8
Exchange with more experienced colleagues (6)	
Asking colleagues for advice or help	
Mutual control and critique	
Exchange with the supervisor	4/5
Discussing the issue with the supervisor (2)	
Asking the supervisor for help (2)	
Root cause analysis together with the supervisor	
Open discussion within the team	3/3
Open discussion in team meetings, so that all team members have the opportunity to learn from the error (3)	
(b) Individual reflection	n.a./6
Root cause analysis	4/4
(Self-)reflection about possible causes of the error (4)	
Reflection on alternative action strategies	2/2
Reflection on what has do be done differently the next time (2)	
(c) Deliberative self-regulated learning	4/6
Closing gaps in one's professional knowledge by oneself and taking care that one is up-to date (3)	
Reading professional journals (2)	
Updating one's knowledge about current standards	
(2) Formal learning	5/6
Attending training and professional development courses (5)	
Identifying one's need for further training	
(3) Emotional reaction	4/4
Emotional conditioning through the error (2)	
Remaining in a state of brooding	
Talking to colleagues in order to salve one's conscience	

Note. n = number of subjects; ex = number of given examples; n.a. = not applicable.

environments, such as attending professional training related to methods and skills. This form of learning was mentioned by five subjects. In contrast to self-regulated learning, the subjects' statements implied the notion of classroom-type training.

(c) A last aspect concerns emotionally based reactions to the error situation. This category does not represent learning activities in the sense of the theoretical framework provided above. However, the interplay between errors, negative emotions and learning has been addressed frequently in the literature about learning from errors (Keith & Frese, 2005; Mehl, 1993; Meurier et al., 1997; Oser & Spychiger, 2005; Rybowiak et al., 1999; Zapf, 1991; Zhao & Olivera, 2006).

Compared with the original framework of learning activities (Tab. 1), the experts' answers covered individual as well as socially orientated learning activities in the categories 'reflection' and 'development of a new action strategy'. In social learning activities, the subjects did not differentiate between the process of cause analysis and the development of a new strategy. Both aspects are contained in the same category 'learning in social exchange', for example, by seeking help and advice, discussing and analysing the error jointly, and providing mutual control and feedback. However, the subjects differentiated between social

exchange that consists mainly of informal discussions with colleagues or with a supervisor, and discussions in formal team meetings. This extended the original framework. Concerning individual reflection, both processes of cause analysis and development of a new action strategy were present, and closely related to each other.

The ideas of deliberate self-regulated learning and formal learning are only implicitly present in the original framework. Both suggest that in order to learn from an error, it may be important to collect new information in order to change the underlying knowledge base (cf. 'allocation of information and resources' in Tab. 1). The subjects' answers made it explicit, that both formal and self-regulated learning can contribute to this.

Experimentation with and evaluation of a new action strategy were not mentioned in the interviews. From the perspective of learning theory, experimentation and evaluation are important steps in the learning process (Kolb, 1984; Kwakman, 2003). One reason for this gap might be that the subjects attributed these activities not to the learning process, but to its result, the subsequent changed behaviour.

Another extension of the original framework was the fact that the subjects addressed cognitive issues as well as negative emotions that are related to errors. Usually, negative emotions such as embarrassment, shame, guilt, fear or the feeling of incompetence are assumed to be inhibiting for open-error communication and learning from errors (e.g. Keith & Frese, 2005; Rybowiak et al., 1999). However, several subjects in the study claimed that negative emotions can have fostering as well as inhibiting effects for learning: negative emotions (e.g., guilt, fear of punishment) can lead to conditioning, so that the error episode is remembered in similar situations and one has the opportunity to avoid the error. In contrast, the subjects claimed that an inhibiting effect of negative emotions can be to remain in a state of ruminative 'brooding' (Leonard & Tesser, 1996) and not to develop a problem solving or action orientation. As such, the role of negative emotions is ambiguous, as discussed above.

4.3. Conclusions for the further research process

The study succeeded in collecting error examples that can be used to construct authentic cases for KRE, and in contextualising the framework of error-related learning activities in nursing practice. The results are used here to make further decisions about the conceptualisation of the follow-up studies. In summary, the following two conclusions are made. Firstly, error situations regarding the misinterpretation of a situation and subsequently making a wrong decision are focussed upon. Vignettes of error cases for this type of error are constructed from the data. Secondly, social learning activities regarding joint root-cause analysis and joint development of a new strategies to avoid the error in future are selected and focussed upon in the further studies. A rationale for both decisions is given below.

Error examples. A rich range of error types was reported by the participants, even though the focus of the interviews had been restricted to KRE. This was to be expected

because Reason's (1995) taxonomy subsumes several subclasses of errors under this category, as discussed in the section on errors. Therefore, it seems appropriate to make a further selection among the types of KRE to focus on in the further studies. For the following reasons, the decision is made for errors regarding the misinterpretation of a situation and subsequently making a wrong decision. First, this was the largest category in the interviews. Admittedly, this does not yet provide evidence that this type of errors is especially frequent or significant in terms of its practical impact. However, at least for the interviewed experts these errors seemed to be particularly salient and subjectively relevant. A practical consequence is that within this category there is the richest material for the construction of authentic error cases. Secondly, errors of this type are rather prototypical for KRE. As Reason (1995) states, almost all types of KRE involve the misinterpretation of a situation, for example, regarding what knowledge or rules to apply (cf. Wehner & Mehl, 2003). Thirdly, these errors concern practitioners' 'knowing in action' and therefore are particularly relevant for the engagement in learning activities such as reflection on causes and the identification of required changes in action strategies (Schön, 1983). In contrast, errors that are based solely on deficient knowledge and involve no situational judgement may also profit from reflection and social exchange, but seem more prone for the engagement in self-regulated learning or attending formal training in order to consolidate the knowledge base. Since it is decided to focus in the further studies on social learning activities regarding cause analysis and strategy development, as explained below, it seems consistent to select the above mentioned type of error.

The following vignettes of error cases were constructed from the KRE examples provided by the experts (the orignial German versions are available from Appendix A.1).

Case 1: Misinterpreting values from a medical instrument. While attending to a young, artificially respirated female patient, you are reading the value for the concentration of blood oxygen from a screen. You realise that it is at only 70%. Considering this to be an emergency situation, first you increase the induction of oxygen at the oxygen resuscitation apparatus. Next, you call a colleague for help, in order to apply further measures. As she arrives, it becomes obvious that the sensor on the patient's finger is misplaced so that the measurement has been unreliable. Initiating an emergency procedure has been inappropriate ...

Case 2: Inadequate interpretation of complications. During a night shift, you are called by a patient who has been operated on his knee. He claims to suffer from heavy pain in his leg and that he could not sleep because of it. Since currently no physician is available, you decide to apply an analgesic and document it in his file. As some time later a physician comes by, you ask her to look after the patient. She diagnoses that the patient has a thrombosis and intervenes immediately ...

Case 3: Misjudging the risk of bedsore. You are evaluating the risk of bedsore of an elderly, bedfast patient. Using the Braden-Scale, you are judging the risk at 18 points as medium. However, the patient's skin appears to be in an OK state to you. Hence, you do not initiate additional measures of prophylaxis or treatment. At the next evaluation of the same patient a short while afterwards, she already shows initial

> symptoms of bedsore. In this light, the increased risk should have been recognised at the earlier evaluation ...

Case 1 concerns the misinterpretation of critical values on a medical instrument. According to the participant who had given this example, this was an error because the nurse interpreted the situation as an emergency, without considering additional inconsistent context information (i.e., the overall state of the patient). Case 2 is about the wrong interpretation of a patient's complications. The error was that the nurse interpreted pain in the leg as a consequence of a surgery, when in fact it was caused by a thrombosis. According to the interview participant who had provided the example, the nurse should have recognised the thrombosis. Case 3 concerns the wrong judgement of the patent's risk of bedsore. The error is that the nurse, when confronted with borderline values for the risk of bedsore on a standardised instrument, made a personal judgement that proved wrong in the end.

These examples were chosen for case construction, because there was rich information for them in the interviews and they implied not too severe consequences for the patient (i.e., no one died or suffered irreparable damage). The latter might cause problems for the subjects to identify with the cases. After the construction of the cases two experts from the interview study revised the cases and judged them to be valid in medical terms.

Learning activities. About the findings concerning learning activities, two points are apparent. Firstly, non-formal learning activities were described in rich detail. Hence, the subjects did not associate learning from errors only with formal learning, although it was not possible to avoid the term 'learning' completely in the interviews (Simons & Ruijters, 2004). At least in the experts' point of view, a rich repertoire of learning activities is possible in daily nursing practice (cf. Berings et al., 2005; Eraut et al., 1998). A drawback of the new categorisation is the abolition of a sequential order, which would describe a complete process. Rather, the categorisation presents a picture of different possible activities that an individual may engage in. In this case, I prefer the contextualisation of the learning activities over conceptual completeness. The second point is the dominant role of social learning activities. As argued above, social exchange is stressed in research on learning at work and professional development: The interaction with other people at work constitutes one of the most significant sources of learning next to the engagement in the work itself (Billett, 2004a; Eraut et al., 1998; Lehtinen, Hakkarainen, & Palonen, 2004; Smith, 2003). This relates to the issue of how learning from errors can contribute to the learning of a team, a unit or the whole organisation (Cannon & Edmondson, 2001; Edmondson, 2004; Van Dyck et al., 2005). From a quality and patient-safety perspective it seems desirable, that not only one specific individual learns from an error. The category 'open discussion in team meetings' explicitly suggests that others should have the opportunity to learn from an error that happened to one specific person.

On the basis of these findings it was decided to focus in the subsequent studies on social learning activities in the form of joint root cause analysis, and joint development of a new strategy for action. Both learning activities are considered to be related positively, because both involve social interaction and imply making one's mistake public. Note that

this decision does not imply a shift to the level of team learning. The focus is still on individual learning from errors, but the activities through which this learning is achieved are performed in social interaction. As has been argued in Chapter 3, investigating a more narrow selection of learning activities is appropriate because it cannot be taken for granted, that all individually or socially performed learning activities follow the same model of action and are driven by the same individual and contextual factors. This caution seems even more relevant in the light of the revision of the learning cycle to a collection of several relevant learning activities. The rationale for selecting joint root cause analysis and joint development of a new strategy for further investigation is as follows. (a) The decision for focussing on the *social* aspect was made due to its discussed theoretical relevance and its practical significance assigned by the interview participants. The latter neither implies that individuals can only learn from errors in social exchange nor that the interviews provide evidence that this form of learning is superior to individual learning. However, the finding is useful to guide the necessary decision about the selection of learning activities for further studies. (b) The decision for joint *cause analysis* and joint *development of new action strategies* was made because both learning activities address core issues of learning from errors, that is, analysing what went wrong, and why, and what can potentially be done about it. Although analytically they represent different steps in the learning cycle, it is likely that both aspects will be addressed at the same time in joint conversations. Hence, they represent conceptually different types of learning activities that, however, should be closely related and follow similar models of action. The implementation of results from such an analytic process (i.e., the last step in the learning cycle) is not of minor relevance, but may follow a rather different rationale because, constraints in the work context and the distribution of power issues have to be taken into account that may inhibit implementing changes. Therefore learning activities regarding the implementation of new action strategies are not further considered, here.

A question is whether constraining the further analysis to the mentioned social learning activities requires a revision of the stated hypotheses. This does not seem to be the case. As for social learning activities, the individual's perception of whether it is safe and appropriate to approach others as well as others' readiness to provide support and participate in such activities seems to be influential. Engaging in social learning activities involves admitting an error to others and as such encountering interpersonal risk. This depends on the individual's perception of the team members' trustworthiness and readiness to provide support in critical situations (Edmondson, 1999). Likewise, the argument that engaging in learning requires the individual to interpret the error situation as a chance for learning, to regulate negative emotions and to perceive a positive cost-benefit relationship seems especially relevant for potentially precarious learning activities (Cannon & Edmondson, 2001; Rybowiak et al., 1999; Zhao & Olivera, 2006). The mentioned ambiguous finding concerning the role of negative emotions might cast doubt on the hypothesis regarding a straightforward negative relation between negative emotions and the engagement in learning (Hypothesis 2). This negative relation has been hypothesised, because negative emotions such as shame, embarrassment, fear, guilt may interfere with cognitive learning processes (Greif, 1996; Keith & Frese, 2005), may inhibit taking an action or learning ori-

entation after an error (Boud, 1999; Greif, 1996; Rybowiak et al., 1999), and may cause an individual to focus on potential costs of making an error public (Edmondson, 1999; Zhao & Olivera, 2006). In contrast, it has been argued that negative emotions also can have a positive effect by creating a feeling of subjective relevance (Oser & Spychiger, 2005). However, the evidence from the interviews is not strong enough to provide yet a reason to revise the stated hypothesis. Therefore, the hypotheses about the relations among the interpretation of an error, the perception of a safe team-climate, and the engagement in learning activities are upheld and subject to investigation in further studies.

The present study provided information (a) for the development of error vignettes for the Cases Approach and (b) for the contextualisation and selection of learning activities that are needed for the development of ecologically valid measures of learning from errors in nursing (Research Question 1). Open tasks are the development of concrete questionnaires and making a decision between the Critical Incident Technique and the Cases Approach. These tasks are addressed in Study 2, that is presented in the following chapter.

5. Study 2: Development of research instruments and decision between the Critical Incident Technique and the Cases Approach

In Study 2, two questionnaires for measuring learning from errors at work are developed on the basis of the findings from Study 1, applied, and compared (Research Question 1). Its objectives are to inform the decision about how to ground the measurement of the engagement in learning activities in concrete error situations and to provide initial evidence of how the developed scales meet psychometric quality standards regarding reliability (internal consistency) and construct validity. For the comparison, two approaches of grounding were considered for application, as described above. In the Critical Incident Technique (CIT) (Flanagan, 1954) the participants are asked to describe an error situation of their own. In the Cases Approach vignettes of error cases are presented and the participants are asked to identify themselves with one of these examples. Both approaches have in common that subsequent questions on learning activities are grounded in the specific case or incident.

Two criteria are set for the comparison of the approaches. The first criterion is the participation rate. Although this does not guarantee the quality of the measurement, it has to be regarded that errors are a delicate issue and that the readiness of the addressed subjects to participate cannot be taken for granted. Therefore, a method should be applied that reduces this problem. This can be considered to be a prerequisite for the establishment of more rigorous psychometric quality standards. The second criterion is whether the scales used function in the intended way under each condition, that is, produce reliable scores and lead to theoretically plausible and consistent results in testing for relationships with scales on a perceived safe team climate and individual error orientation (cf. the hypotheses stated above). This is supposed to be a preliminary indicator of construct validity and provides a pretest for the main study.

This study contributes to making a decision between the approaches by exploring the viability of two versions of a research instrument and delivering initial evidence for reliability and construct validity of the developed scales. The more promising approach can be applied in further studies. However, it cannot clarify which approach is preferable in terms of criterion-related validity. Evaluating criterion-oriented validity would have required having an established criterion – i.e., an established criterion measure of learning from errors at work – as well as known relationships between this criterion and given predictors at hand, in order to analyse which method is better capable of reproducing these relationships. As argued in Chapter 2.2, such an established measure of learning from errors currently does not exist (Bauer & Mulder, in press).

The following section will provide a description of the sample and the instrument development. Secondly, the findings regarding the participation (Criterion 1), reliability of the scales, and the assumed network of relationships (Criterion 2) are presented. The final discussion summarises the results in relation to the stated criteria and elaborates conclusions for how to measure learning from errors in Study 3.

5.1. Method

5.1.1. Design and sampling

The study followed a cross-sectional design with two independent groups, one for the CIT, and another one for the Cases Approach. A sample of $n = 300$ per group was aimed for, in order to have sufficient power for testing potentially small correlations and for conducting factor analyses on the items. Therefore, a sample of $N = 600$ was addressed for participation in the study. The addressed persons had been selected randomly from the nursing staff of one large hospital and were randomly assigned to one of the two conditions ($n_{CIT} = 300$; $n_{cases} = 300$). The field access had been established by permission of the hospital's CEO for nursing. Each subject received a personal letter, the questionnaire, and a return envelope. Anonymity and independence of the study from the hospital were ensured. One problem was that the study was conducted shortly after a two month period of strike in public service. It is hard to judge how this situation affected the participation. However, since the field access had been established and the strike had already caused a considerable delay, it was decided not to postpone the data collection further.

5.1.2. Instruments

Two questionnaires were developed, based on either the CIT or the Cases Approach. The standardised nature of both questionnaires contributes to the objectivity of the measurement. Both questionnaires started with a definition of the term 'error' in the context of the study. It was emphasised, that the study dealt with wrong decisions based on the misinterpretation of a situation, and that medication errors – belonging to the error category of slips and lapses – were not covered in the study. This definition was illustrated by

examples, that were derived from the interview study, in order to increase the subjects' understanding of which type of errors were in the focus of the study.

Grounding. In the CIT Condition the nurses were asked to provide a short description of an error situation which they had encountered at work. Subsequently, they rated their engagement in learning activities after this incident by indicating how much time they had spent after the error with the activities named in the items (six-point Likert scale: 1 = no time at all; 6 = very much time).

In the Cases Condition the subjects were presented with the vignettes of error cases that had been constructed from the examples for knowledge- and rule based errors provided by experts in Study 1. All of them comprised the misinterpretation of a situation and a subsequent inadequate decision. The subjects were asked to identify themselves with one of these cases, and to imagine the situation vividly. Subsequently, they were asked to answer questions about how likely they would be to engage in the given learning activities, after this situation (six-point Likert scale: 1 = very unlikely; 6 = very likely). The subjects could identify well with the cases, which is an indicator of the cases' authenticity (cf. Tab. 5; six-point Likert scale: 1 = low identification; 6 = high identification). A MANOVA indicated that the engagement in learning activities is independent from the chosen case ($F(6, 74) = 1.04$, n.s.).

Scales. Both instruments contained similar scales, related, however, to the specific type of grounding. Scales on the following constructs were included in the instruments: (a) Engagement in social learning activities (i.e., joint cause analysis, joint development of a new strategy), (b) interpretation of errors (i.e., errors as chance for learning, error strain, covering up errors), (c) a safe team climate (i.e., trust, non-punitive orientation). Their composition is described below. The complete item contents can be obtained from appendix A.2. Descriptive statistics and reliability estimates for these scales can be obtained from Table 5.

Engagement in social learning activities. Learning activities after an error were operationalised by two scales on the engagement in joint cause analysis and in the joint development of new action strategies after the error. To attain content and ecological validity, the items were constructed on the basis of the theoretical framework, examples of learning activities from the interviews, and some items on constructive versus defensive changes after an error provided by Meurier et al. (1997). The scale 'joint cause analysis' contains facets of analysing possible causes for the error (e.g., own competence, interaction with the patient and colleagues, workplace conditions) either in informal discussions with team members or at formal team meetings (9 items, e.g., 'Analysing jointly with members of my team, what has led to the error.'). The scale 'joint development of a new action strategy' contains facets of considering and discussing new ways of behaviour or new guidelines either in informal discussions with team members or at formal team meetings (7 items, e.g.,

'Initiating a discussion in a team meeting, how we could prevent similar errors in future.').

Interpretation of errors. The interpretation of errors as chance for learning, error strain and the tendency to cover up errors are measured by three scales from the German version of the Error Orientation Questionnaire (Rybowiak et al., 1999) with a six-point Likert scale as answer format (1 = low agreement; 6 = high agreement): errors as a chance for learning (4 items, e.g., 'Mistakes assist me to improve my work.'); error strain (5 items, e.g., 'I feel embarrassed when I make an error.'); covering up errors (6 items; e.g., 'It is disadvantageous to make one's mistakes public.'). The scales are assumed to be interrelated, but to represent conceptually different aspects of an individual's interpretation of errors. Evidence for their reliability, unidimensionality, and construct validity exists from the original publication and from Keith and Frese (2005).

Safe team climate. The perception of a safe team climate was operationalised by two scales regarding the perception of the trustworthiness of the team members (Bauer et al., 2007; Büssing & Glaser, 2002) and the perception how safe or precarious it is to admit an error within the team (Van Dyck et al., 2005; Tjosvold et al., 2004). Edmondson's scale of psychological safety combines both aspects (1999). However, the present operationalisation is appropriate given that having both aspects in one scale may result in problems of multidimensionality and finding German equivalents as well as a contextualisation of items to the domain of nursing were required, anyway. The scale 'trust' represents the general perception of the trustworthiness of the team members (10 items, e.g., 'There is a trustful relationship between the colleagues at my ward.'). It contains facets of perceived mutual backup, relatedness and support, and the opportunity to come up with critical problems. Items with similar contents could be obtained from Edmondson (1999), a scale on the relatedness to a nursing team by Büssing and Glaser (2002), and from a scale on the quality of social relationships at work by Bauer et al. (2007). The scale 'non-punitive orientation to errors' represents the perception of how precarious it is to admit an error within the team (6 items, e.g., 'If you make a mistake on this team, it is often held against you.'; scored reverse; Edmondson, 1999). Items could be obtained from scales by Edmondson (1999); Tjosvold et al. (2004); Van Dyck et al. (2005). For both scales, a six-point Likert scale is used as answer format (1 = low agreement; 6 = high agreement).

5.2. Findings

5.2.1. Participation

The degree of participation was calculated by the ratio between the returned and the successfully delivered questionnaires. Eight questionnaires in the CIT and twelve questionnaires in Cases Group could not be delivered to the subjects, because the nurses no longer worked at the ward. From the CIT Group $n = 23$ of 292 correctly delivered questionnaires were returned (7.9%). However, within this group only ten subjects gave an

error example, resulting in a rate of 3.4%. From the Cases Group $n = 45$ of 288 delivered questionnaires were returned (15.6%). This is in an expectable range for postal survey (Diekmann, 2007; Porst, 2001).

The low participation inhibited further analyses. Firstly, the samples have to be regarded as being selective. Secondly, further analyses were conducted only for the Cases Group, because of the particularly low participation in the CIT Group. The planned factor analyses had to be postponed until Study 3.

5.2.2. Scale construction and reliability

In order to assess the reliability of the developed scales, item and scale analyses were conducted. The procedure involved examining the item-discrimination (i.e., corrected item-scale-intercorrelation) and the items' contribution to internal consistency (Cronbach's α). Items were excluded from a scale if the discrimination was below .5 or the exclusion would increase reliability; however, only if this seemed theoretically justifiable (Bortz & Döring, 2006). For the learning activity scales, four items from the cause analysis scale did not match the stated criteria and one item had to be removed from the scale 'development of new strategies". From the safe team climate scales, three items from the non-punitive orientation scale did not match the criteria. In contrast, the trust scale had a high initial internal consistency after deleting one item ($\alpha = .92$). Hence, the scale could be made more parsimonious by removing items that are redundant to the scale in terms that they do not contribute to raise its reliability (Bühner, 2006). From the error orientation scales, one (chance for learning, error strain) and two (covering up errors) items did not match the stated criteria, respectively. Table 5 depicts the remaining number of items, reliability, and descriptive statistics of the scales.

The described procedure yielded sufficiently reliable scales, with the lowest reliability for the scale 'errors as chance for learning'. All other scales show good to very good internal consistencies and no excessive floor or ceiling effects were to be observed. This holds also for the newly developed learning activity scales.

5.2.3. Testing the assumed relationships

The correlations between the scales can be obtained from Table 6. Power for a medium effect size of $r = .3$ is 67% for one-tailed tests, given this sample size and a significance level of $p < .05$ (Faul, Erdfelder, Lang, & Buchner, 2007). Significance tests for effect sizes below .24 should not be interpreted because the power decreases below 50%. Descriptive effect sizes and the directions of the correlations are interpreted as preliminary information, acknowledging that it cannot be assumed that the effects would have been significant in a larger sample.

Intercorrelation of scales within a construct. The intercorrelation of the scales belonging to the same construct had the expected directions. (a) From the error orientation scales, as expected, error strain and covering errors are related positively ($p < .01$) with

Table 5: Descriptive statistics and reliability of the scales, authenticity of the cases.

Constructs and scales	*Items*	α	*M*	*SD*
Error orientation				
Chance for learning	3	.65	4.05	1.04
Error strain	4	.87	3.14	1.28
Covering up errors	4	.82	2.22	0.91
Safe team climate				
Trust	5	.92	4.04	1.07
Non-punitive orientation	3	.80	4.16	1.06
Engagement in social learning activities				
Cause analysis	5	.83	3.50	1.12
New strategy	6	.84	3.80	0.98
Authenticity of error cases				
Values on a medical instrument			4.72	1.45
Misinterpreting complications			5.36	0.67
Misjudging risk of bedsore			5.10	0.88

Note. Statistics for Cases Condition; $n = 45$; 6-point Likert scale, higher numbers indicate higher agreement/engagement.

a medium effect size. Both are related negatively to the appraisal of errors as a chance for learning, although insignificant and with small effect sizes that are similar to those found by Rybowiak et al. (1999). (b) Both team climate scales are interrelated positively ($p < .01$) with a large effect size. (c) Both learning activity scales are interrelated positively ($p < .01$) with a large effect size.

Correlation between the interpretation of an error and the perception of a safe team climate. As expected, both psychological safety scales are correlated negatively with error strain and covering up errors ($p < .01$), with medium and large effect sizes,

Table 6: Correlations between the scales.

Scale	1	2	3	4	5	6	7
1 Chance for learning	—						
2 Error strain	−.19	—					
3 Covering up errors	−.12	.46**	—				
4 Trust	.18	−.38**	−.40**	—			
5 Non-punitive orientation	.05	−.55**	−.57**	.72**	—		
6 Cause analysis	.22	.03	−.20	.28*	.12	—	
7 New strategy	.21	−.15	−.34*	.40**	.16	.64**	—

Note. Statistics for Cases Condition; $n = 45$; one-tailed test, *$p < .05$, **$p < .01$.

respectively. The correlations of the psychological safety scales with the appraisal of errors as a chance for learning are positive, although with small or essentially zero effect sizes (n.s.). The signs of the correlations for both psychological safety scales are consistent with each other.

Correlations of error orientation and safe team climate scales with learning activities. The signs of the correlations among the learning activity scales and the other scales are consistent and in the expected directions with one exception, as indicated below. (a) The interpretation of errors as a chance for learning is positively related to both learning activity scales, although not significant. (b) Covering up errors is negatively correlated with cause analysis (n.s.) and the development of new strategies ($p < .05$). (c) Against expectation, error strain had an essentially zero correlation with cause analysis. The correlation with the development of a new strategy is negative, but fails significance. (d) Both learning activity scales have significant positive correlations with trust in the team members. (e) The correlations of learning activities with the perception of a non-punitive orientation towards errors within a team are positive, but not significant.

5.3. Discussion and conclusions for the further research process

The goal of this study was to develop research instruments for learning from errors and to decide between the CIT and the Cases Approach in measuring the engagement in learning activities after an error. Below, the findings are discussed in relation to the stated criteria and conclusions for the further research process in Study 3 are drawn.

5.3.1. Criterion 1: Return quote

Both approaches performed poorly in criterion one, the return quote, resulting in a considerable selectivity of the samples. Further studies are needed in order to check whether the present findings can be replicated and to what extent they are biased. Beyond the mentioned strike that may have had a negative effect on the overall willingness to participate, there is unfortunately little information about potential reasons for non-response. A reason for the particularly low participation in the CIT Condition may be that the subjects could not give an example, e.g., because they did not remember one or did not understand the instructions in the questionnaire properly. An alternative interpretation is that the subjects may have been unwilling to communicate an error example, e.g., because they did not want to make the effort, or did not trust the anonymity of the study.

These possibilities cannot be further explored with the current data. In any case, the present finding of a low participation in the CIT Condition is similar to the one of an interview study on learning from errors, in which employees from high-technology and service enterprises were asked to describe self-experienced error situations (Harteis et al., 2007). In the interviews, the subjects often had problems remembering an error case – or were reluctant to tell one. In contrast, Meurier et al. (1997) had successfully implemented the CIT in a study on errors, using anonymous questionnaires. Therefore, the failure of this

method in the present study was not to be expected. Next to the strike, these discrepant findings may potentially be due also to cultural differences between Meurier's (1997) and the present sample (UK versus Germany, different local culture at the hospitals). For the moment, the results for the participation rate and the fact that hardly any of the participating subjects in the CIT Condition gave an error example are interpreted to argue for the application of the Cases Approach in Study 3.

5.3.2. Criterion 2: Reliability and construct validity

Scrutinising Criterion 2 involved an examination of the relationships between the learning activities and supposedly related variables. Unfortunately, this was inhibited by the low participation rate. For the CIT Condition, no further analyses could be carried out. For the Cases Condition, the present analysis does not yet provide a rigorous test of construct validity, especially given the selective sample and the low statistical power. However, the findings deliver preliminary information that the scales worked in the intended way under the Cases Approach. Reliable scores could be established for the learning activity scales. The initial item selection worked better in the strategy development scale, in which only one item had to be removed. For the cause analysis scale, four items did not fulfil the criteria, indicating requirements for revision. The overall results from the correlation tests indicated a plausible network of expected relationships in terms of the directions of the correlations. A task for Study 3 is to test to what extent these results can be replicated in a larger sample.

5.3.3. Conclusions

In Study 2, two questionnaires for measuring learning from errors at work were developed and applied in order to inform the decision between the CIT and the Cases Approach and to provide initial evidence of the psychometric properties of the developed scales. Although the conclusiveness of the findings is limited due to the selective sample, Study 2 was helpful for attaining these goals. The results are encouraging in that reliable scales could be built and that theoretically expected correlations with the interpretation of an error situation and the perception of a safe team climate could be found, at least on the level of descriptive effect sizes. These findings legitimate further efforts to advance and validate the operationalisation of learning from errors. Furthermore, the findings provide sufficient information for considering the Cases Approach for application in Study 3. This is not only because of the higher return quote, but also because of the potential problem that only a special part of the population with a low tendency to cover up errors may be ready to participate in the CIT Condition. In the Cases Approach, this problem is less likely to arise, because the cases used are not directly related to the subjects and thus participation may seem less precarious. Additional efforts to increase the return rate in Study 3 may involve reducing the amount of personal information requested in the questionnaire in order to mitigate potential fears of being identifiable. Furthermore, the subjects' ratings of the cases argue for their authenticity. The mentioned concern

that the Cases Approach asks for hypothetical behaviour can be taken into account in the interpretation of the data. Given the present findings and the discussed problems of observation methods, the Cases Approach seems to be a viable method for measuring learning from errors.

Together, Studies 1 and 2 contributed to the development of a measurement instrument for the engagement in learning from errors in nursing (Research Question 1). An exemplary operationalisation of learning from errors in terms of learning activities that start a process of inquiry into root-causes and aim at changing the underlying causes has been developed. This activity perspective on learning from errors is systematically derived from experiential learning theory (Gruber, 1999a; Kolb, 1984; Kolodner, 1983; Schank, 1999), which is a prerequisite for content validity. Furthermore, it is contextualised to the field of nursing, as a prerequisite for ecological validity. The developed operationalisation is restricted to the field of nursing, to a specific type of error (i.e., misjudging a situation and subsequently making a wrong decision), and to the special case of learning activities that are performed in social exchange. However, this degree of specificity is required, because asking for learning activities taken after errors in general neglects the variability of errors (Reason, 1995) and the incidental and situated nature of learning from errors and work related learning (Billett, 2004b). Study 2 delivered initial evidence for the reliability and construct validity of the scales. The developed instrument will be applied in Study 3, in order to address Research Questions 2—4.

6. Study 3: Testing and advancing the research model

The study presented in this chapter contributes in two steps to answering the research questions about the relations among the interpretation of an error, the perception of a safe team-climate, and the engagement in learning activities (Research Questions 2—4). In the first step, the research model presented in Figure 1 is tested. This involves a process of building a statistical model on the basis of the substantive model, to check whether this model adequately fits the data, and to test the hypotheses derived from the theoretical framework. The second step is to advance the model on the basis of the results and substantive considerations. This exploratory step is relevant for answering the research questions because it contributes to differentiate theorising about how the interplay of the investigated variables may foster or constrain learning from errors. Therefore, it enables us to state more differentiated hypotheses for further research that builds upon the results of this study in a cumulative way.

Hence, the goals of Study 3 are to test and to advance the model for the engagement in error-related learning activities in nursing. For this purpose, a sample of nurses from several hospitals is surveyed in a cross-sectional field study with the research instrument developed in Studies 1 and 2. The gathered data are analysed in a structural equation model. Below, first the employed methods are elaborated, comprising a description of the sample, the instrument, and the analytic procedure. Secondly, the results for testing the

model, and the findings from the exploratory analyses are presented. Finally, the results are discussed in relation to the research questions.

6.1. Method

6.1.1. Sample

Participants in the study were full-time nurses from hospitals located in the German Federal State of Bavaria. The study was restricted to Bavaria, because the two prior studies had taken place in this region and because yielding a representative sample for all of Germany could not be achieved within the scope of this study. In order to test and advance the research model employing structural equation modelling, a large sample was required. Given the relative simplicity of the model under study, a sample size of $N = 300$ was assumed to yield a stable estimation and sufficient power to test the model (Faul et al., 2007; Kim & Bentler, 2006). In order to account for the diversity of hospitals in terms of their sponsorship, size, and the level of medical care they supply, nurses from multiple organisations had to be recruited for the sample. In Bavaria, 56.8% of the hospitals are under public sponsorship, whereas 43.2% are run by private and charitable organisations (Bayerische Krankenhausgesellschaft e.V., 2005b). Furthermore the hospitals differ in the level of medical care they supply, which also reflects their size (Bayerische Krankenhausgesellschaft e.V., 2005a; Bayerisches Staatsministerium für Arbeit und Sozialordnung, Familie und Frauen [BSASFF], 2007). Four service levels can be distinguished: hospitals on the lowest level (Level 1) are typically small and provide basic service in surgery and internal medical care. Level 2 hospitals are larger and provide additional special units, such as intensive care, ear, nose, and throat medicine, gynaecology, etc. Level 3 hospitals are large supraregional hospitals that provide extensive and fully differentiated services in medical care. Beyond these three levels, there is a fourth category for highly specialised hospitals that focus on specific diseases, treatments, or age groups. Only hospitals from Levels 1—3 were considered for inclusion in this study, because the developed cases might not have applied to the highly specialised hospitals. From the total number of hospitals on Levels 1—3 in Bavaria, 79.5% are Level 1, 16.0% Level 2, and 4.6% Level 3 (BSAFF, 2007). It was planned to recruit a sample that represents these distributions of sponsorship and service level. Furthermore, it was planned to place the main focus on nurses in surgical and internal medical care units, because these are core units that are present in all hospitals in levels 1—3 (Bayerische Krankenhausgesellschaft e.V., 2005a).

Nine out of 16 addressed hospitals agreed to participate in the study, provided that they would stay anonymous. Table 7 provides an overview of the hospitals and their characteristics regarding sponsorship, service level, and nursing staff. None of the participating hospitals had implemented an incident reporting system or quality management guidelines concerning error management or learning from errors. Among these nine hospitals five (55.6%) are under public and four (44.4%) under private or charitable sponsorship. Furthermore, five are on Service Level 1 (55.6%), three on Level 2 (33.3%), and one on Level 3 (11.1%). Hence, the sample reflects the distribution of sponsorship in Bavaria adequately,

whereas there is a bias in relation to the service levels: large hospitals on Level 3 are overrepresented, Level 1 hospitals are underrepresented. However, the sample reflects at least the order of the distribution, that is, Level 1 hospitals are the largest group, followed by Level 2 and Level 3 hospitals. The characteristics of the non-participating hospitals show no specific pattern, except that no hospital with over 1000 employed nurses participated. Typical arguments for non-participation were ongoing reorganisation processes in the hospital.

A total of $N = 864$ nurses could be addressed with the developed questionnaire. Unlike Study 2, no random sampling procedure could be applied, because the hospitals did not allow access to their personnel data bases. The field access relied on the compliance of the hospitals' managers and therefore had to be realised according to their rules, that is, they defined the number of nurses that could be contacted and that the nurses were addressed via them and their immediate supervisors. For the nurses, participation in the study was voluntary and the confidentiality of the answers was guaranteed. As a consequence of the experiences in Study 2, hardly any personal information was requested in the questionnaire that might have induced a feeling of being identifiable, in order to increase the nurses' readiness to participate. Problems of this sampling procedure are that the representativeness of the sample cannot be ensured, that potentially only a specific part of the population may have participated, and that the actual participation of the addressed subjects could not be controlled. This control would not only have been impractical to accomplish under the given conditions, but it also might have had negative effects on the subjects' readiness to answer the questions honestly. Presumably, employees who complete the questionnaire involuntarily may tend to give socially desirable answers. In order to mitigate this problem, the selectivity of the sample was accepted. Instead, the managers were asked to administer the questionnaire to all full-time nurses on surgical and internal medical units, and to as many nurses from other wards as possible, where the error examples are relevant.

A total of $N = 284$ nurses participated in the study. Table 7 contains the sample sizes and return quotes for the total sample and the subsamples. The overall return quote is 33%, which is above an expectable range for postal survey (Diekmann, 2007; Porst, 1998, 2001) and above both conditions in Study 2. From these nurses, 57.7% were employed by public hospitals, 42.3% by private and charitable hospitals. As for the service levels, 45.8% of the surveyed nurses worked in Level 1 hospitals, 33.8% in Level 2 hospitals, and 20.4% in the Level 3 hospital. This reflects the distributions of the participating hospitals given above. The mean professional age of the participants was $M = 15.09$ years with a standard deviation of $SD = 9.90$. The majority worked in surgical (40%) and internal medical units (33%), followed by intensive care (6%) and paediatric units (4%).

During data entry two participants were removed from the data set, because comments they had written on the questionnaire indicated that they did not take the questions seriously. In a first data screening, two more cases with many missing values had to be removed. Remaining missing values were imputed in EQS using the EM-algorithm (Schafer & Graham, 2002). These concerned one case with two, and seven cases with one missing value and can be considered negligible. Preliminary analyses with the resulting sample

Table 7: Composition of the sample

Hospital	*Sponsorship*	*Service level*	*Nursing staff*	*Addressed nurses*	*Returned questionnaires*	*Return quote*
Participating hospitals						
1	p/c	2	200 – 500	100	36	36%
2	p	1	< 200	20	17	85%
3	p	1	200 – 500	60	36	60%
4	p	1	< 200	60	23	38%
5	p/c	2	200 – 500	60	30	50%
6	p	3	500 – 1000	300	58	19%
7	p	2	500 – 1000	90	30	33%
8	p/c	1	< 200	134	27	20%
9	p/c	1	200 – 500	40	27	68%
Total				864	284	33%
Non-participating hospitals						
10	p	1	< 200			
11	p	3	> 1000			
12	p/c	2	200 – 500			
13	p	3	200 – 500			
14	p	1	< 200			
15	p	3	> 1000			
16	p/c	2	500 – 1000			

Note. p = public, p/c = private/charitable sponsorship; medical service levels: 1 = basic, 2 = advanced, 3 = extensive service.

identified four further cases as multivariate outliers by means of their contribution to Mardia's normalised estimate of multivariate kurtosis (Bentler, 2006). They were excluded from further analyses. This procedure left an effective sample size of $N = 276$ for the analyses. Given that the hypothesised model has 37 free parameters to estimate (cf. p. 81), this makes a ratio of 7.5 cases per estimated parameter, which is between the recommended ratio of 10:1 and the recommended minimum ratio of 5:1 subjects per estimated parameter in structural equation modelling (Kim & Bentler, 2006).

Despite the problems discussed above that speak to the selectivity of the sample, it can be considered adequate for answering the stated research questions: The sample is sufficiently large for testing the model, it reflects the distribution of sponsorship in Bavaria, and reflects at least the order of the distribution according to the service levels of hospitals. As intended, the majority of the participating nurses work in surgical and internal medical units, which reflects the fact that these are the major units of hospitals and present on all investigated service levels (Bayerische Krankenhausgesellschaft e.V., 2005a). In order to check the degree to which the results obtained from this study are biased due to the problems mentioned, cross-validation in future studies is required.

Table 8: Authenticity and severity of the error cases

Error case	*Authenticity*		*Severity*	
	M	*SD*	*M*	*SD*
1 Values on a medical instrument	1.98	1.05	4.04	1.13
2 Misinterpreting complications	1.85	1.01	3.42	1.39
3 Misjudging risk of bedsore	2.11	0.94	3.13	1.22

Note. $N = 276$; 6-point Likert scale, lower numbers indicate higher authenticity/severity.

6.1.2. Instrument

The instrument used was almost identical to the Cases Approach questionnaire in Study 2. Study 2 had provided initial evidence for the reliability and construct validity of the scales (cf. Chapter 5). The following changes were made for further improvement. Firstly, the direction of the Likert scale was inverted so that it reflected the German school-grade system (i.e., lower numbers indicate a higher intensity). This should assist the subjects' comprehension of the answer format. Secondly, the perceived severity of the error cases was asked, in order to control for it. Thirdly, the items of the three error orientation scales were modified, so that they referred more precisely to the chosen error case, in order to increase the consistency with the Cases Approach and with the interpretation of error orientation as a situational construct. The modification involved minor corrections in the item wording. Finally, items from Study 2 that had not worked well in terms of discrimination or reliability were reformulated or replaced. The revised scale 'joint cause analysis' consisted of eight items, 'joint development of new strategies' of seven items. The item contents can be obtained from appendix A.3. Descriptive statistics and reliability estimates for the scales will be provided below.

As in Study 2, the subjects indicated that they could identify well with the cases (cf. Tab. 8). 20.0% of the surveyed nurses chose Case 1 (misinterpretation of values on a medical instrument), 57.5% Case 2 (misjudgement of complications), and 22.5% Case 3 (misjudgement of the risk of bedsore). Initial analyses indicated that the engagement in learning activities was independent from the chosen example (MANOVA, $F(4, 550) = 2.30$, n.s.), from the ability to identify with the example (cause analysis: $r = .06$, n.s.; strategy development: $r = .02$, n.s.) and from how severe the subjects estimated the error case to be (cause analysis: $r = -.01$, n.s.; strategy development: $r = -.03$, n.s.).

6.1.3. Analyses

For performing the tasks of testing and advancing the research model, structural equation modelling (SEM) was employed. Since SEM provides a blend of confirmatory and exploratory procedures (Kline, 2005), it is appropriate for this purpose. Compared to traditional regression analysis, SEM has the advantages of providing information about model fit and correcting for measurement error. Testing a structural equation model is a

process of consecutive steps: (a) to specify a statistical model on the basis of a hypothesised substantive model, (b) to estimate the model with a computer program, and (c) to test the model by evaluating its fit to the data and – given adequate fit – testing the hypotheses upon which it is built. (d) After this confirmatory part of model testing, a model can be advanced in post hoc analyses by respecifying it on the basis of identified sources of misfit as well as substantive considerations, and subsequently estimating and testing the respecified model (Byrne, 2006; Jöreskog, 1993; Kline, 2005; Schumacker & Lomax, 2004). This exploratory, model generating mode of analysis is appropriate for the goal to provide an advanced model with adequate fit to the current data as hypothesis for further research (e.g., Jöreskog, 1993).

The discussion below elaborates how these steps are performed to attain the goals of testing and advancing the research model for nurses' engagement in social learning activities after an error (Fig. 1), in order to answer Research Questions 2—4. Because the sample size in Study 2 allowed to perform only preliminary item and scale analyses, first, preparatory item analyses were required in order to specify adequately the measurement part of the structural equation models (i.e., the part of the model that specifies the relations between the items and the respective variables). Therefore, the discussion starts with a description of these preparatory analyses and their results, before elaborating how the steps of the SEM process are performed.

Preparatory item analyses and construction of scales. According to the described theoretical structures of the variables (Chapters 2.2 and 2.3) and the findings of Study 2, the following structure of the measurement model was planned.

Error orientation. The three variables regarding the estimation of an error chance for learning, error strain, and covering up an error were planned to be represented by three latent variables in the model, because they are conceptually different aspects of interpreting an error situation.

A safe team climate. The perception of a safe team climate was planned as one latent variable with the two scales 'trust' and 'non-punitive orientation to errors' as indicators, because these two scales have been conceptualised as two facets of the same construct and both were correlated highly in the Study 2 ($r = .72$).

Engagement in social learning activities. Given that joint cause analysis and joint strategy development concern two conceptually distinct, but empirically related learning activities (in Study 2: $r = .64$), it was planned to model them as two latent variables that together build the second order latent variable 'engagement in social learning activities'.

Because the findings from Study 2 did not deliver sufficient evidence for the dimensionality of the learning activity scales (i.e., no factor analyses could be conducted), the following two steps of preparatory item and scale analyses were taken, in order to specify an adequate measurement part of the structural equation model.

Firstly, the items of each scale were screened for their discrimination and contribution to reliability, employing the same criteria as in Study 2. From each of the learning activity

scales and from the scale non-punitive orientation, one item had to be removed because of low discrimination. An overview of which items actually were used for the later analyses can be obtained from appendix A.3.

Secondly, exploratory factor analyses with oblique rotation were applied in order to check the dimensionality of the scales (principal axes factor analysis (PFA), direct oblimin rotation). PFA is an appropriate extraction method when the goal of the analysis is to identify latent constructs underlying measured variables, and oblique rotation is to be preferred over orthogonal rotation, because it provides important information concerning the relations among extracted factors (Fabrigar, Wegener, MacCallum, & Strahan, 1999). Whereas several authors reject conducting exploratory factor analyses prior to SEM based on the same data (Byrne, 2006; Kline, 2005), others recommend this if the dimensionality of a set of items is uncertain and the purpose of the study is not instrument development, but testing the relations between variables (Gerbing & Hamilton, 1996; Little, Cunningham, Shahar, & Widaman, 2002). Given that this was the case in this study and that no factor analyses could be performed in Study 2, this strategy was considered appropriate. Single factor solutions were expected because each scale was supposed to measure one underlying construct.

The exploratory factor analyses strengthened the assumption of unidimensionality for all scales, except for the scale 'cause analysis'. In contrast to the expectation, the analysis indicated a two factor solution, as judged by the Kaiser criterion, the scree test, and Velicner's MAP test (O'Connor, 2000). After removing one item that loaded lower than .5 on both factors and one cross-loading item, an interpretable solution with two correlated factors ($r = .32$) could be obtained that explains 72.5% variance in the items. Factor 1 contains items that indicate a general readiness to address other team members in order to communicate about the error and to analyse it (two items, e.g., "Analysing with my colleagues why I made this error."). The factor therefore is interpreted as 'general cause analysis'. The items of Factor 2 address joint discussions about how specific causes may have contributed to the error (three items, e.g., "Analysing with my colleagues whether there was a problem in the communication with the patient."). It therefore is interpreted as 'specific cause analysis'.

On this basis, it was decided to split up the variable 'cause analysis' into the two related latent variables 'general cause analysis' and 'specific cause analysis'. This implies that instead of two, three latent variables (i.e., 'general cause analysis', 'specific cause analysis', and 'strategy development') build the second order variable 'engagement in social learning activities'. A point of concern in this solution is that two and three items, respectively, build latent variables. This flaw is resolved by the fact that these variables are combined on the level of the second order variable and that this variable is used as the dependent variable in the analyses on the structural level. The separation of the identified factors on the measurement level is, however, required in order to account for the empirical structure of the items. Otherwise, it would not be possible to know whether misfit in the model results from misspecification on the measurement level or from misspecification on the structural level (Jöreskog, 1993; Kline, 2005; Schumacker & Lomax, 2004). For answering the research questions, misfit on the structural level is relevant, that results from wrong

substantive assumptions about the relations between the variables regarding the interpretation of an error, the perception of a safe team climate, and the engagement in social learning activities. The descriptive statistics and reliabilities for the scales built from the factor analysis and for the other used scales can be obtained from Table 9.

Table 9: Descriptive statistics and reliability of the scales.

Constructs and scales	*Items*	α	*M*	*SD*
Error orientation				
Chance for learning	4	.91	2.38	1.15
Error strain	5	.90	2.99	1.32
Covering up errors	5	.81	5.05	0.89
Safe team climate				
Trust	5	.91	2.23	0.90
Non-punitive orientation	6	.87	2.23	0.97
Engagement in social learning activities				
General cause analysis	2	.86	2.02	0.92
Specific cause analysis	3	.68	3.48	1.16
New strategy	6	.87	2.82	1.07

Note. $N = 276$; 6-point Likert scale, lower numbers indicate higher agreement/engagement.

Model specification. Model specification involves defining the structural as well as the measurement part of the model, and to ensure the model's overidentification. Overidentification implies that the specified model has positive degrees of freedom in order to estimate its fit to the data and to test the hypotheses (MacCallum, 1995). These tasks are addressed, below. The resulting specified statistical model is depicted in Figure 2. Latent variables are shown in ellipses, and observed indicators for the variables are shown in rectangles. For clarity, the structural part is printed bold.

The structural part of the specified statistical model is identical with the stated research model shown in Figure 1 and contains the stated hypotheses. The measurement part is formulated on the basis of the planned structure of the variables and the item analyses, both described in the previous paragraph. For each latent variable (except general and specific cause analysis) two 'item parcels' were constructed as indicators, that is, using mean scores of scales or split-half scales as indicators for latent variables instead of single items (Bandalos & Finney, 2001; Holt, 2004; Little et al., 2002; Schumacker & Lomax, 2004; West, Finch, & Curran, 1995). Because cause analysis had to be separated into the two variables general and specific cause analysis, there were too few items for building item parcels. Therefore, both variables are modelled using the items of their scales as indicators. This is no substantial problem here, because modelling on the item level

implies an even more rigorous test of the measurement model than using parcels (Little et al., 2002). Except for the discussed separation of cause analysis into two variables, the described structure of the measurement model matches the planned structure discussed in the previous paragraph. The correlation matrix and the descriptive statistics of the built indicators can be obtained from Appendix A.3.

The following steps were taken in order to ensure the overidentification of the model, (cf. Byrne, 2006; Kline, 2005; MacCallum, 1995; Schumacker & Lomax, 2004). For each latent variable, the loading of the first respective indicator was fixed to 1. To ensure local overidentification of latent variables with two indicators, equality constraints were imposed on their error variances. For the second order variable 'engagement in social learning activities' the loading of the latent variable 'development of new strategies' was fixed to 1. The resulting model contains 37 free parameters that have to be estimated and is overidentified with 83 degrees of freedom (cf. Raykov & Marcoulides, 2006).

Model estimation. The specified model was analysed with EQS 6.1 (Bentler, 2006) using robust Maximum Likelihood (ML) estimation. Robust estimation was used because of evidence of multivariate non-normality in the data. Even after deleting the four above mentioned multivariate outliers, Mardia's normalised estimate of multivariate kurtosis at 11.67 indicated that the assumption of multivariate normal distribution is not met[7]. Robust ML estimation in EQS involves the use of the Satorra-Bentler scaled χ^2-statistic, robust standard errors, and corrected fit indices. Currently, this technique is considered to be the most effective way to deal with non-normal data in SEM (Bentler, 2006; Byrne, 2006; Schermelleh-Engel, Moosbrugger, & Müller, 2003; Tabachnik & Fidell, 2007).

Testing the model: Evaluation of model fit and test of the hypotheses. Testing the specified model involves the steps of (a) evaluating the model fit for the measurement model, (b) evaluating the model fit for the full structural equation model (c) and – provided that the full model adequately fits the data – testing the hypotheses. This consecutive process is required because testing the structural model – i.e., the specified theory – may be meaningless unless it is first established that the measurement model holds (Jöreskog, 1993; Schumacker & Lomax, 2004). The following measures of model fit are relevant for this study:

- The solution has to be checked for inadmissible estimates (i.e., negative variances, correlations > 1.0, excessively large standard errors) and for the largest standardised residuals. Standardised residuals $> \pm 2.58$ are indicative of misspecification (Byrne, 2006).
- A robust version of the χ^2 test (i.e., Satorra-Bentler scaled χ^2) is applied to evaluate whether there is a significant difference between the model and the data. A significant χ^2 test rejects the hypothesis that the model fits the data. However, because of its oversensitivity in large samples – particularly above $N = 200$ – a significant χ^2 test must be interpreted in the context of other fit indices (Schumacker & Lomax, 2004).

[7] Values larger 5.00 are indicative of multivariate non-normality (Bentler, 2006).

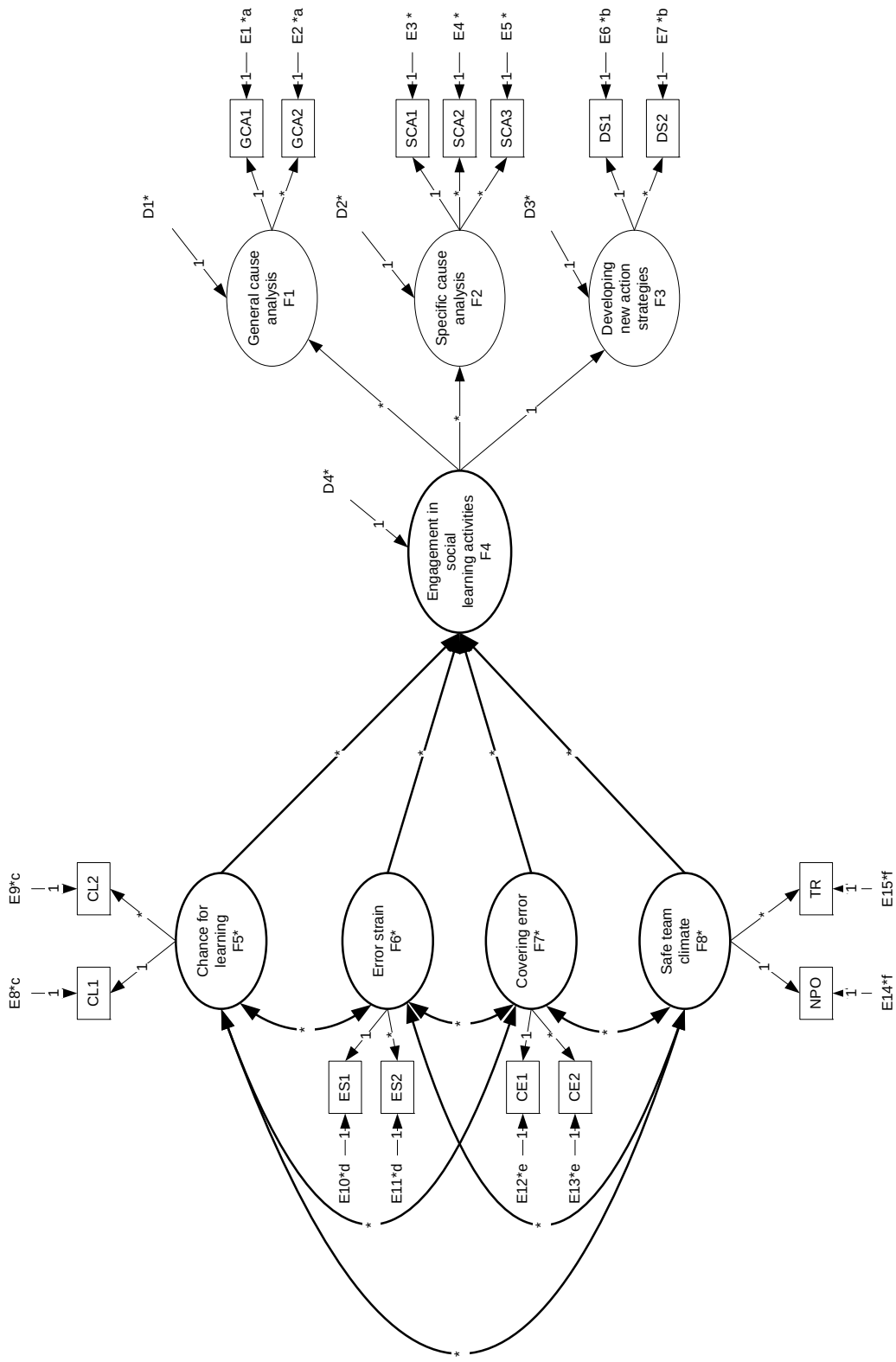


Figure 2: Hypothesised model for the engagement in social learning activities. Latent variables are shown in ellipses, observed indicators are shown in rectangles; the structural part is printed bold; GCA = general cause analysis; SCA = specific cause analysis; DS = development of new strategies; CL = chance for learning; ES = error strain; CE = covering errors; NPO = non-punitive orientation; TR = trust; D1–D4 = regression residuals; E1–E15 = measurement error terms; * = free parameter; *a–*f = parameters with same letter constrained to be equal; total free parameters = 37; $df = 83$.

- In accordance with the recommendations in the recent SEM literature, the combination of fit indices and cut-off values depicted in Table 10 is used to evaluate model fit (Bühner, 2006; Byrne, 2006; Kline, 2005; Schermelleh-Engel et al., 2003). In the left column the fit indices are listed, where asterisks printed before fit indices indicate robust versions. The following three columns list for each index the possible range and the cut-off values for good and acceptable fit, respectively.

Table 10: Goodness of fit indices and cut-off values.

Fit index	Range	Good fit	Acceptable fit
*S-Bχ^2/df	$0 -$	$0 \leq 2$	$2 < 3$
SRMR	$0 - 1$	$0 \leq .05$	$.05 < .1$
*CFI	$0 - 1$	$.95 \leq 1$	$.90 < .95$
*RMSEA	$0 - 1$	$0 \leq .05$	$.05 < .08$
*RMSEA 90% C.I.		close to RMSEA, left boundary $0 \leq .05$	close to RMSEA

Note. * = robust version; S-Bχ^2 = Satorra Bentler scaled χ^2; *df* = degrees of freedom; SRMR = standardised root mean square residual; CFI = comparative fit index; RMSEA = root mean square error of approximation; C.I. = confidence interval.

Advancing the model. 'Advancing' means to develop a respecified model that provides an equal or improved fit to the data, that is more parsimonious, or that provides a more differentiated substantive interpretation of the relations among the investigated variables (Jöreskog, 1993). Possibilities to advance the model are considered on a twofold basis. Firstly, empirical modification indices are inspected that are provided by EQS (Bentler, 2006; Byrne, 2006). These indices inform us about sources of empirical misspecification in the model, that is, whether there are omitted paths or specified paths that are inappropriate. The LM-test is used to check whether adding paths to the model results in a significant improvement of fit. As a general rule, only paths that can be interpreted substantively are eligible for inclusion in the model (Byrne, 2006; Jöreskog, 1993; Kline, 2005; Schumacker & Lomax, 2004). The W-test is used to check whether paths can be removed without a significant loss of model fit. Secondly, the pattern of results from testing the hypothesised model can be interpreted substantively to suggest changes in the model.

Because these ways of advancing the model are exploratory, their findings constitute new hypotheses about the relations between the interpretation of an error, the perception of a safe team climate, and learning from errors, that have to be validated in further studies. Nevertheless, only such model modifications are appropriate that – beyond having a substantive interpretation – provide adequate fit and are statistically significant in the current sample (Jöreskog, 1993; Schumacker & Lomax, 2004). This model generating

approach of model modification is appropriate to deliver more differentiated hypotheses as a basis for further research on learning from errors.

6.2. Results

This section presents in two parts the results from the analyses. The first part starts with the results from testing the stated research model (Fig. 2). In the second part possibilities to advance the model will be identified and findings from the exploratory analyses are reported that suggest hypotheses for further research.

6.2.1. Results from testing the research model

Testing the model involved evaluating the model fit of (a) the measurement model, (b) the full structural equation model, and (c) testing the stated hypotheses. The results of these steps are reported, below.

Evaluation of the model fit of the measurement model. The measurement model was evaluated by estimating a model with all latent variables as correlated factors (Jöreskog, 1993; Kline, 2005). No problems were encountered during the estimation and all estimates appeared in order. The fit indices indicate a well fitting model, though the χ^2 test is significant (S-B$\chi^2_{(75)} = 127.04$, $p = .000$, S-B$\chi^2/df = 1.69$, SRMR = .05, *CFI = .97, *RMSEA = .05 with 90% C.I. .04−.07). No standardised residuals larger than ±2.58 were present. All factor loadings were statistically significant and had a substantial size (lowest loading of item SCA3 on 'specific cause analysis' at .47, all other loadings above .5). Estimates for all factor loadings are depicted below for the full structural equation model (Fig. 3). Given this evidence of a well established measurement model, the full structural equation model could be tested.

Evaluation of the model fit of the full structural equation model. No problems were encountered during the estimation for the hypothesised model and all estimates appeared in order. The fit indices indicate adequate model fit (S-B$\chi^2_{(83)} = 170.60$, $p = .000$, S-B$\chi^2/df = 2.06$, SRMR = .07, *CFI = .96, *RMSEA = .06 with 90% C.I. .05 − .08). An examination of the standardised residuals revealed one residual larger than ±2.58 associated with the covariance between item GCA1 and the item parcel CE2. The second largest standardised residual was close below the recommended cut-off value and concerned the covariance between item GCA2 and item parcel CE2. This indicates that the hypothesised model underestimates the covariances between items associated to general cause analysis and to covering errors. Despite of these residuals, the hypothesised model provides an adequate overall fit to the data, so that the stated hypotheses can be tested.

Test of the hypotheses. Figure 3 presents the standardised estimates for the hypothesised model. Statistically insignificant paths are indicated by dashed lines. All other

estimates are statistically significant. The total explained variance for the engagement in social learning activities is 29%. Concerning the hypotheses about the relation between the interpretation of an error and the engagement in social learning activities (Research Question 2), the following can be stated.

Hypothesis 1. The hypothesis is confirmed. As expected, the estimation of an error as a chance for learning predicts the engagement in social learning activities positively, with a medium effect size.

Hypothesis 2. The hypothesis is rejected. In contrast to the expectation, error strain did not significantly predict the engagement in social learning activities.

Hypothesis 3. The hypothesis is confirmed. As expected, the tendency to cover up an error predicts the engagement in social learning activities negatively, with a medium effect size.

Concerning the hypothesis about the relation between the perception of the social context and the engagement in social learning activities (Research Question 3), the following can be stated.

Hypothesis 4. The hypothesis is rejected. In contrast to the expectation, the perception of a safe team climate did not significantly predict the engagement in social learning activities.

Concerning the hypotheses about the interrelation between the interpretation of an error and the perception of a safe team climate (Research Question 4), the following can be stated.

Hypothesis 5. The hypothesis is rejected. In contrast to the expectation, the estimation of an error as a chance for learning is not significantly correlated with the tendency to cover up an error.

Hypothesis 6. The hypothesis is rejected. In contrast to the expectation, the estimation of an error as a chance for learning is positively correlated with error strain. The correlation is large and statistically significant, but opposite to the expected direction.

Hypothesis 7. The hypothesis is rejected. In contrast to the expectation, the tendency to cover up an error is not significantly correlated with error strain.

Hypothesis 8. The hypothesis is rejected. In contrast to the expectation, the perception of a safe team climate is not significantly correlated with the individual estimation of errors as a chance for learning.

Hypothesis 9. The hypothesis is confirmed. As expected, the perception of a safe team climate is team negatively correlated with the individual tendency to cover up errors, with a medium to large effect size.

Hypothesis 10. The hypothesis is rejected. In contrast to the expectation, the perception of a safe team climate is not significantly correlated with error strain.

These results represent the final step of testing the stated research model and its hypotheses in a confirmatory mode of analysis. In summary, the results indicate that the estimation of an error as a chance for learning and the tendency to cover up an error significantly predict

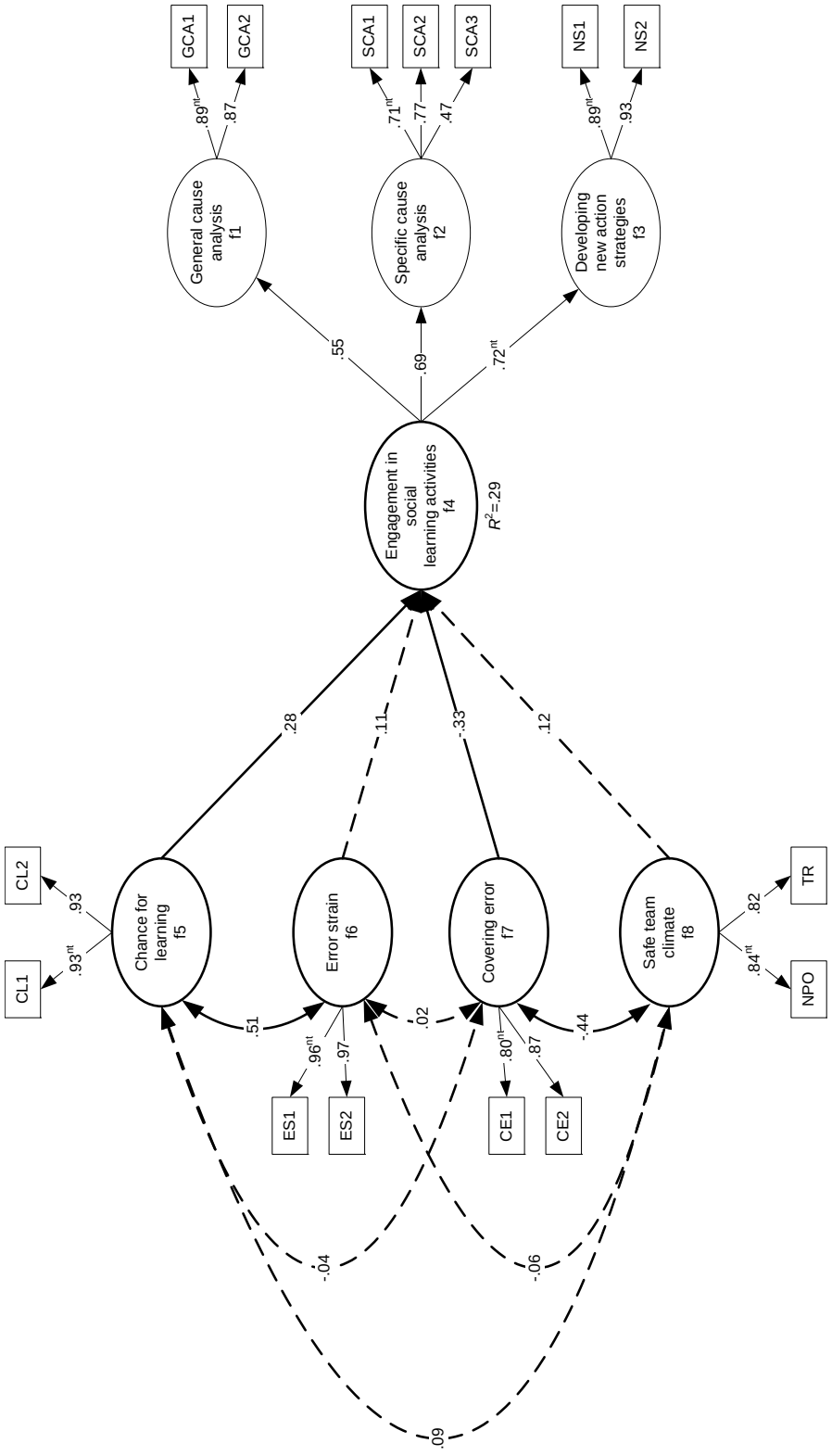


Figure 3: Standardised estimates for the hypothesised model for the engagement in social learning activities; the structural part is printed bold; model fit: S-B$\chi^2_{(83)} = 170.60$, $p = .000$, S-B$\chi^2/df = 2.06$, SRMR = .07, *CFI = .96, *RMSEA = .06 with 90% C.I. .05 – .08; nt = not tested; dashed arrow = path n.s.; all other estimates $p < .05$.

nurses' engagement in social learning activities after an error, whereas negative emotions resulting from an error and the perception of a safe team climate do not. Furthermore, there are large correlations (a) between the estimation of an error as a chance for learning and error strain, and (b) between the tendency to cover the error and a safe team climate, whereas the other hypothesised correlations are insignificant. Interpretations of the results will be given in the discussion. The section below will explore possibilities to advance the model, based on these findings.

6.2.2. Advancing the research model

Based on the results from testing the research model, tasks to explore possibilities of advancing the model are identified below.

1. Given that the hypothesised model provided an adequate fit to the data, no paths have to be added to the model on the basis of the LM-test in order to achieve a better model fit. As MacCallum, Roznowski, and Necowitz (1992) caution, "(...) when an initial model fits well, it is probably unwise to modify it to achieve even better fit because the modifications may simply be fitting small idiosyncratic characteristics of the sample" (p. 501). In order to provide information for potential replication studies, LM-test findings are reported below, but not considered for inclusion in the model until replication in further studies.
2. It has to be checked whether there are redundant paths that can be removed from the model without a substantial loss of model fit and explained variance in the engagement in social learning activities (W-Test). This would contribute to advancing the model by providing a more parsimonious explanation for the relations among the investigated variables (i.e., a model with fewer paths). According to the parsimony principle, from two different models with similar explanatory power for the same data, the simpler model is to be preferred (Kline, 2005; MacCallum, 1995).
3. An emerging question from the pattern of findings discussed above is whether error strain and a safe team climate are indeed unrelated to the engagement in learning activities or whether their statistical insignificance is an effect of the mentioned large correlations (Urban & Mayerl, 2006). Hence, it has to be checked whether error strain and a safe team climate significantly predict the engagement in social learning activities, when analysed alone. A significant finding would be indicative of a mediation model in which (a) the estimation of an error as a chance for learning is dependent on the amount of strain suffered from an error and, in turn, predicts the engagement in social learning activities, and (b) the tendency to cover errors is dependent on the perception of a safe team climate and, in turn, predicts the engagement in social learning activities. For exploring this potential mediation model, firstly, direct relations are hypothesised between error strain and chance for learning, and between a safe team climate and the tendency to cover up an error. A substantive rationale for this is provided below. Secondly, it has to be checked, whether the indirect relations of error strain and safe team climate with the engagement in learning activities are significant (Kline, 2005). In this case, it would be legitimate to suggest the mediation

model as a hypothesis for further research. This would advance the originally stated research model by contributing to differentiate the assumptions about the interplay of the investigated predictors (Research Question 4) and about how they relate to the engagement in learning activities (Research Questions 2 and 3).

The findings from these three steps are reported below. Required substantive rationales are provided shortly and are elaborated in the discussion. For clarity, the originally specified model (Fig. 2) will be referred to as Model 1 and subsequent models are numbered consecutively.

Findings from the LM-test: Information about potentially omitted paths. The findings of the LM-test performed on Model 1 identified one path whose contribution to improve the model fit (i.e., a reduction the χ^2 for 36.63) stands apart from the rest (Bentler, 2006; Byrne, 2006). This finding indicates adding a structural path to the model, flowing from covering up an error to general cause analysis (in Fig. 2: f7→f1), with an expected effect size of -.47. This path addresses exactly the residuals mentioned in the test of Model 1 and indicates that there is a substantial amount of covariation between covering up an error and the engagement in general cause analysis that is not captured by the second order variable engagement in social learning activities. A substantive interpretation of this path can be obtained from reviewing the item contents. The items of the scale 'covering up errors' refer to expected disadvantages from communicating an error to others. The items of 'general cause analysis' contain a general readiness to communicate with other team members about the error. Furthermore, especially item GCA1 is directed towards the self ("... why *I* made this mistake."). Hence, a substantive interpretation of the suggested path may be that nurses with an especially defensive orientation towards an error – as expressed by the tendency to cover it up – may particularly fear to make an initial step of communicating an error to others and to analyse their own contribution to the error. In this interpretation, general cause analysis may serve as a gate keeper that has to be passed before more specific causes or strategies to deal with the error in future can be addressed.

Despite of the possibility of finding a substantive interpretation for this path, it is not considered for inclusion in the model here, because Model 1 provided sufficient model fit and because paths indicated by the LM-test are often instable (MacCallum et al., 1992). Caution is also required because of the problem discussed above that 'specific cause analysis' is represented by only two items. The indicated path is reported here in order to provide information for potential replication studies. If the finding should replicate, the path should be included in the model (MacCallum et al., 1992; Schumacker & Lomax, 2004).

Findings from the W-test: Dropping redundant paths. Performing the W-Test on Model 1 indicated exactly the six insignificant paths identified above as being redundant to the model. No paths that were statistically significant in Model 1 were suggested for exclusion by the test. Removing the insignificant paths from the model yielded a largely unaffected and still adequate model fit (Model 2: S-B$\chi^2_{(89)} = 178.66$, $p = .000$,

S-B$\chi^2/df = 2.01$, SRMR = .08, *CFI = .96, *RMSEA = .06 with 90% C.I. $.05 - .07$) with a statistically insignificant increase of the χ^2 (scaled difference: ΔS-B$\chi^2_{(6)} = 7.76$; n.s.). Furthermore, removing the paths resulted only in a minor reduction of the explained variance in the engagement in social learning activities from 29% to 28%. Hence, the insignificant paths can be removed from the model without a substantial loss of model fit and explained variance in the engagement in social learning activities. The fact that no other requirements for modification were identified by the W-test strengthens the findings from Model 1 by indicating that all statistically significant paths are also important for the model in terms of their contribution to model fit.

Although removing the insignificant paths could contribute to making Model 1 more parsimonious, a substantive problem is that error strain and the perception of a safe team climate are only indirectly connected to the engagement in learning activities via their correlations with a chance for learning and the tendency to cover up an error, respectively (cf. Fig. 3). Hence, they have currently no substantive function in the model. This provides a further reason to proceed with analysing a potential indirect relation of these variables with the engagement in learning activities.

Exploring a potential mediation model. Checking a potential indirect relation of error strain and covering up errors with the engagement in learning activities involved two steps. Firstly, it had to be checked whether error strain and covering up errors are indeed unrelated to the engagement in learning activities, or whether the finding from Model 1 is an effect of the shared variance with the interpretation of an error as a chance for learning and the tendency to cover up an error, respectively. In the former case, the findings would indicate removing error strain and a safe team climate completely from the model because they are irrelevant for explaining the engagement in social learning activities. In the latter case, the pattern of findings would be indicative of an indirect relation (i.e., a mediation model), to be explored in a second step. Demonstrating a mediation effect requires significant indirect but not direct relations of error strain and a safe team climate with the engagement in learning activities when analysed together with chance for learning and covering errors (Kline, 2005).

Hence, first, a model with only error strain and the perception of a safe team climate as uncorrelated predictors for the engagement in social learning activities was estimated (Model 3). The solution for this model resulted in a well fitting model (S-B$\chi^2_{(43)} = 72.23$, $p = .003$, S-B$\chi^2/df = 1.68$, SRMR = .08, *CFI = .98, *RMSEA = .05 with 90% C.I. $.03 - .07$). Unlike Model 1, the engagement in social learning activities was predicted significantly by error strain (.23) and a safe team climate (.29), with 14% explained variance. These findings support the conjecture that the insignificant contribution of these variables in Model 1 is an effect of the large correlations with the estimation of an error as a chance for learning and the tendency to cover up an error. When analysed together, error strain and a safe team climate have too little independent predictive variance.

The findings so far indicate that error strain and safe team climate are significantly related with the engagement in social learning activities when analysed alone (Model 3), and that

this relation disappears when analysed together with chance for learning and covering up an error (Model 1). This pattern of results argues for a model with the discussed indirect relations (Baron & Kenny, 1986; Kline, 2005). In this potential model the estimation of an error as a chance for learning is an mediating variable between error strain and the engagement in social learning activities, and the tendency to cover errors is a mediating variable between the perception of a safe team climate and the engagement in social learning activities. However, suggesting such a model for further research requires answering the question whether the hypotheses (a) that error strain predicts the estimation of an error as a chance for learning and (b) that the perception of a safe team climate predicts the tendency to cover up an error, are substantively meaningful. The position taken here is that these hypotheses are consistent with the theory provided above (cf. Chapter 2.3). Concerning (a) it can be argued that the emotions experienced after an error have an impact on whether it is perceived as a relevant learning situation. This can be explained with the argument from research on experiential learning that episodes need to be experienced as personally salient in order to become relevant for the engagement in learning activities (Gruber, 1999a). Concerning (b) it has been stated above that a perceived safe social environment at work may reduce fears of being accused and therefore mitigate expected disadvantages of communicating an error to colleagues (Edmondson, 1999). Hence, the tendency to cover up an error in a specific situation may be dependent on the general perception of the social context, and in turn affect the decision to address others for learning activities. Although the mediation model and Model 2 are statistically equivalent (i.e., they produce the same model fit; Hershberger, 2006; MacCallum, 1995), the mediation model is substantively more meaningful than Model 2, because error strain and a safe team climate contribute indirectly to explaining the engagement in learning activities.

In order to check whether the current data support hypothesising this mediation model for further studies, it was specified, estimated, and the indirect relations of error strain and a safe team climate with the engagement in social learning activities were tested for significance (Model 4; Fig. 4). The findings indicate small but statistically significant indirect paths from error strain and a safe team climate to the engagement in social learning activities (strain = .18, climate = .18), together with no direct paths from these variables on the engagement in social learning activities present in the model. This is indicative of a full mediation status (Kline, 2005).

6.3. Discussion

The goals of this study were to test and to advance the developed research model in order to answer the research questions about the relations among the interpretation of an error, the perception of a safe team-climate, and nurses' engagement in social learning activities (Research Questions 2—4). For this purpose, a large sample of nurses from several hospitals was surveyed in a cross-sectional field study employing the Cases Approach. This section starts with providing a summary of the results from testing the model and from the exploratory analyses presented in the previous section. Secondly, these results are interpreted and discussed for their implications for the theory provided above. Finally,

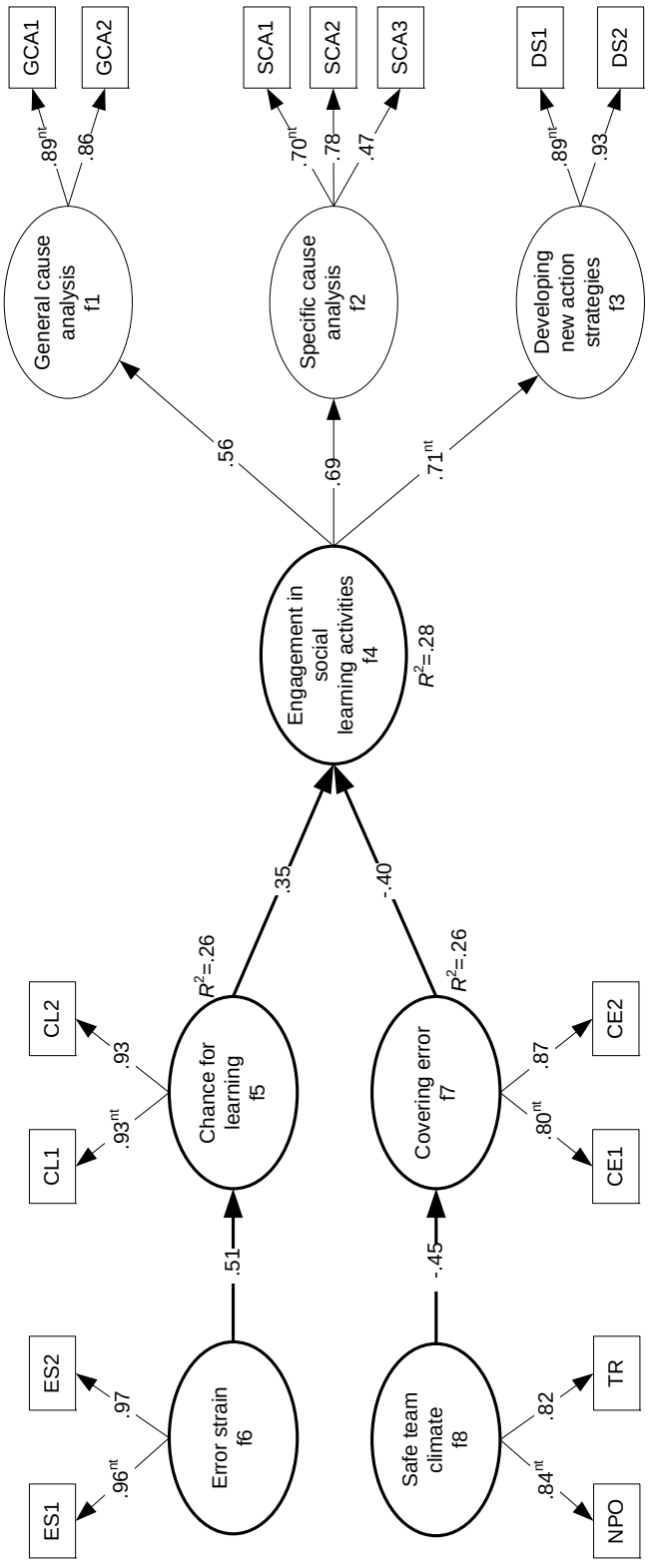


Figure 4: Standardised estimates for the suggested mediation model of the engagement in social learning activities (Model 4); the structural part is printed bold; model fit: S-B$\chi^2_{(89)} = 178.66$, $p = .000$, *S-B$\chi^2/df = 2.01$, SRMR = .08, *CFI = .96, *RMSEA = .06 with 90% C.I. .05 – .07; nt = not tested; indirect effects for $f6 = .18$ and $f8 = .18$ $p < .05$; all other estimates $p < .05$.

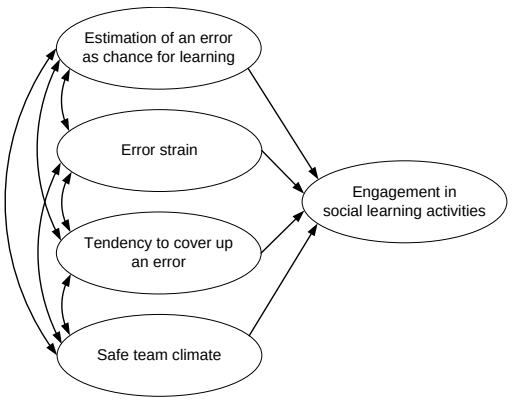
the conclusiveness of the study is reflected by elaborating on strong and weak aspects, and conclusions for the research questions are summarised.

Summary of the results. The main results from testing the research model and the findings from the exploratory analyses are summarised in Figure 5 through a comparison of models. For clarity, the measurement parts of the models are omitted.

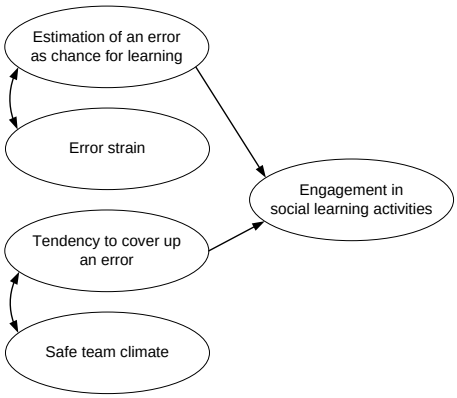
The hypothesised research model is depicted in Figure 5a. After preparatory item analyses that aimed to specify an adequate measurement part of the model, a statistical model has been specified on the basis of this research model. In the analysis, this model provided an adequate fit to the data so that the stated hypotheses could be tested. Figure 5b illustrates which of the assumed relationships have actually been found. Paths that were found to be insignificant are omitted for this purpose. These results can be summarised as follows. From the variables regarding the interpretation of an error situation, the estimation of an error as a chance for learning and the tendency to cover up an error significantly predict nurses' engagement in social learning activities after an error, whereas negative emotions resulting from an error do not (Hypotheses 1—3). The perception of the social context in terms of a safe team climate did not significantly contribute to explain the engagement in social learning activities (Hypothesis 4). Concerning the interrelation of the variables regarding the interpretation of an error situation and the perception of the social context, large correlations were found between the estimation of an error as a chance for learning and error strain (Hypothesis 6), and between the tendency to cover the error and a safe team climate (Hypothesis 9), whereas the other hypothesised correlations were insignificant (Hypotheses 5, 7, 8, & 10).

In order to elicit possibilities to advance the model, the following steps were taken. In a first step, empirical modification indices were inspected (LM-test, W-test). The LM-test findings indicated a potentially omitted path from the tendency to cover up an error to the engagement in general cause analysis in the model. The hypothesis suggested by this path is that there may be a stronger threshold to pass for people with a particular defensive orientation towards errors, before they initiate action- and future-oriented analyses of an error. However, because of the adequate fit of the initial model and the tentative status of this path, it was not considered for inclusion in the model. The W-test identified only the insignificant paths from Model 1 as being redundant and made no further suggestions to remove paths. Hence, after removing the insignificant paths, no measures for increasing the model's parsimony had to be taken.

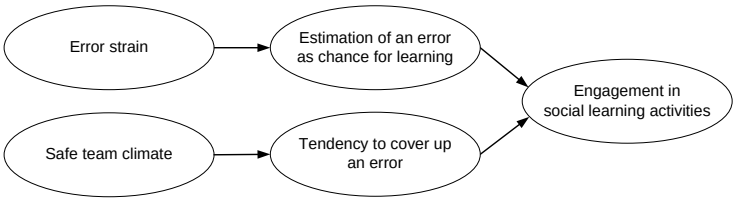
In a second step, it was checked whether the insignificant contribution of error strain and the perception of a safe team climate to the explanation of nurses' engagement in social learning activities in Model 1 is an effect of the shared variance with the respective other predictors. Indeed, the findings indicated that both variables were significant predictors for the engagement in learning activities when analysed alone. The fact that this significant relation disappears in the joint analysis with the estimation of an error as a chance for learning and the tendency to cover up an error indicates that error strain and a safe team climate have too little independent predictive variance. On the basis of this



(a) Research model



(b) Results for the research model



(c) Suggested mediation model

Figure 5: Comparison of the models based on (a) the hypothesised research model, (b) the results from the test of the research model, and (c) the mediation model as hypothesis for further research.

pattern of findings the research model was reinterpreted to build a mediation model as a hypothesis for further research (Fig. 5c). In this model (a) the estimation of an error as a chance for learning is hypothesised to be a mediating variable between error strain and the engagement in social learning activities, and (b) the tendency to cover errors is hypothesised to be a mediating variable between the perception of a safe team climate and the engagement in social learning activities. A respective model provided good fit to the data and the indirect relations of error strain and safe team climate on the engagement in learning activities were small but statistically significant.

The following paragraphs will elaborate substantive interpretations of the described results and their implications for the theory provided above.

Interpretation of the findings and their implications for theory. Concerning the relation between variables regarding the individual interpretation of an error situation in nursing and nurses' engagement in social learning activities after an error (Research Question 2), the study provided evidence that the estimation of an error as a chance for learning is a facilitating variable. The more nurses think that an error situation is prone to deliver relevant information for the improvement of their work, the more they are prepared to address others at work for joint analyses of the error and the development of strategies to avoid it in future. This finding is consistent with the assumption that learning

from an error requires a subject to take a learning orientation and to expect benefits in return for the effort of engaging in learning (Cannon & Edmondson, 2001; Rybowiak et al., 1999; Zhao & Olivera, 2006). It also strengthens the proposition that only those episodes which are perceived as relevant for the engagement in learning activities become learning experiences (Gruber, 1999a).

Furthermore, the tendency to cover up an error, that is, focusing on disadvantages from communicating about an error, is an inhibiting factor. Nurses who have the perception that it is useful to conceal that an error has happened, avoid approaching others for the engagement in learning activities. This result supports the conjecture that anticipated uselessness or disutility of communicating an error episode to team members – as expressed by the tendency to cover up an error – inhibits taking a problem solving or action orientation after an error and addressing others for cause analysis and strategy development (Arndt, 1996; Edmondson, 1999; Meurier et al., 1997; Rybowiak et al., 1999; Zhao & Olivera, 2006). It has been stated that such a tendency may result from individual fear by perceiving the error as a threat, as well as from the anticipation that the social and organisational context will react with accusations and negative sanctions (Barach & Small, 2000; Edmondson, 1999). This interpretation also receives support from the strong negative correlation of the tendency to cover up an error with the perception of a safe team climate.

Both described results are obtained from the confirmatory test of the hypothesised model, replicate findings from Study 2, and match the expectations derived from the theory and the findings presented above. The total variance explained by these predictors is 28% when analysed alone (cf. Model 2) and in a range that can be expected from non-experimental field research. In combination, these results provide support to the assumption that learning from errors involves a cost-benefit evaluation (Zhao & Olivera, 2006). The evaluation of an error as a chance for learning focusses on potential benefits of the error, while covering the error focusses on the costs. More broadly speaking, this is in line with expectancy-value models of human motivation and action (Beckmann & Heckhausen, 2006).

In contrast to the theoretical expectations, the hypothesis that negative emotions experienced after an error situation inhibit the engagement in learning activities after an error was rejected by the model test (Research Question 2). The same holds true for the hypothesis that a safe team climate facilitates addressing colleagues for discussing and analysing an error (Research Question 3). Both variables were insignificant in Model 1. However, the position advanced here is that these results do not imply a complete rejection of the theory regarding the impact of negative emotions and the perception of a safe team climate on learning from errors, but suggest a differentiation that is expressed in the hypothesised mediation model. As proposed by the post hoc analyses, the insignificant contribution of both variables in Model 1 is not due to the fact that they are unrelated to the engagement in social learning activities, but seems to be an effect of the large amount of shared variance between a chance for learning and error strain, and covering up the error and a safe team climate, respectively. The findings of Model 3 – with only error strain and safe team climate as predictors – indicated that both variables are significantly related with the engagement in social learning activities, when analysed alone. The fact that these

relations disappear in the joint comparison in Model 1 points to the suggested mediation model.

Concerning the interrelation of the variables regarding the interpretation of an error and the perception of a safe social context (Research Question 4), two significant correlations were found, whereas the other hypotheses were rejected. In accordance with the expectation, a significant negative correlation between the perception of a safe team climate and the tendency to cover up an error could be found. The more nurses perceive a trustful team climate in their wards that enables the open discussion of errors, the less they tend to perceive advantages from covering up an error. This result replicates the finding from Study 2. It is consistent with the assumption that a safe team climate should mitigate potential fears from having committed an error as well as anticipated risks of admitting an error to others and, therefore, reduce the tendency to cover it up (Edmondson, 1999). In the mediation model, this has been reinterpreted in terms of a direct relation by hypothesising that the perception of a safe team climate predicts the tendency to cover up an error.

The correlation between the experience of negative emotions after an error and the estimation that an error is a chance for learning was significant, but in contrast to the expectation with a positive sign. The more nurses experience emotional strain after an error situation the more they estimate it as a relevant chance for learning. The insignificant path between error strain and the engagement in learning activities in Model 1 was also positive. This contradicts the conjecture that negative emotions may inhibit taking a learning orientation after an error (Boud, 1999; Greif, 1996; Rybowiak et al., 1999; Zhao & Olivera, 2006). In contrast, the finding is consistent with the proposition of the potentially fostering role of consternation (Oser & Spychiger, 2005) and the argument that the experience of negative emotions may create a personal feeling of salience that is required to interpret the episode as relevant for learning (Gruber, 1999a). Negative emotions may create a desire not to repeat the experience and therefore lead to the conclusion that learning activities are required that aim at identifying potential causes and changing them. More broadly, this is in line with a conception of emotions as self-regulatory processes. This conception proposes that emotions modulate cognitive and motivational processes, and shape action tendencies via them (Dörner, 2004; Forgas, 1995; Zhao & Olivera, 2006). In the suggested mediation model, this has been reinterpreted in terms of a directed relation by hypothesising that negative emotions predict the estimation of an error as a chance for learning. However, more research is required on the impact of negative emotions. Even if the finding that negative emotions create a motivational relevance for learning from errors could be consolidated, it still might be that they interfere with the quality of cognitive elaboration processes. Spitzer (2007) points out that fear in particular causes quick learning but inhibits a deep integration with prior knowledge, decreases flexible application of the constructed knowledge, and induces rigid cognitive styles that prevent finding creative problem solutions. Exactly these processes are required for learning from errors, involving the search for effective new strategies for avoiding an error in future. Further studies should aim to identify qualities of motivation induced by negative emotions about an error as well as to elicit cognitive processes. For this purpose, more differentiated perspectives

on negative emotions and how they may relate to learning from errors are needed. One may be to search for interaction effects or non-linear relationships. However, the inspection of scatter plots in this study yielded no sign of such a non-linear relationship. Another perspective is to differentiate more clearly between different kinds of negative emotions. In the scale error strain different feelings such as shame, fear, and anger are treated as a single variable. Though the results of this study and the analyses from Rybowiak et al. (1999) indicate the unidimensionality of the scale error strain, the assumption that these emotions work in a similar way may be inadequate. Finally, a differentiation between the time directly after the error, and a later time when a re-evaluation of the experience and the involved emotions has taken place, may be required.

Beyond the just discussed two significant correlations, the results from the study indicated that several of the hypothesised correlations among the predictor variables are insignificant and essentially zero. This concerns the correlations between (a) a chance for learning and covering up an error, (b) error strain and covering up an error, (c) a safe team climate and a chance for learning, and (d) a safe team climate and error strain (Hypotheses 5, 7, 8, and 10). The rejection of these hypotheses draws a picture that is apparent from Figure 5b. It indicates that the four predictor variables operate – or at least are measured – on two separate levels. On the upper side of Figure 5b are variables that primarily concern the personal interpretation of the error, that is, the emotions aroused by the error and the estimated relevance of the experienced episode for learning. The variables on the lower side concern the interpretation or anticipation of social interactions (i.e., the perception of a safe climate, anticipated disadvantages from communication of the error). This suggests that the tendency to cover up an error has more to do with the situationally dependent anticipation of social interactions, than with a purely individual decision to disclose an error. In contrast, negative emotions and the evaluation of an error as a chance for learning seem to belong mainly to the individual and are not intertwined with the perception of a safe team context, as originally expected.

Substantively, the lack of relations between these levels indicates that the way nurses feel about an error and their estimation of its relevance for learning belongs to their own subjective interpretation of the episode and is independent of the perception of the social context. Whereas a safe team climate seems to mitigate anticipated disadvantages from communicating an error, it does not alleviate feeling bad about having committed an error. This interpretation also accounts for the failure to find the hypothesised relationship between error strain and covering up an error. Both findings indicate that the negative emotions measured by the scale error strain mainly express nurses' dissatisfaction or indignation with themselves, and less socially oriented emotions (Pekrun & Frese, 1992). Furthermore, the absence of a relationship between a safe team climate and the estimation of an error as a chance for learning seems to contradict a finding from Cannon and Edmondson (2001) that team members tend to hold shared beliefs about errors. This discrepancy may be due to the strong situational emphasis in the present study. Whereas it may be the case that team members hold similar generalised beliefs about errors, the interpretation of an error in a specific situation may be mainly dependent on the characteristics of this very episode. A similar explanation can be applied to the findings that the

tendency to cover up an error is unrelated with the estimation of the error as a chance for learning. Whereas a general positive attitude towards errors in terms of conceiving them as learning chances may be negatively related to a general tendency not to communicate about errors (if such general tendencies exist) the present results suggest that the situational interpretation of a single error episode as a chance for learning, and the anticipation of disadvantages from communicating about it, address independent aspects of this episode. Put simply, thinking that an error is a useful chance for learning and thinking that it may be wise to keep it for oneself are not related with each other.

Because of the adequate initial model fit, exploring possibilities to advance the model relied mainly on interpreting the overall pattern of the findings discussed so far. These findings can be integrated to build the hypothesised mediation model that is a substantive reinterpretation of the research model. The mediation model advances the research model by differentiating the assumptions about the interplay between the variables concerning the interpretation of an error and the perception of the context (Research Question 4), and about how these variables relate to the engagement in learning activities after an error (Research Questions 2 and 3), as discussed below.

Mediation models are receiving increasing attention in the social sciences and particularly in research on professional learning (Cannon & Edmondson, 2001; Keith & Frese, 2005; Van den Bossche, 2006), because they allow us to model explanations for how relations between 'input' and 'output' variables may work (Bentler, 2006; Wu & Zumbo, in press). The proposed model suggests that cognitive interpretations (i.e., of an error as a chance for learning, of expected disadvantages from communicating an error) intervene between experiences (i.e., strain suffered from the error, safety of the social context) and the intention to engage in learning activities. This assumption is consistent with the proposition made above that emotions as well as contextual characteristics at work influence behaviour primarily through their effects on individual cognition (Billett, 2006; Dörner, 2004; Forgas, 1995; Jørgensen & Warring, 2002; Zhao & Olivera, 2006). More precisely, the mediation model differentiates the assumptions about the impact of negative emotions on learning from errors by hypothesising that the experience of negative emotions creates a feeling of salience for estimating an error episode as relevant for learning (Gruber, 1999a; Oser & Spychiger, 2005) and therefore indirectly affects the engagement in learning activities via this estimation. Furthermore, the model hypothesises that a safe team climate reduces perceived disadvantages from communicating an error to colleagues (Edmondson, 1999), and therefore indirectly facilitates the engagement in learning activities through this reduction of potential costs. This proposition differentiates the assumption that initiating learning behaviour within a team may be constrained by the fear to appear incompetent or to lose face (Argyris, 1982; Argyris & Schön, 1996; Van Dyck et al., 2005; Edmondson, 1999) by emphasising the role of intervening cognitive processes regarding the interpretation of a specific situation.

In the proposed mediation model, the correlations (a) between error strain and the estimation of an error as a chance for learning, and (b) between a safe team climate and covering up errors are reinterpreted as hypotheses about direct relations. Because no causal conclusions can be drawn from the correlative findings from this study, the hypothesised

direction of the relations is assumed for the substantive reasons provided above and cannot be clarified with the present data. It is acknowledged that there may be also arguments to assume the opposite directions. Concerning (a) the hypothesis that the estimation of an error as a chance for learning has an effect on the experience of negative emotions is possible. Consistent with the assumption that reflection involves a (re-)interpretation of the emotions involved in an episode (Boud et al., 1989a), it can be argued that the estimation of an error as a chance for learning involves a re-appraisal of the involved emotions. Nevertheless, the position advanced here is that negative emotions result in the first place from having committed an error (Keith & Frese, 2005; Zapf, 1991). Reflective processes involving cognitive reinterpretations of the event and of the involved emotions take place subsequently. Furthermore, individuals have been found to use occurring emotions as heuristics that inform their judgements of situations (Forgas, 1995; Zhao & Olivera, 2006). Concerning (b) it may be argued that the experience of specific error episodes leads to the reappraisal of the perceived safety of the social context. However, this effect should work over a longer time, because the perception of the social context is the result of a cumulated experience over a prolonged interaction history (Kramer, 2006). In contrast, the perception of the social context provides an expectational backdrop for interpretation of specific error episodes within this context (Edmondson, 1999; Kramer, 2006). Since the error orientation variables have been conceptualised as situationally grounded in the error cases, assuming an immediate effect of the tendency to cover up an error in a given error situation on the general perception of a safe team climate seems implausible.

Concluding the discussion of the mediation model, the position taken here is that the findings from Model 1 do not suggest a rejection, but a differentiation of the theory regarding the impact of error strain and a safe team climate on learning from errors. Hypothesising the described mediation model is theoretically attractive, because cognitive interpretations intervene between experiences and intended behaviour. This advances the originally stated research model by contributing to differentiate the assumptions about the interplay of the interpretation of an error situation and the perception of the social context (Research Question 4) and about how these variables relate to the engagement in learning activities (Research Questions 2 and 3). Because mediation models require that the direction of relations is correctly specified (Kline, 2005), further studies should address the issue of direction of causality in the proposed relations, for example, by using cross-lagged panel designs (Bortz & Döring, 2006). Furthermore, qualitative data could be helpful to deepen the understanding of the processes going on.

The paragraph below will critically reflect on the conclusiveness of this study and summarise the discussion so far, leading to conclusions for the research questions.

Limitations and summary of the conclusions for the research questions. This study contributed to answering the research questions about how nurses' engagement in social learning activities after an error at work relates to their interpretation of the error and to the perception of a safe team climate (Research Questions 2 and 3). These variables have widely been assumed to foster or constrain learning from errors at work (Arndt, 1996; Cannon & Edmondson, 2001; Edmondson, 1996, 1999; Meurier et al., 1997; Tjosvold et

al., 2004; Tucker & Edmondson, 2003; Van Woerkom, 2003). Furthermore, the study addressed the question about how the variables regarding the interpretation of an error and the perception of a safe social context interrelate (Research Question 4). Before turning to a summary of the conclusions for these research questions, a summary of weak and strong aspects of the present study is appropriate.

Weaknesses of this study that constrain its conclusiveness concern the limited explanatory power of the non-experimental design, that the findings are limited to the field of nursing, and the potential selectivity of the sample. However, the study provided information about the association between the investigated variables as an elementary precondition for potential causal relations (Hoyle, 1995) and thereby contributed to identify and select potential determinants for learning from errors at work that can be investigated more deeply in further studies. Furthermore, a problem was that the scale 'cause analysis' did not work exactly in the intended way. In contrast to the intention, the factor analysis revealed a two-dimensional structure of the original scale 'joint cause analysis'. This underlying two-dimensionality may be a reason why in Study 2 several items had to be excluded from this scale. However, the resulting factor solution was interpretable, the items had substantial loadings on their factors, and the scales that were built on the basis of the factors proved to be reliable. The problem that the scales consist only of few items was resolved by the fact that the scales were used in combination as the second order variable 'engagement in social learning activities'. Furthermore, for many applications it is preferable to have a few good indicators than many items that are actually paraphrases of one question (Schumacker & Lomax, 2004). Nevertheless, the scales should be extended in a revision. In terms of content validity, the scale general cause analysis has a narrow construct scope (i.e., an initial readiness to communicate about an error), so that with one or two additional items the scale should represent the construct adequately. The scale specific cause analysis should be extended in a way that it reflects more relevant reasons that underlie the present error cases. Despite of the problem with the cause analysis scale, the instrument seems to have been adequate: a reliable and well fitting measurement model could be established on its basis.

Overall, the implementation of the Cases Approach seems to have been successful. The majority of the participants' perceived the error vignettes as authentic, in both Studies 1 and 2. This supports the assumption that they worked in the intended way. Although the position advanced here is that the Cases Approach is a more valid way of investigating learning from errors than asking for activities after errors in general, a concern regarding this approach may be that it is uncertain to what degree the results generalise to other kinds of knowledge- and rule-based errors. This concern can, however, be clarified empirically in further studies.

That the initial model provided an adequate fit to the data enhances the conclusiveness of the findings, because it rendered an overreliance on modification indices in order to attain adequate model fit unnecessary (MacCallum et al., 1992). Nevertheless, the discussed limitations and the fact that a research method has been applied that is novel to this field of research, caution from making final conclusions regarding the support or rejection of theoretical assumptions on the basis of the study. The finding that several of the

hypothesised relationships could not be found despite of theoretical plausibility or previous evidence may be an effect of the strong situational interpretation of learning from errors and the respective design of the study. Whether these results demand revisions in theory will depend on their stability in further studies.

Taking into account the above mentioned problems, the study still delivered adequate information for a test of the hypotheses and contributed to answering the research questions. The results from testing the hypothesised research model as well as from the exploratory analyses that aimed to advance it help to differentiate theorising and to state more elaborate hypotheses about learning from errors. The main conclusions from the study for the research questions can be summarised as follows.

Research Question 2. The results support the assumption that the interpretation of an error situation in terms of the estimation as a chance for learning fosters nurses' engagement in social learning activities regarding joint analysis of causes and the development of new action strategies. In contrast, the tendency to cover up an error seems to be an inhibiting variable. These findings are consistent with the assumption that open communication about an error at work depends on a perceived positive cost-benefit balance (Zhao & Olivera, 2006). In contrast, the amount of negative emotions aroused by having committed an error made no independent contribution to explain nurses' engagement in learning activities. The exploratory analyses indicated that the theoretical assumptions about the impact of negative emotions may need to be differentiated in the sense that additional cognitive processes intervene between emotions and the engagement in learning.

Research Question 3. The findings for the assumption that a perceived safe team climate supports nurses' engagement in social learning activities indicate that a safe team climate did not independently contribute to explain the engagement in learning activities. As for the variable error strain, the theoretical assumptions about the impact of a safe team climate on nurses' learning activities may have to be differentiated by considering additional cognitive processes regarding the estimation of potential disadvantages from communicating the error (Zhao & Olivera, 2006).

Research Question 4. The study revealed a negative correlation between the perception of a safe team climate and the tendency to cover up an error. This is consistent with the assumption that a safe team climate is relevant to mitigate fears about social repercussions from communicating an error to colleagues (Edmondson, 1999). Further research should investigate whether the hypothesis that a safe team climate reduces the tendency to cover up errors is sustainable. Furthermore, the study indicated a positive correlation between the amount of negative emotions experienced after an error and the estimation of the error as a chance for learning. Concerning the contested role of negative emotions for learning from errors (Greif, 1996; Keith & Frese, 2005; Mehl, 1993; Oser & Spychiger, 2005; Rybowiak et al., 1999; Zapf, 1991; Zhao & Olivera, 2006), the finding can be interpreted in a sense that negative emotions create a motivational relevance for the interpretation of the error as a learning situation (Gruber, 1999a; Oser & Spychiger, 2005). Still, negative emotions may have

detrimental effects on cognitive elaboration processes (Greif, 1996; Keith & Frese, 2005; Spitzer, 2007). Further research should investigate whether the hypothesis that negative emotions predict the estimation of an error as a chance for learning is sustainable. Furthermore, more differentiated analyses concerning different qualities of negative emotions are required. Beyond these found relations, the study revealed that variables regarding the personal interpretation of the error on the one side and the perception of the social context or its anticipated reactions to the error on the other side are not as narrowly intertwined as assumed. The findings indicate that the individual interpretation of an error in terms of aroused emotions and the estimated relevance for learning is independent of the perception of the quality of social relationships at work and of perceived disadvantages of communicating an error.

The present study has made a first contribution to answering the stated research questions. Primary tasks for further research are to cross-validate the findings and to check the assumed directions of the relations among the variables in experimental studies. For this purpose, a revision and extension of the cause analysis scales is required. Two more issues for further research come to mind. The first is how to increase the amount of explained variance in the engagement in learning activities. For this purpose, it may be worthwhile to include variables that have been found to influence many relevant outcomes in work and organisational psychology, such as self-efficacy, motivational orientations, and attributional styles (A. B. Weinert, 2004). An inclusion of these variables was beyond the scope of this study, given that the goal was to investigate those variables that most prominently have been assumed to affect learning from errors at work. Furthermore, in applied field research a tribute has to be paid to the amount of time and effort people in work organisations are prepared to spend participating in research. Another way to increase the explained variance may be to investigate more systematically how organisational characteristics add to explaining learning from errors. For example, the existence of critical incident reporting systems or compulsory after event meetings could be varied systematically in order to evaluate their effects. Multi level analysis is an appropriate tool for this purpose (Hox, 1998).

Another question is how to substantiate the validity of the activity approach to learning from errors. This might prove difficult, due to the lack of established outcome criteria for learning from errors. The introduced process approach to learning in terms of the engagement in learning activities was chosen, because learning from errors occurs incidentally and no meaningful learning outcomes can be defined without referring to specific error episodes. In laboratory experiments with induced error situations, knowledge elicitation techniques such as concept maps or the critical decision method may be used in order to investigate how the engagement in joint discussions and analyses about an error changes individuals' knowledge (Hoffman & Lintern, 2006; O'Hare & Wiggins, 2004). In simulation studies, performance measures could also be used, if tasks can be constructed that involve the same demands as in an error situation, but allow no immediate practice effects (Mehl & Wehner, in press). In nursing, judging the risk of bedsore might be such a task.

Concerning practical implications, the question arises what possibly can be done to support nurses to take a learning orientation and to engage in learning after an error. A cynical

interpretation of the found relation between error strain and the estimation of an error as a chance for learning may be that it should ensure that nurses feel bad about their errors. This conclusion is not supported by the data from this study. A blaming versus a non-punitive approach to errors is a facet of the variable 'safe team climate' that has been found to be unrelated to error strain and negatively related to covering up an error in this study. Substantively, this implies that the way people feel about an error belongs to themselves and is not related to their perception about how errors are dealt with in the team. This is consistent with the proposal that only a kind of embarrassment that is internally driven by individuals' self-indignation will create a feeling of relevance for learning from an error (Oser & Spychiger, 2005). Put simply, being blamed or accused may not induce the same quality of relevance as feeling bad about the error for intrinsic reasons. In contrast, blaming may increase the tendency to disclose errors. Based on the current findings, what a hospital may do is to create relevance by emphasising the importance of discussing errors and to reduce potential costs of discussing errors by promoting a safe team climate, even if the effect may only be indirect.

7. General discussion and outlook on further research issues

To conclude this thesis, it has to be elaborated what the studies have contributed to answering the research questions, what has been added to our understanding of learning from errors at work, and in what ways this opens new perspectives for research in this area. Four research questions have been stated in the opening chapter.

> **Research Question 1.** *How can learning from errors at work be conceptualised and measured?*
> **Research Question 2.** *To what degree does the individual interpretation of an error situation foster or constrain the engagement in learning from errors at work?*
> **Research Question 3.** *To what degree does the perception of the social context at work foster or constrain the engagement in learning from errors at work?*
> **Research Question 4.** *How are the variables regarding the individual interpretation of an error and the perception of the social context at work interrelated?*

How these research questions have been addressed and the contributions arising through that process are summarised below.

Contribution for answering the research questions. For addressing Research Question 1, a theoretical framework of learning from errors at work has been developed. The contribution of this framework lies in drawing on different fields of research on errors and integrating their perspectives. Existing studies are often too much focussed on the problems, theories, and perspectives of their specific field and fail to incorporate valuable solutions from other domains (Bauer & Mulder, in press). Research on human factors

and safety management has developed precise and detailed definitions, taxonomies, and explanations of human error (Reason, 1990; Senders & Moray, 1991). However, it often fails to inform about individual learning and, rarely, incorporates findings from cognitive-psychological and educational studies on expertise and learning at work. In contrast, many existing studies on learning from errors use too little of the available knowledge about errors and, therefore, neglect to elaborate on the conceptual premises of their research. These conceptual problems inhibit the integration of findings to build a cumulative body of research (Ohlsson, 1996; Sitkin, 1992). In order to understand and elaborate the concept of error, the potential of errors as antecedents of learning, and the processes and outcomes of learning from errors, the theoretical framework presented in Chapter 2 draws on and integrates concepts and findings from cognitive and action-oriented approaches to human error on the one hand (e.g., Frese & Zapf, 1994; Reason, 1990; Senders & Moray, 1991), and research on experiential learning, adult learning, learning at work, and professional development on the other hand (e.g., Billett, 2004b; Gruber, 1999a; Kolb, 1984).

On the basis of the developed framework, two propositions about how to measure learning from errors at work have been advanced. First, learning from errors can be operationalised in terms of learning activities that start a process of inquiry into root-causes and aim at changing the underlying causes. This activity perspective on learning from errors is systematically derived from experiential learning theory (Gruber, 1999a; Kolb, 1984; Kolodner, 1983; Schank, 1999), which is a prerequisite for the content validity of the operationalisation. Secondly, questions about the engagement in error-related learning activities should be grounded in concrete error cases that represent a specific type of error. Reasons for this are (a) that different types of errors bear a different potential for learning and may require specific learning activities that do not generalise to other types of errors (Glendon et al., 2006; Keith & Frese, 2005) and (b) that employees are better able to explicate knowledge or learning activities when questions refer to concrete events at work (Billett, 2000; Eraut et al., 1998; Ericsson, 2006b; Ericsson & Simon, 1984; Simons, 2005).

In Studies 1 and 2 an exemplary operationalisation of the engagement in error-related learning activities in nursing has been developed and applied in Study 3. In Study 1 relevant examples of error cases and learning activities were collected to assist the development of an operationalisation that is contextualised to the domain of nursing. On the basis of the findings, the decision was made to focus on socially performed learning activities and errors regarding the misinterpretation of a situation. In Study 2 a decision between the Critical Incident Technique and the Cases Approach to grounding was made and initial evidence about the psychometric properties of the learning activity scales was gathered. Although the conclusiveness of the findings is limited due to the selective sample, the results were also encouraging in that reliable scales could be built and that theoretically expected correlations with the interpretation of an error situation and the perception of a safe team climate could be found. The required separation of the scale 'cause analysis' into general and specific cause analysis in Study 3 indicates requirements for revising and extending the developed scales. However, the fact that a reliable and well fitting measurement model could be specified in this study justifies further efforts to advance and validate the developed operationalisation of learning from errors.

In summary, the proposed answer to Research Question 1 is that learning from errors can be conceptualised and measured in terms of the engagement in learning activities that aim to change potential underlying cases and to prevent the recurrence of the error. It is acknowledged that the developed operationalisation is limited (a) to the domain of nursing, (b) to a specific type of error (i.e., misjudging a situation and subsequently making a wrong decision), and (c) to the special case of learning activities that are performed in social exchange. However, the position advanced here is that this degree of specificity is necessary, because asking for activities taken after errors in general neglects the variability of errors (Reason, 1995) and the situated nature of work related learning (Billett, 2004a). Nevertheless the proposed learning activity perspective can potentially be applied flexibly. Combining the introduced learning activity framework with error taxonomies allows us to construct new operationalisations of learning activities systematically for given errors in given domains of work.

Research Questions 2—4 were addressed in combination, because they concern the interplay of individual and contextual variables for explaining the engagement in learning activities after an error in nursing. Based on current theorising on learning from errors and learning at work, hypotheses were derived (a) about the potential impact of the individual interpretation of an error – in terms of estimating the error as a chance for learning, negative emotions aroused by having committed an error, and the motivational tendency to cover up an error (Rybowiak et al., 1999) – and (b) about the potential relevance of a safe team climate for openly discussing an error with colleagues (Edmondson, 1999). (c) The expectation of a tight interrelation between individual and social aspects of learning from errors was informed both by theorising on learning at work (Billett, 2004b; Eraut et al., 1998) and learning from errors (Zhao & Olivera, 2006). The developed hypotheses were integrated in the research model depicted in Figure 1, that subsequently was subject to empirical investigation.

The process of examining the research model involved, first, several steps of narrowing the scope, in order to make it more specific, manageable, and precise. This involved the above mentioned decision to focus on social learning activities and on errors in terms of misinterpretations of a situation, based on the findings from Study 1. Secondly, the research model was tested and advanced in the Study 3 by surveying a large sample of nurses from different hospitals with the developed questionnaire. It has been acknowledged that the conclusiveness of this study is limited through the non-experimental design, a potentially selective sample, and the focus on the domain of nursing. However, the study contributed to answer the research questions by delivering initial evidence that can be cross-validated and deepened in further studies. With all required caution, the findings from the study indicate the following answers on the Research Questions 2—4.

The findings on the individual interpretation of the error situation support the assumption that the estimation of an error situation as a chance for learning fosters exchange with other nurses about potential causes and strategies to avoid similar errors in future. In contrast, perceiving advantages from hiding an error seems to be an inhibiting factor. These findings are consistent with the proposal that learning from errors depends on a subjective cost-benefit balance (Zhao & Olivera, 2006). Negative emotions aroused by having committed

an error seem to play only a marginal role for the engagement in learning activities. The same was observed for the perception of a safe team climate, that did not independently contributed to explain nurses' engagement in learning activities.

The findings concerning the interrelation of the interpretation of the error and the perception of the social context indicate that negative emotions and the estimation of an error as a chance for learning seem to belong mainly to the individual and are not intertwined with the perception of a safe team context, as originally expected. The tendency to cover up an error seems to have more to do with the situationally dependent anticipation of social interactions, than with a purely individual decision to disclose an error. As indicated by the found correlations, the experience of negative emotions is associated with the estimation of an error as a chance for learning, and the perception of a safe team climate with the tendency to cover up an error.

On the basis of this pattern of findings, a mediation model has been suggested as hypothesis for further research that differentiates the initial assumptions about relevant predictors for learning from errors. It proposes that negative emotions after an error create a feeling of salience as a basis for estimating an error as relevant for learning and for engaging in learning activities. Furthermore, the model proposes that a safe team climate reduces perceived disadvantages that may hinder communicating an error to others. These hypotheses require validation in further studies.

By delivering these findings and further hypotheses, Study 3 contributed to deepen our understanding of learning from errors at work. It enables further studies that cumulatively build upon the current findings in order to answer more fully the question what individual and contextual variables foster or constrain employees' engagement in learning after the experience of an error at work. Findings from the current and future studies may eventually enable intervention programmes for supporting learning from errors in nursing and other work domains. Below, an outlook on several salient issues for further research is provided.

Outlook: Issues for further research. Conducting the studies presented above comprised a process of continuously narrowing the focus on learning from errors, in order to understand its processes and potential enabling factors. Two lines of further inquiry are worth pursuing from here. The first one is to go for even greater specificity and to engage in exploring the detailed relationships between the variables in more depth than was possible in this research. Several respective research problems have been identified in the discussion of Study 3. These are to deepen our understanding of the relationships between the evaluation of an error as a chance for learning and error strain, and between a safe team climate and the tendency to cover up an error, to further explore and explain the diverse role of negative emotions on learning motivation and cognitive processes, to include further potentially relevant variables, and to integrate the learning activity perspective with a knowledge perspective. The second way is to pick up open questions that were excluded by the decisions made. These concern (a) other types of errors, (b) other types of learning activities, (c) specific combinations of types of errors, types of learning activities, and their outcomes, (d) other levels of learning, (e) other domains of work, and

(f) alternative research methods. An outlook on these potential further lines of inquiry is provided, below.

The decision to focus on the misinterpretation of a situation excluded many other subtypes of knowledge- and rule-based errors that may ask for other kinds of learning activities than those addressed in the present study. One of the reasons for this decision was that misinterpretations of situations are to a certain extent representative for knowledge- and rule-based errors (Reason, 1995). Despite this, other forms of knowledge- and rule-based errors are worthy of investigation. For example, errors that are mainly based on deficient domain specific knowledge may be best solved by training or self-regulated learning activities, such as reading (Glendon et al., 2006). Hence, an open issue is to analyse which types of errors may be addressed by which types of learning activities.

The decision to focus on social learning activities, demands that we explore other ones that have not been addressed here. This concerns the whole side of individually performed learning activities (cf. Tab. 1) and the issue of how the conclusions that may be derived from reflection on causes can be shaped into strategies to avoid an error in future and implemented in work practice. This implementation is not solely a matter of individual motivation, but also has to take constraints in the social context, power issues, and features of the organisation of work into account. For example, even if an individual elects to seek social exchange after an error, those approached for participation might refuse to participate or resist the individual attempt to initiate a change. A community may have a particular interest in *not* analysing an error and in maintaining a current practice, even though it is contested (Hoeve & Nieuwenhuis, 2006). If team members typically react like that, this may lead to a perception that the team is unsupportive and that it is of little use to approach others for help or reflection (Arndt, 1996; Edmondson, 1999). Furthermore, characteristics of the organisation of work, such as the work pace and intensity, number of patients per ward, or the availability of help and resources, cannot simply be changed by an individual employee's or sometimes even a team's or the management's decision. They may reflect the socio-historically developed nature of a work domain (Billett, 2001a).

In combination, the two issues above ask researchers to investigate specific combinations of types of errors, on the one hand, and sets of learning activities, on the other. An even more demanding problem would be, to integrate the issue of the relationship among types of errors, learning activities, and different types of knowledge that can be constructed from them. This is important to deepen our understanding about what kinds of learning activities are helpful in what kinds of error situations, and what kind of knowledge can be constructed from a given type of error.

Since the present research focussed on the individual, a next step would comprise to investigate learning from errors on the team level more systematically. This regards errors, the learning processes, and outcomes in the form of knowledge and behaviour. Errors that emerge directly out of joint team work were not addressed in this study. The implicit assumption, that only the individual actor is responsible for a given error, is very rigid and inapplicable to many work situations (Wehner & Mehl, 2003). As for the issue of team learning processes, the present theoretical framework provided a number of links

between individual and team learning from errors. This has been most explicit in the focus on socially oriented learning activities. Furthermore, the processes and outcomes of learning at work have been characterised as the change of scripts. Equivalent processes can be modelled regarding the change of routines that are assumed to express the enacted knowledge of a team (Becker, 2004; Hoeve & Nieuwenhuis, 2006). An interesting perspective for further research would be to analyse the impact of errors on a team's shared or distributed knowledge. This could be done by investigating how team mental models or team transactive memory systems change after errors, and how knowledge about errors is transmitted in work groups (Levine & Moreland, 1999; Moreland, 1999; Van den Bossche, 2006).

The decision to focus on the domain of nursing limits the findings to this specific domain. While the developed theoretical framework may be contextualised to other domains, no claim is made that the results from the studies generalise. Investigating other domains will become increasingly complex according to the level to which the criteria for judging errors become dubious or idiosyncratic for a given domain. For example, investigating learning from errors in business consulting may be interesting, but the criteria for evaluating actions as errors are less codified in this domain than in health care. Discourse analyses on who participates in the definition of an acceptable practice may be required in such domains prior to conducting research on learning from errors (Arndt, 1996; Heid, 1999).

The last issue concerns the applied methodology. Although the position has been taken above that the grounding in concrete error episodes enhances the validity of the measurement of learning from errors, the implemented Cases Approach has to be validated and complemented with other methods. Whereas the Cases Approach enhances the standardisation of error episodes, it imposes the chosen situations on the participants and loses a rich data source as compared to the Critical Incident Technique. It should be critically evaluated under what conditions the Critical Incident Technique works for researching learning from errors and whether the results are comparable with the cases approach. The Multitrait-Multimethod Technique provides a useful perspective for comparing the validity of these approaches (Eid, Lischetzke, & Nussbeck, 2006). Another issue is how to reduce self-serving and social desirability tendencies. The Randomised Response Technique may be useful here (Clark & Desharnais, 1998), but it is unlikely to work in large samples because it is very time consuming and not easy to understand for the participants. Therefore, developing alternative methods that get close to actual errors, facilitate participation in the research, and mitigate methodological biases, would be helpful.

The proposed lines of inquiry indicate that the contribution of this thesis lies in preparing the field by providing a conceptual framework of learning from errors, a research instrument, and initial evidence for what individual and contextual variables may foster or constrain it. Based on the findings and substantive considerations, it is proposed that the individual interpretation of an error situation in terms of a cost-benefit balance is relevant for the decision to engage in learning activities. The perception of contextual characteristics, such as the quality of social relationships and interactions is potentially indirectly relevant through this cognitive evaluation of costs and benefits. A central message at the end of this thesis is that individuals can learn from their errors at work and that the investigation of the underlying processes and conditions is both relevant and accessible for empirical research.

References

Anderson, J. R. (2005). *Cognitive psychology and its implications.* New York: Freeman.

Anderson, N. R., & West, M. A. (1994). *Team climate inventory.* Windsor: Berks ASE.

Argote, L., & Todocara, G. (2007). Organizational learning. In G. P. Hodgkinson & J. K. Ford (Eds.), *International review of industrial and organizational psychology* (Vol. 22, pp. 193-234). Chichester, NY: Wiley.

Argyris, C. (1982). *Reasoning, learning, and action. Individual and organizational.* San Francisco, CA: Jossey-Bass.

Argyris, C., & Schön, D. (1996). *Organizational learning II: Theory, Method, and Practice.* Reading, MA: Addison-Wesley.

Arndt, M. (1994). *Nurses' medication errors - an interpretative study of experiences.* Bern: Lang.

Arndt, M. (1996). Aus Fehlern lernen [Learning from errors]. *Pflege*, *9*, 12-18.

Aspden, P., Corrigan, J. M., Wolcott, J., & Erickson, S. M. (2004). *Patient safety.* Washington, D.C.: National Academies Press.

Atkinson, J. W. (1986). Michigan studies of fear of failure. In F. Halisch & J. Kuhl (Eds.), *Motivation, intention, and volition* (pp. 47-59). Berlin: Springer.

Badke-Schaub, P. (2002). Kritische Situationen als Analyseeinheit komplexer Handlungen [Critical situations as unit of analysis of complex actions]. In R. Trimpop, B. Zimolong, & A. Kalveram (Eds.), *Psychologie der Arbeitssicherheit und Gesundheit. Neue Welten - alte Welten* (pp. 137-142). Heidelberg: Asanger.

Bandalos, D. L., & Finney, S. J. (2001). Item-parceling issues in structural equation modeling. In G. A. Marcoulides & R. E. Schumacker (Eds.), *New developments and techniques in structural equation modeling* (pp. 269-296). Mahwah, N.J.: LEA.

Barach, P., & Small, S. D. (2000). Reporting and preventing medical mishaps: lessons from non-medical near miss reporting systems. *British Medical Journal*, *320*, 759-765.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*, 1173-1182.

Bauer, J. (2004). Fehlerkultur und epistemische Überzeugungen als Einflussfaktoren individuellen Kompetenzerwerbs im Arbeitsalltag [Error culture and epistemological beliefs as determinants of competence development during daily work]. In H. Gruber, C. Harteis, H. Heid, & B. Meier (Eds.), *Kapital und Kompetenz. Veränderungen der Arbeitswelt und ihre Auswirkungen aus erziehungswissenschaftlicher Sicht* (pp. 59-75). Wiesbaden: VS-Verlag.

Bauer, J., Festner, D., Harteis, C., Heid, H., & Gruber, H. (2004). Fehlerorientierung im betrieblichen Arbeitsalltag. Ein Vergleich zwischen Führungskräften und Beschäftigten ohne Führungsfunktion [Error orientation in daily work. A comparison of managers and staff members]. *Zeitschrift für Berufs und Wirtschaftspädagogik*, *100*, 65-82.

Bauer, J., & Gruber, H. (2007). Workplace changes and workplace learning: advantages of an educational micro perspective. *International Journal of Lifelong Education*, *26*, 675-688.

Bauer, J., & Mulder, R. H. (2007). Modelling learning from errors in daily work. *Learning in Health and Social Care*, *6*, 121-133.

Bauer, J., & Mulder, R. H. (in press). Conceptualising learning from errors at work: A literature review. In S. Billett, C. Harteis, & A. Eteläpelto (Eds.), *Emerging perspectives on learning through work.* Rotterdam: Sense Publishers.

Bauer, J., Rehrl, M., & Harteis, C. (2007). Measurement of learning culture: a motivational approach. In H. Gruber & T. Palonen (Eds.), *Learning at the workplace – new developments* (pp. 21-50). Turku: Finnish Educational Research Association.

Bayerische Krankenhausgesellschaft e.V. (2005a). *Die Krankenhausversorgung in Bayern* [Supply with hopsitals in Bavaria]. Retrieved October 30, 2007, from `http://www.bkg-online.de/bkg/app/Content/BKG/Info_und_Service_Seiten/KH_Versorgung/index.jsp`.

Bayerische Krankenhausgesellschaft e.V. (2005b). *Sammlung von aktuellem statistischem Material über die deutschen Krankenhäuser* [Collection of current statistical data on German hospitals]. Retrieved October 30, 2007, from `http://www.bkg-online.de/bkg/app/Content/BKG/Info_und_Service_Seiten/downloads/dl-22-2005-Schlagzeilen-anlage.pdf`.

Bayerisches Staatsministerium für Arbeit und Sozialordnung, Familie und Frauen. (2007). *Krankenhausplan des Freistaates Bayern* [Hospital plan of the Fedaral State of Bavaria]. Retrieved May 14, 2007. from `http://www.stmas.bayern.de/krankenhaus/plan/index.htm`.

Becker, M. C. (2004). Organizational routines: a review of the literature. *Industrial and Corporate Change*, *13*, 643-677.

Beckmann, J., & Heckhausen, H. (2006). Motivation durch Erwartung und Anreiz [Motivation through expectancy and value]. In J. Heckhausen & H. Heckhausen (Eds.), *Motivation und Handeln* (pp. 105-142). Berlin: Springer.

Bentler, P. M. (2006). *EQS 6 structural equations program manual.* Encino, CA: Multivariate Software, Inc.

Berings, M. G. M. C., Gelissen, J. P. T. M., & Poell, R. F. (2005, December). *What and how do nurses learn on the job? The development of a classification.* Paper presented at the 4th International Conference on Researching Work and Learning, Sydney (Australia).

Bühner, M. (2006). *Einführung in die Test- und Fragebogenkonstruktion* [Construction of tests and questionnaires]. München: Pearson.

Billett, S. (2000). Guided learning at work. *Journal of Workplace Learning*, *12*, 272-285.

Billett, S. (2001a). Knowing in practice: Re-conceptualising vocational expertise. *Learning and Instruction*, *11*, 431-452.

Billett, S. (2001b). *Learning in the workplace: strategies for effective practice.* Crows Nest: Allen and Unwin.

Billett, S. (2001c). Learning through work: workplace affordances and individual engagement. *Journal of Workplace Learning*, *13*, 209-214.

Billett, S. (2004a). Learning through work: workplace participatory practices. In H. Rainbird, A. Fuller, & A. Munro (Eds.), *Workplace learning in context* (pp. 109-125). London: Routledge.

Billett, S.(2004b). Workplace participatory practices. Conceptualising workplaces as learning environments. *Journal of Workplace Learning*, *16*, 312-324.

Billett, S.(2006). Work, subjectivity and learning. In S. Billett, T. Fenwick, & M. Sommerville (Eds.), *Work, subjectivity and learning* (pp. 1-20). Dordrecht: Springer.

Bogner, M. S. (Ed.). (1994). *Human error in medicine.* Hillsdale, NJ: LEA.

Bollen, K. A.(1989). *Structural equations with latent variables.* New York: Wiley.

Bortz, J., & Döring, N.(2006). *Forschungsmethoden und Evaluation* [Research methods and evaluation]. Berlin: Springer.

Boshuizen, H. P. A.(2004). Does practice make perfect? A slow and discontinuous process. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: gaps and transitions on the way from novice to expert* (pp. 73-95). Dordrecht: Kluwer.

Boshuizen, H. P. A., Bromme, R., & Gruber, H.(2004a). On the long way from novice to expert and how traveling changes the traveller. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: gaps and transitions on the way from novice to expert* (pp. 3-8). Dordrecht: Kluwer.

Boshuizen, H. P. A., Bromme, R., & Gruber, H. (Eds.). (2004b). *Professional learning: gaps and transitions on the way from novice to expert.* Dordrecht: Kluwer.

Boud, D.(1999). *Experience and learning: Reflection at work.* Deakin: Deakin University.

Boud, D. (2006). Creating the space for reflection at work. In D. Boud, P. Cressey, & P. Docherty (Eds.), *Productive reflection at work* (pp. 158-169). London: Routledge.

Boud, D., Cressey, P., & Docherty, P. (Eds.). (2006). *Productive reflection at work.* London: Routledge.

Boud, D., Keogh, R., & Walker, D.(1989a). Promoting reflection in learning: a model. In D. Boud, R. Keogh, & D. Walker (Eds.), *Reflection: turning experience into learning* (pp. 18-40). London: Kogan Page.

Boud, D., Keogh, R., & Walker, D.(1989b). What is reflection in learning? In D. Boud, R. Keogh, & D. Walker (Eds.), *Reflection: turning experience into learning* (pp. 7-17). London: Kogan Page.

Boud, D., & Middleton, H.(2003). Lerarning from others at work: communities of practice and informal learning. *Journal of Workplace Learning*, *15*, 194-202.

Büssing, A., & Glaser, J. (2002). *Das Tätigkeits- und Arbeitsanalyseverfahren für das Krankenhaus - Selbstbeobachtungsversion (TAA-KH-S)* [Activity and work analysis inventory for hospitals - self report version]. Göttingen: Hogrefe.

Büssing, A., & Glaser, J.(2003). Dienstleistungsqualität und Qualität des Arbeitserlebens im Krankenhaus: Einleitung und Überblick [Service quality and work satisfaction in hospitals: introduction and overview]. In A. Büssing & J. Glaser (Eds.), *Dienstleistungsqualität und Qualität des Arbeitserlebens im Krankenhaus* (pp. 15-34). Göttingen: Hogrefe.

Byrne, B. M.(2006). *Structural equation modeling with EQS.* Mahwah, NJ: LEA.

Cannon, M. D., & Edmondson, A. C.(2001). Confronting failure: Antecedents and consequences of shared beliefs about failure in organizational work groups. *Journal of Organizational Behavior*, *22*, 161-177.

Cannon, M. D., & Edmondson, A. C.(2005). Failing to learn and learning to fail (intelli-

gently): how great organizations put failure to work to innovate and improve. *Long Range Planning: International Journal of Strategic Management*, *38*, 299-319.

CIRSmedical. (2005). *Cumputerbasiertes anonymes critical incident reproting: Ein Beitrag zur Patientensicherheit* [Cumputer-based anonymous critical incident reproting: a contribution to patient safety]. Retrieved November 14, 2005 from `https://www.cirsmedical.ch/dokument/CIRSmedINFO.htm`.

Clark, S. J., & Desharnais, R. A. (1998). Honest answers to embarrassing questions: detecting cheating in the randomized response model. *Psychological Methods*, *3*, 160-168.

Collins, A. (1990). Reformulating testing to measure learning and thinking. In N. Frederiksen, R. Glaser, A. Lesgold, & M. G. Shafto (Eds.), *Diagnostic monitoring of skill and knowledge acquisition* (pp. 75-87). Hillsdale, NJ: LEA.

Cressey, P., Boud, D., & Docherty, P. (2006). The emergence of productive reflection. In D. Boud, P. Cressey, & P. Docherty (Eds.), *Productive reflection at work* (pp. 11-26). London: Routledge.

Cseh, M., Watkins, K. E., & Marsick, J., Victoria. (2000). Informal and incidental learning in the workplace. In G. Straka (Ed.), *Conceptions of self-directed learning: theoretical and conceptional considerations* (pp. 59-74). Münster: Waxmann.

Csikszentmihalyi, M. (1999). Implications of a systems perspective for the study of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 313-335). Cambridge: Cambridge University Press.

Deutsches Netzwerk für Qualitätsentwicklung in der Pflege. (2007). *Expertenstandards in der Pflege: Zur Entwicklung wissenschaftsbasierter Expertenstandards* [Expert standards for nursing: on the development of evidence based expert standards]. Retrieved October 30, 2007, from `http://www.dnqp.de/Qualimeth.htm`.

Diekmann, A. (2007). *Empirische Sozialforschung. Grundlagen, Methoden, Anwendungen* [Empirical social science. Foundations, methods, applications]. Reinbeck: Rowohlt.

Dovey, S. M., & Phillips, R. L. (2004). What should we report to medical error reporting systems? *Quality and Safety in Health Care*, *13*, 322 - 323.

Dörner, D. (2004). Emotion und Wissen [Emotion and knowledge]. In G. Reinmann & H. Mandl (Eds.), *Psychologie des Wissensmanagements* (pp. 117-132). Göttingen: Hogrefe.

Duffy, T. M., Lowyck, J., & Jonassen, D. H. (Eds.). (1993). *Constructivism and the design of learning environments: context and authentic activities for learning.* Berlin: Springer.

Edmondson, A. C. (1996). Learning from mistakes is easier said than done: group and organisational influences on the detection and correction of human error. *Journal of Applied Behavioral Science*, *32*, 5-28.

Edmondson, A. C. (1999). Psychological safety and working behaviour in work teams. *Administrative Science Quarterly*, *44*, 350-383.

Edmondson, A. C. (2004). Learning from errors in health care: frequent opportunities, pervasive barriers. *Quality and Safety in Health Care*, *13*, 3-9.

Eid, M., Lischetzke, T., & Nussbeck, F. W. (2006). Structural equation models for multitrait-multimethod data. In M. Eid & E. Diener (Eds.), *Handbook of psycho-*

logical measurement: A multimethod perspective (pp. 283-299). Washington, DC: American Psychological Association.

Ellis, S., & Davidi, I. (2005). After-event reviews: drawing lessons from successful and failed experience. *Journal of Applied Psychology*, *90*, 857-871.

Ellström, P.-E. (2001). Integrating learning and work: problems and prospects. *Human Resource Development Quarterly*, *12*, 421-435.

Ellström, P.-E. (2006). The meaning and role of reflection in informal learning at work. In D. Boud, P. Cressey, & P. Docherty (Eds.), *Productive reflection at work* (pp. 43-53). London: Routledge.

Eraut, M. (1994). *Developing professional knowledge and competence*. London: Routledge-Falmer.

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, *70*, 113-136.

Eraut, M., Alderton, J., Cole, G., & Senker, P. (1998). *Development of knowledge and skills in employment* (Research Report No. 5). Sussex: University of Sussex, Institute of Education.

Eraut, M., Alderton, J., Cole, G., & Senker, P. (2002). Learning from other people at work. In R. Harrison, F. Reeve, A. Hanson, & J. Clarke (Eds.), *Supporting Lifelong Learning, Vol 1, Perspectives on Learning* (pp. 90-108). London: Routledge/Falmer.

Ericsson, K. A. (2006a). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 683-703). Cambridge: Cambridge University Press.

Ericsson, K. A. (2006b). Protocol analysis and expert thought: concurrent verbalization of thinking during experts' performance on representative tasks. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 223-241). Cambridge: Cambridge University Press.

Ericsson, K. A. (2006c). *Reproducibly superior professional performance in a changing world: How it is maintained and improved by deliberate practice.* Presentation at the EARLI SIG Professional Learning and Development Conference, Heerlen (The Netherlands).

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: evidence of maximal adaptation to task constraints. *Annual Review of Psychology*, *47*, 273-305.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis. Verbal reports as data.* Cambridge, MA: MIT Press.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, J., Erin. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, *4*, 272-299.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191.

Feldman, S. E., & Roblin, D. W. (2000). Accident investigation and anticipatory failure

analysis in hospitals. In P. Spath (Ed.), *Error reduction in health care. A systems approach to improving patient safety* (pp. 139-154). San Francisco, CA: Jossey Bass.

Felstead, A., Fuller, A., Unwin, L., Ashton, D., Butler, P., & Lee, T. (2005). Surveying the scene: learning metaphors, survey design and the workplace context. *Journal of Education and Work*, *18*, 359-383.

Fenwick, T. (2003). *Learning through experience.* Malabar, FL: Krieger.

Fivars, G., & Fitzpatrick, R. (2001). *The critical incident technique bibliography.* APA Online PsychINFO.

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin*, *51*, 327-358.

Forgas, J. P. (1995). Mood and judgment: the affect infusion model (AIM). *Psychological Bulletin*, *117*, 39–66.

Frese, M., & Zapf, D. (1994). Action as the core of work psychology: a German approach. In H. C. Triandis, M. D. Dunette, & L. M. Hough (Eds.), *Handbook of industrial and organizational psychology* (2 ed., Vol. 4, pp. 271-340). Palo Alto, CA: Consulting Psychologists Press.

Gerbing, D. W., & Hamilton, J. G. (1996). Viability of exploratory factor analysis as a precursor to confirmatory factor analysis. *Structural Equation Modeling*, *3*, 62-72.

Glazinski, R., & Wiedensohler, R. (2004). *Patientensicherheit und Fehlerkultur im Gesundheitswesen* [Patient safety and error culture in health care]. Eschborn: Brainwave.

Glendon, I., Clarke, S. G., & McKenna, E. F. (2006). *Human safety and risk management.* Boca Raton, FL: Taylor and Francis.

Greif, S. (1996). Lernen aus Fehlern [Learning from errors]. In S. Greif & H.-J. Kurtz (Eds.), *Handbuch selbstorganisiertes Lernen* (pp. 313-327). Göttingen: Hogrefe.

Gruber, H. (1999a). *Erfahrung als Grundlage kompetenten Handelns* [Experience as basis of competent action]. Bern: Huber.

Gruber, H. (1999b). Wissen [Knowledge]. In C. Perleth & A. Ziegler (Eds.), *Pädagogische Psychologie* (pp. 94-112). Bern: Huber.

Gruber, H., Harteis, C., Mulder, R. H., & Rehrl, M. (Eds.). (2005). *Bridging individual, organisational, and cultural aspects of professional learning.* Regensburg: Roderer.

Hacker, W. (1998). *Allgemeine Arbeitspsychologie. Psychische Regulation von Arbeitstätigkeiten* [Work psychology]. Bern: Huber.

Hacker, W. (1999). Regulation und Struktur von Arbeitstätigkeiten [Regulation and structure of work activities]. In C. G. Hoyos & D. Frey (Eds.), *Arbeits- und Organisationspsychologie* (pp. 385-397). Weinheim: Beltz.

Hager, P. (2004a). The conceptualization and measurement of learning at work. In H. Rainbird, A. Fuller, & A. Munro (Eds.), *Workplace learning in context* (pp. 242-258). London: Routledge.

Hager, P. (2004b). Lifelong learning in the workplace? Challenges and issues. *Journal of Workplace Learning*, *16*, 22-32.

Hakkarainen, K., Palonen, T., Paavola, S., & Lehtinen, E. (2004). *Communities of networked expertise: educational and professional perspectives.* Amsterdam: Elsevier.

Harteis, C., Bauer, J., & Haltia, P. (2007). Learning from errors at the workplace - insights from two studies in Germany and Finland. In H. Gruber & T. Palonen

(Eds.), *Learning at the workplace - new developments* (pp. 119-138). Turku: Finnish Educational Research Association.

Harteis, C., Bauer, J., & Heid, H. (2006). Der Umgang mit Fehlern als Merkmal betrieblicher Fehlerkultur und Voraussetzung für Professional Learning [Handling of errors as indicator for organisational error culture and condition for professional learning]. *Schweizerische Zeitschrift für Bildungswissenschaften*, *28*, 111-129.

Heckhausen, H. (1975). Fear of failure as a self-reinforcing motive system. In I. G. Sarason & C. D. Spielberger (Eds.), *Stress and anxiety* (Vol. 2, pp. 117-128). Washington, D.C.: Hemisphere.

Heckhausen, H., & Beckmann, J. (1990). Intentional action and action slips. *Psychological Review*, *97*, 36-48.

Heid, H. (1999). Autorität. Über die Verwandlung von Fehlern in Verfehlungen [Authority. On the transformation of misconducts into errors]. In W. Althof (Ed.), *Fehlerwelten. Vom Fehlermachen und Lernen aus Fehlern* (pp. 129-136). Opladen: Leske+Budrich.

Heid, H. (2005). Übertragung von Verantwortung [Delegation of responsibility]. In M. Eigenstetter & M. Hammerl (Eds.), *Wirtschafts- und Unternehmensethik - ein Widerspruch in sich?* (pp. 163-182). Kröningen: Asanger.

Heimbeck, D., Frese, M., Sonnentag, S., & Keith, N. (2003). Integrating errors in the training process: the function of error management instructions and the role of goal orientation. *Personnel Psychology*, *56*, 333-361.

Hershberger, S. L. (2006). The problem of equivalent structural models. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: a second course* (pp. 13-42). Greenwich, CT: Information Age Publishing.

Hoeve, A., Mittendorff, K., & Nieuwenhuis, L. F. M. (2003, July). *The interface between learning and innovation: Building a conceptual model.* Paper presented at the 3rd International Conference of Researching Work and Learning (RWL), Tampere (Finland).

Hoeve, A., & Nieuwenhuis, L. F. M. (2006). Learning routines in innovation processes. *Journal of Workplace Learning*, *18*, 171-185.

Hoffman, R. R., & Lintern, G. (2006). Eliciting and representing the knowledge of experts. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 203-222). Cambridge: Cambridge University Press.

Hofinger, G. (2002). Erfassung kritischer Zwischenfälle am Beispiel der Luftfahrt und Medizin [Analysis of critical incidents – examples from aviation and health care]. In R. Trimpop, B. Zimolong, & A. Kalveram (Eds.), *Psychologie der Arbeitssicherheit und Gesundheit* (pp. 143-148). Heidelberg: Asanger.

Holt, J. K. (2004, October). *Item parceling in structural equation models for optimum solutions.* Paper presented at the Annual Meeting of the Mid-Western Educational Research Association, Columbus, OH (USA).

Holzer, E., Thomeczek, C., Hauke, E., Cohnen, D., & Hochreutener, A.-A. (Eds.). (2005). *Patientensicherheit. Leitfaden für den Umgang mit Risiken im Gesundheitswesen* [Patient safety. Guidelines for handling risks in health care]. Wien: Facultas.

Honebein, P. C., Duffy, T. M., & Fishman, B. J. (1993). Constructivism and the design

of learning environments: context and authentic activities for learning. In T. M. Duff, J. Lowyck, & D. H. Jonassen (Eds.), *Designing environments for constructive learning* (pp. 87-108). Berlin: Springer.

Hox, J. J. (1998). Multilevel modeling: when and why? In I. Balderjahn, R. Mathar, & M. Schader (Eds.), *Classification, data analysis, and data highways* (pp. 147-154). New York: Springer.

Hoyle, R. H. (1995). The structural equation modeling approach: Basic concepts and fundamental issues. In R. H. Hoyle (Ed.), *Structural equation modeling. Concepts, issues, and applications* (pp. 1-15). Thousand Oaks: Sage.

Høyrup, S., & Elkjaer, B. (2006). Reflection: taking it beyond the individual. In D. Boud, P. Cressey, & P. Docherty (Eds.), *Productive reflection at work* (pp. 29-42). London: Routledge.

Jørgensen, C. H., & Warring, N. (2002). Learning in the workplace - the interplay between learning environments and biographical learning trajectories. In C. H. Jørgensen & N. Warring (Eds.), *Adult education and the labour market VII* (Vol. B, pp. 9-33). Roskilde: Roskilde University Press.

Jöreskog, K. G. (1993). Testing structural equation models. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 294-316). London: Sage.

Järvinen, A., & Poikela, E. (2001). Modeling reflective and contextual learning at work. *Journal of Workplace Learning*, *13*, 282-289.

Kaufmann, M., Staender, S., Below, G. von, Brunner, H. H., Portenier, L., & Scheidegger, D. (2002). Computerbasiertes anonymes Critical Incident Reporting: ein Beitrag zur Patientensicherheit [Computer based, anonymous Critical Incident Reporting: a contribution to patient safety]. *Schweizerische Ärztezeitung*, *83*, 2554-2558.

Keith, N., & Frese, M. (2005). Self-regulation in error management training: emotion control and metacognition as mediators of performance effects. *Journal of Applied Psychology*, *90*, 677-691.

Keith, N., & Frese, M. (2008). Effectiveness of error management training: a meta analysis. *Journal of Applied Psychology*, *93*, 59-69.

Kela, N., & Kela, P. (2006). Miteinander statt gegeneinander. Fehlermanagement in Krankenhäusern und Pflegeeinrichtungen [Together, not against each other. Error management in hospitals and care facilities]. *Pflegezeitschrift*, *59*, 54-57.

Kim, K. H., & Bentler, P. M. (2006). Data modeling: structural equation modeling. In J. L. Green, G. Camilli, & P. B. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 161-175). Mahwah, NJ: LEA.

Kleinbeck, U. (2006). Handlungsziele [Action goals]. In J. Heckhausen & H. Heckhausen (Eds.), *Motivation und Handeln* (pp. 255-276). Berlin: Springer.

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2 ed.). New York: Guilford.

Klockmann, D. (2005). Didaktische Modellierung und empirische Annäherung an das Lernen aus Fehlern [Learning from errors. Didactical model and empirical approach]. In P. Gonon, R. Huisinga, F. Klauser, & R. Nickolaus (Eds.), *Kompetenz, Kognition und neue Konzepte der beruflichen Bildung* (pp. 177-189). Wiesbaden: VS-Verlag.

Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (Eds.). (1999). *To err is human.*

Building a safer health system. Washington, DC: National Academy Press.

Kolb, D. A. (1984). *Experiential Learning.* Englewood Cliffs, NJ: Prentice Hall.

Kolodner, J. (1983). Towards an understanding of the role of experience in the evolution from novice to expert. *International Journal of Man-Machine Studies*, *19*, 497-518.

Kolodner, J. (1993). *Case-based reasoning.* San Mateo, CA: Morgan Kaufman Publishers.

Kolodner, J. (1997). Educational implications of analogy. *American Psychologist*, *52*, 57-66.

Kolodner, J., & Simpson, R. L. (1986). Problem solving and dynamic memory. In J. L. K. Riesbeck & C. K. Riesbeck (Eds.), *Experience, memory, and reasoning* (pp. 99-114). Hillsdale, NJ: LEA.

Korsten, V. A. (2003). *The development of an management error orientation questionnaire.* Unpublished doctoral dissertation, Rand Afrikaans University, Johannesburg, South Africa.

Kramer, R. M. (1999). Trust and distrust in organizations: emerging perspectives, enduring questions. *Annual Review of Psychology*, *50*, 569-598.

Kramer, R. M. (2006). Organizational trust: progress and promise in theory and research. In R. M. Kramer (Ed.), *Organizational trust: a reader* (pp. 1-17). Oxford: Oxford University Press.

Kriegesmann, B., Kley, T., & Schwering, M. G. (2005). Creative errors and heroic failures: capturing their innovative potential. *Journal of Business Strategy*, *26*, 57-64.

Kwakman, K. (2003). Factors affecting teachers' participation in professional learning activities. *Teaching and Teacher Education*, *19*, 149-170.

Lave, J. (1991). Situating learning in communities of practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 63-82). Washington, DC: APA.

Law, L.-C., & Wong, K.-M. P. (1996). Expertise und Instructional Design [Expertise and instructional design]. In H. Gruber & A. Ziegler (Eds.), *Expertiseforschung* (pp. 115-147). Opladen: Westdeutscher Verlag.

Lehtinen, E., Hakkarainen, K., & Palonen, T. (2004). Organisationales Lernen und Expertennetzwerke [Organisational learning and expert networks]. In H. Gruber, C. Harteis, H. Heid, & B. Meier (Eds.), *Kapital und Kompetenz. Veränderungen der Arbeitswelt und ihre Auswirkungen aus erziehungswissenschaftlicher Sicht* (pp. 199-224). Wiesbaden: VS-Verlag.

Leonard, L. M., & Tesser, A. (1996). Some ruminative thoughts. In R. S. Wyer (Ed.), *Ruminative thoughts* (pp. 1-47). Mahwah, NJ: LEA.

Leontiev, A. (1978). *Activity, consciousness, and personality.* Englewood Cliffs, CA: Prentice-Hall.

Levine, J. M., & Moreland, R. L. (1999). Knowledge transmission in work groups: Helping newcomers to succeed. In L. L. Thompson, J. M. Levine, & D. M. Messick (Eds.), *Shared cognition in organisations* (pp. 267-296). Mahwah, NJ: LEA.

Little, T. D., Cunningham, W. A., Shahar, G., & Widaman, K. F. (2002). To parcel or not to parcel: exploring the question, weighting the merits. *Structural Equation Modeling*, *9*, 151-173.

MacCallum, R. C. (1995). Model specification. Procedures, strategies, and related issues. In

R. H. Hoyle (Ed.), *Structural equation modeling. Concepts, issues, and applications* (pp. 16-36). Thousand Oaks: Sage.

MacCallum, R. C., Roznowski, M., & Necowitz, L. B. (1992). Model modifications in covariance structure analysis: The problem of capitalization on chance. *Psychological Bulletin*, *111*, 490-504.

Mayer, R. C., Davis, J., & Schoorman, F. D.(1995). An integrative model of organizational trust. *Academy of Management Review*, *20*, 709-734.

Mehl, K. (1993). *Über einen funktionalen Aspekt von Handlungsfehlern. Was lernt man wie aus Fehlern?* [On a functional aspect of action slips. What can be learned how from errors?]. Münster: Lit.

Mehl, K., & Wehner, T. (in press). Über die Schwierigkeiten, aus Fehlern zu lernen [On the difficulties of learning from errors]. *Erwägen, Wissen, Ethik.*

Meurier, C. E. (2000). Understanding the nature of errors in nursing: using a model to analyse critical incident reports of errors which had resulted in an adverse or potentially adverse event. *Journal of Advanced Nursing*, *32*, 202-207.

Meurier, C. E., Vincent, C. A., & Parmar, D. G. (1997). Learning from errors in nursing practice. *Journal of Advanced Nursing*, *26*, 111-119.

Meyer, L., Seidel, T., & Prenzel, M. (2006). Wenn Lernsituationen zu Leistungssituationen werden: Untersuchungen zur Fehlerkultur in einer Videostudie [When learning situations become achievement situations: investigation of error culture in a video study]. *Schweizerische Zeitschrift für Bildungswissenschaften*, *28*, 21-41.

Mezirow, J.(1990). How critical reflection triggers transformative learning. In J. Mezirow (Ed.), *Fostering critical reflection in adulthood* (pp. 1-20). San Francisco, CA: Jossey Bass.

Miller, G. A., Galanter, E., & Pribram, K. H.(1960). *Plans and the structure of behavior.* New York: Holt, Rinehart and Winston.

Moon, J.(2004). *Reflection in learning and professional development.* London: Routledge-Falmer.

Moreland, R. L.(1999). Transactive memory: Learning who knows what in work groups and organizations. In L. L. Thompson, J. M. Levine, & D. M. Messick (Eds.), *Shared cognition in organisations* (pp. 3-31). Mahwah, NJ: LEA.

Norman, D. A.(1981). Categorization of action slips. *Psychological Review*, *88*, 1-15.

O'Connor, B. P.(2000). Using parallel analysis and Velicner's MAP test. *Behavior Research Methods, Instruments, & Computers*, *32*, 396-402.

O'Hare, D., & Wiggins, M. (2004). Remembrance of cases past: who remembers what, when confronting critical flight events? *Human Factors*, *46*, 277-287.

Ohlsson, S.(1996). Learning from performance errors. *Psychological Review*, *103*, 241-262.

Oser, F., & Spychiger, M.(2005). *Lernen ist schmerzhaft* [Learning is painful]. Weinheim: Basel.

Palonen, T. (2003). *Shared knowledge and the web of relationships.* Turku: Univeristy of Turku.

Palonen, T., Hakkarainen, K., Talvitie, J., & Lehtinen, E.(2004). Network ties, cognitive centrality, and team interaction within a telecommunication company. In H. P. A.

Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: gaps and transitions on the way from novice to expert* (pp. 271-294). Dordrecht: Kluwer.

Pekrun, R., & Frese, M.(1992). Emotions in work and achievement. In C. L. Cooper & I. T. Robertson (Eds.), *International review of industrial and organizational psychology* (Vol. 7, pp. 153-200). Chichester, NY: Wiley.

Perrow, C.(1984). *Normal accidents: living with high risk technologies.* Princeton: Princeton University Press.

Peters, T. J., & Peters, T. (1987). *Thriving on Chaos: Handbook for a Management Revolution.* New York: Alfred Knopf.

Popper, K. R.(1968). *The logic of scientific discovery.* London: Hutchinson.

Popper, K. R. (1992). *In search of a better world: lectures and essays from thirty years.* New York: Routledge.

Porst, R. (1998). *Im Vorfeld der Befragung: Planung, Fragebogenentwicklung, Pretesting* [Before survey: design, construction of questionnaires, pretesting] (ZUMA-Arbeitsbericht No. 98/02). Mannheim: Zentrum für Umfragen, Methoden und Analysen.

Porst, R.(2001). *Wie man die Rücklaufquote bei postalischen Befragungen erhöht* [How to increase the return quote in postal survey] (ZUMA How-to-Reihe No. 9). Mannheim: Zentrum für Umfragen, Methoden und Analysen.

Putz, D., Schilling, J., Kluge, A., & Stangenberg, C.(in press). OLAF - Fragebogen zur Erfassung des organisationalen Klimas für Lernen aus Fehlern [OLAF - a questionnaire for measuring the organisational climate for learning from errors]. In W. Sarges, H. Wottawa, & C. Roos (Eds.), *Handbuch wirtschaftspsychologischer Testverfahren. Band 2: Organisationspsychologische Instrumente.* Langerich: Pabst.

Rasmussen, J.(1987a). Cognitive control and human error mechanisms. In J. Rasmussen, K. Duncan, & J. Leplat (Eds.), *New technology and human error* (pp. 53-60). Chichester: Wiley.

Rasmussen, J.(1987b). The definition of human error and a taxonomy for technical system design. In J. Rasmussen, K. Duncan, & J. Leplat (Eds.), *New technology and human error* (pp. 23-30). Chichester: Wiley.

Rasmussen, J.(1987c). Reasons, causes, and human error. In J. Rasmussen, K. Duncan, & J. Leplat (Eds.), *New technology and human error* (pp. 293-301). Chichester: Wiley.

Raykov, T., & Marcoulides, G. A.(2006). *A first course in structural equation modeling.* Mahwah, NJ: LEA.

Reason, J. T.(1990). *Human error.* Cambridge: Cambridge University Press.

Reason, J. T. (1995). Understanding adverse events: human factors. *Quality in Health Care*, *4*, 80-89.

Reason, J. T. (2005). Human error: models and management. *British Medical Journal*, *320*, 768-770.

Rehrl, M., Gruber, H., & Palonen, T. (2006, July). *Expertise development in science: Network analysis of EARLI SIG "Professional learning and development" activities.* Paper presented at the conference Expertise in Context, Berlin (Germany).

Robinson, S. L. (1996). Trust and breach of the psychological contract. *Administrative Science Quarterly*, *41*, 574-599.

Rogoff, B. (1984). Introduction: Thinking and learning in social context. In J. Lave & B. Rogoff (Eds.), *Everyday cognition in social context* (pp. 1-8). Cambridge, MA: Harvard University Press.

Rybowiak, V., Garst, H., Frese, M., & Batinic, B. (1999). Error orientation questionnaire (EOQ): reliability, validity, and different language equivalence. *Journal of Organizational Behavior*, *20*, 527-547.

Schafer, J. L., & Graham, J. W. (2002). Missing data: our view of the state of the art. *Psychological Methods*, *7*, 147-177.

Schank, R. C. (1999). *Dynamic memory revisited.* Cambridge: Cambridge University Press.

Schank, R. C., & Abelson, R. (1977). *Scripts, plans, goals, and understanding.* Hillsdale, NJ: Erlbaum.

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online*, *8*, 23-74.

Schiefele, U., & Schiefele, H. (1997). Motivationale Orientierung und Prozesse des Wissenserwerbs [Motivational orientation an processes of knowledge acquisition]. In H. Gruber & A. Renkl (Eds.), *Wege zum Können. Determinanten des Kompetenzerwerbs* (pp. 14-31). Bern: Huber.

Schön, D. (1983). *The reflective practitioner. How professionals think in action.* London: Temple Smith.

Schumacker, R. E., & Lomax, R. G. (2004). *A beginner's guide to structural equation modeling.* Mahwah, NJ: LEA.

Scriven, M. (1991). *Evaluation thesaurus.* London: Sage.

Senders, J. W., & Moray, N. P. (1991). *Human error. Cause, prediction, and reduction.* Hillsdale, NJ: LEA.

Senge, P. (1990). *The fifth discipline: the art and practice of the learning organization.* New York: Random House.

Simons, P. R.-J. (2005). Theories of unconscious learning confronted. *European Journal of School Psychology*, *3*, 41-55.

Simons, P. R.-J., & Ruijters, M. C. P. (2004). Learning professionals: Towards an integrated model. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: Gaps and transitions on the way from novice to expert* (pp. 207-229). Dordrecht: Kluwer.

Sitkin, S. B. (1992). Learning through failure: The strategy of small losses. *Research in Organizational Behavior*, *14*, 231-266.

Smith, P. J. (2003). Workplace learning and flexible delivery. *Review of Educational Research*, *73*, 53-88.

Spitzer, M. (2007). *Lernen* [Learning]. München: Elsevier.

Stangenberg, C. (2005). *Entwicklung eines Fragebogens zur Erhebung des organisationalen Klimas für Lernen aus Fehlern bei der Arbeit* [Development of a questionnaire for measuring the organisational climate for learning from errors at work]. Unpublished master's thesis, RWTH Aachen, Aachen.

Stark, R., Mandl, H., Gruber, H., & Renkl, A. (1998). Indeed, sometimes knowledge does not help: a replication study. *Instructional Science*, *26*, 391-407.

Sternberg, R. J., & Lubart, T. I. (1992). Buy low and sell high: an investment approach to creativity. *Current Directions in Psychological Science*, *1*, 1-5.

Stiensmeier-Pelster, J., & Heckhausen, H. (2006). Kausalattribution von Verhalten und Leistung [Causal attribution of behaviour and achievement]. In H. Heckhausen & J. Heckhausen (Eds.), *Motivation und Handeln* (pp. 355-392). Berlin: Springer.

Strasser, J., & Gruber, H. (2004). The role of experience in professional training and development of psychological counsellors. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: gaps and transitions on the way from novice to expert* (pp. 11-27). Dordrecht: Kluwer.

Strauch, B. (2002). *Investigating human error: incidents, accidents, and complex systems.* Aldershot: Ashgate.

Tabachnik, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston: Pearson.

Thompson, M. A., & Kahnweiler, W. M. (2002). An exploratory investigation of learning culture theory and employee participation in decision making. *Human Resource Development Quarterly*, *13*, 271-288.

Thorndike, E. L. (1913). *Educational psychology: The psychology of learning. Vol 2.* New York: Teachers College.

Tjosvold, D., Yu, Z.-Y., & Hui, C. (2004). Team learning from mistakes: The contribution of cooperative goals and problem solving. *Journal of Management Studies*, *41*, 1223-1245.

Tucker, A. L., & Edmondson, A. C. (2003). Why hospitals don't learn from failures: organizational and psychological dynamics that inhibit system change. *California Management Review*, *45*, 55-72.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381-403). New York: Academic Press.

Tulving, E. (1993). What is episodic memory? *Current Directions in Psychological Science*, *2*, 67-70.

Tulving, E. (2002). Episodic memory: from mind to brain. *Annual Review of Psychology*, *53*, 1-25.

Urban, D., & Mayerl, J. (2006). *Regressionsanalyse: Theorie, Technik und Anwendung* [Regression analysis: theory, techniques, and application]. Wiesbaden: VS-Verlag.

Uribe, C. L., Schweikhart, S. B., Pathak, D. S., & Marsh, G. B. (2002). Perceived barriers to medical-error reporting: An exploratory investigation. *Journal of Healthcare Management*, *47*, 264-279.

Valisner, J., & Van der Veer, R. (2000). *The social mind. Construction of the idea.* Cambridge: Cambridge University Press.

Van de Wiel, M. W. J., Szegedi, K. H. P., & Weggeman, M. C. D. P. (2004). Professional learning: Deliberate attempts at developing expertise. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: Gaps and transitions on the way from novice to expert* (pp. 181-206). Dordrecht: Kluwer.

Van den Bossche, P. (2006). *Minds in Teams. The influence of social and cognitive factors on team learning.* Maastricht: Datawyse.

Van Dyck, C., Frese, M., Baer, M., & Sonnentag, S. (2005). Organizational error management culture and its impact on performance: a two-study replication. *Journal of Applied Psychology, 90*, 1228-1240.

Van Lehn, K. (1988). Towards a theory of impasse-driven learning. In H. Mandl & A. Lesgold (Eds.), *Learning issues for intelligent tutoring systems* (pp. 19-41). New York: Springer.

Van Woerkom, M. (2003). *Critical reflection at work. Bridging individual and organisational learning.* Twente: Twente University Press.

Volpert, W. (1987). Psychische Regulation von Arbeitstätigkeiten [Psychological regulation of work activities]. In U. Kleinbeck & J. Rutenfranz (Eds.), *Enzyklopädie der Psychologie, Themenbereich D, Serie III, Band 1, Arbeitspsychologie* (pp. 1-42). Göttingen: Hogrefe.

Volpert, W. (1992). *Wie wir handeln - was wir können* [How we act - what we can do]. Heidelberg: Asanger.

Wehner, T. (Ed.). (1992). *Sicherheit als Fehlerfreundlichkeit* [Safety as error friendliness]. Opladen: Westdeutscher Verlag.

Wehner, T., & Mehl, K. (2001). Handlungsfehlerforschung und kein Ende [Research on action errors: not an end]. In H. Reuter, P. Schwab, D. Kleiber, & G. Gniech (Eds.), *Wahrnehmen und Erkennen- Festschrift zum 60. Geburtstag von Michael A. Stadler* (pp. 264-274). Lengerich: Pabst.

Wehner, T., & Mehl, K. (2003). Über die Vitalität fehlerhaften Handelns und den vermeintlichen Gegensatz zur Unfall- und Sicherheitsforschung [On the vitality of erroneous actions and the seeming contradiction to accident and safety research]. In B. Boothe & W. Marx (Eds.), *Panne, Irrtum, Missgeschick. Die Psychopathologie des Alltagslebens aus interdisziplinärer Perspektive.* (pp. 107-126). Bern: Huber.

Wehner, T., & Stadler, S. (1989). Fehler und Fehlhandlungen [Errors and action slips]. In S. Greif, H. Holling, & N. Nicholson (Eds.), *Arbeits- und Organisationspsychologie. Handbuch in Schlüsselbegriffen.* München: PVU.

Wehner, T., & Stadler, S. (1996). Gestaltpsychologische Beiträge zur Struktur und Dynamikfehlerhafter Handlungsabläufe [Gestalt-psychological contributions on the structur and dynamics of erroneous actions]. In J. Kuhl & H. Heckhausen (Eds.), *Enzyklopädie der Psychologie, Themenbereich C, Serie IV, Band 4, Motivation, Volition und Handlung* (pp. 795-815). Göttingen: Hogrefe.

Weiner, B., Frieze, I. H., Kukla, A., Reed, L., Rest, S., & Rosenbaum, R. M. (1971). *Perceiving the causes of success and failure.* New York: General Learning.

Weinert, A. B. (2004). *Organisations- und Personalpsychologie* [Organisational and personnel psychology]. Weinheim: Beltz PVU.

Weinert, F. E. (1999). Aus Fehlern lernen und Fehler vermeiden lernen [Learning from errors and learning to avoid errors]. In W. Althof (Ed.), *Fehlerwelten. Vom Fehlermachen und Lernen aus Fehlern* (pp. 101-109). Opladen: Leske + Budrich.

Weingardt, M. (2004). *Fehler zeichnen uns aus* [Errors characterise us]. Bad Heilbrunn: Klinkhardt.

Wenger, E.(1998). *Communities of practice. Learning, meaning, and identity.* Cambridge: Cambridge University Press.

West, S. G., Finch, J. F., & Curran, P. J.(1995). Structural equation models with nonnormal variables. In R. H. Hoyle (Ed.), *Structural equation modeling. Concepts, issues, and applications* (pp. 56-75). Thousand Oaks: Sage.

Westermann, R.(2002). Merkmale und Varianten von Evaluation: Überblick und Klassifikation [Characteristics and types of evaluation studies: a review and classification]. *Zeitschrift für Psychologie*, *210*, 4-26.

Wu, A. D., & Zumbo, B. D.(in press). Understanding and using mediators and moderators. *Social Indicators Research.*

Zapf, D. (1991). Fehler, Stress und organisationaler Kontext [Errors, stress, and the organisational context]. In M. Frese & D. Zapf (Eds.), *Fehler bei der Arbeit mit dem Computer* (pp. 106-117). Bern: Huber.

Zapf, D., Frese, M., & Brodbeck, F. C.(1999). Fehler und Fehlermanagement [Errors and error management]. In C. G. Hoyos & D. Frey (Eds.), *Organisationspsychologie* (pp. 398-411). Weinheim: Beltz PVU.

Zapf, D., Lang, T., & Wittmann, A.(1991). Der Fehlerbewältigungsprozess [Error recovery processes]. In M. Frese & D. Zapf (Eds.), *Fehler bei der Arbeit mit dem Computer* (pp. 60-79). Bern: Huber.

Zhao, B., & Olivera, F.(2006). Error reporting in organizations. *Academy of Management Review*, *31*, 1012-1030.

Zimolong, B. (1990). Fehler und Zuverlässigkeit [Errors and reliability]. In B. Zimolong & C. G. Hoyos (Eds.), *Enzyklopädie der Psychologie, Themenbereich D, Serie III, Band 2, Ingenieurspsychologie* (pp. 313-345). Göttingen: Hogrefe.

A. Appendices

A.1. Appendices for Study 1

Original German vignettes of the error cases

Beispiel 1: Falsche Interpretation von Messwerten. Bei der Krankenbeobachtung einer jungen, künstlich beatmeten Patientin lesen Sie den Messwert für die Sauerstoffkonzentration im Blut von einem Monitor ab. Dabei stellen Sie fest, dass der Wert bei nur gut 70 liegt! Sie fassen dies als kritische Situation auf und stellen als erstes die Sauerstoffkonzentration am Beatmungsgerät höher. Außerdem rufen Sie eine Kollegin zur Unterstützung, um weitere Maßnahmen einzuleiten. Als die Kollegin da ist, stellt sich heraus, dass der Sensor am Finger der Patientin so platziert ist, dass die Messung nicht zuverlässig war. Das Einleiten einer Notfallprozedur war also nicht angebracht ...

Beispiel 2: Falsche Einschätzung von Komplikationen. Sie werden während einer Nachtschicht von einem Patienten gerufen, der nach einem Sturz wegen einer Verletzung am Knie operiert wurde. Er klagt über Schmerzen im Bein und dass er deshalb nicht schlafen könne. Da momentan kein Arzt erreichbar ist, müssen Sie selbst entscheiden. Sie geben dem Mann ein Schmerzmittel und dokumentieren die Verabreichung. Als kurz darauf eine Ärztin ihre Runde macht, bitten Sie sie, sich den Patienten anzusehen. Sie stellt fest, dass der Patient eine Thrombose im Bein hat und leitet sofort entsprechende Maßnahmen ein ...

Beispiel 3: Falsche Einschätzung des Dekubitus-Risikos. Sie sind dabei, das Dekubitus-Risiko einer älteren, bettlägerigen Patientin einzuschätzen. Anhand der Braden-Skala schätzen Sie das Dekubitus-Risiko mit 18 Punkten als mittelmäßig ein. Ihnen persönlich erscheint die Haut der Patientin aber in Ordnung zu sein. Sie leiten deshalb keine zusätzlichen Prophylaxe- oder Behandlungsmaßnahmen ein. Bei der nächsten Beurteilung derselben Patientin kurze Zeit später stellt sich heraus, dass die Patientin bereits leichte Symptome von Dekubitus zeigt. Ein erhöhtes Risiko wäre - nach der Einschätzung zum jetzigen Zeitpunkt - auch schon bei der vorherigen Beurteilung erkennbar gewesen ...

A.2. Appendices for Study 2

Table 11: Items used in Study 2

Constructs and scales	*Items*
Error orientation	
Estimation of errors as chance for learning	
	Fehler sind für mich sehr hilfreich, um meine Arbeit zu verbessern.
	Wenn mir ein Fehler passiert, ist dies eine wichtige Information für die Durchführung meiner Arbeit.
	Meine Fehler zeigen mir, was ich besser machen kann.
	Aus eigenen Fehlern habe ich schon viel für die Bewältigung meiner Aufgabe gelernt.
Error strain	
	Ich empfinde es als belastend, einen Fehler zu machen.
	Ich habe öfter Angst davor, Fehler zu machen.
	Wenn mir ein Fehler passiert ist, schäme ich mich dafür.
	Wenn ich bei meiner Arbeit einen Fehler mache, dann verliere ich den kühlen Kopf und ärgere mich.
	Ich mache mir während meiner Arbeit öfter Sorgen, etwas falsch zu machen.
Covering up errors	
	Warum einen Fehler erwähnen, wenn er nicht auffällt.
	Es hat nur Nachteile, wenn man in der Arbeit seine Fehler preisgibt.
	Für mich ist es von geringem Nutzen, wenn ich über meine Fehler rede.
	Es hat Vorteile, Fehler zu vertuschen.
	Ich behalte meine Fehler lieber für mich.
	Arbeitende, die ihre Fehler zugeben, machen damit einen großen Fehler.
Safe team climate	
Trust	
	Die Leute in meiner Arbeitsgruppe sind in der Lage, Probleme und kritische Fragen anzusprechen.
	Ich habe den Eindruck, mich in dem was ich Mitgliedern meiner Arbeitsgruppe gegenüber äußere, vorsichtig verhalten zu müssen.^{r}
	Bei seiner Arbeit auf dieser Station besteht unter den Kollegen/innen ein vertrauensvolles Verhältnis.
	Bei seiner Arbeit auf dieser Station geht man unter den Kollegen/innen fair miteinander um.
	Bei seiner Arbeit auf dieser Station hält man unter den Kollegen/innen zusammen.
	Die Leute, mit denen ich zusammenarbeite mögen mich nicht besonders.^{r}
	Bei seiner Arbeit auf dieser Station bestehen unter den Kollegen/innen Konflikte und Spannungen.^{r}
	Bei seiner Arbeit auf dieser Station besteht unter den Kollegen/innen gegenseitige Achtung und Anerkennung.
	Es ist schwierig, Mitglieder meiner Arbeitsgruppe um Hilfe zu bitten.^{r}
	Wenn jemand in meiner Arbeitsgruppe einen Fehler gemacht hat, kann er die anderen um Rat fragen, wie es weitergehen soll.

(*Table continues*)

(*Table 11 continued*)

Constructs and scales	*Items*
Non-punitive orientation	
	Wenn jemand aus meiner Arbeitsgruppe einen Fehler macht, wird das häufig gegen diese Person verwendet.^{r}
	Wenn in meiner Arbeitsgruppe ein Fehler passiert, ist die Frage, wer Schuld hat mindestens genauso wichtig, wie die Situation schnell zu bereinigen.^{r}
	Wer in meiner Arbeitsgruppe einen Fehler zugibt, bekommt ganz schön Ärger.^{r}
	Die Leute in meiner Arbeitsgruppe haben Angst davor, Fehler zu machen.^{r}
	Normalerweise schämen sich Mitgliedern meiner Arbeitsgruppe sehr, wenn sie einen Fehler gemacht haben.^{r}
	Die Leute in meiner Arbeitsgruppe sind ziemlich froh, wenn ein Fehler nicht ihnen selbst, sondern jemand anderem passiert ist.^{r}
	Die Leute in meiner Arbeitsgruppe denken, dass uns unsere Fehler zeigen, was wir besser machen können.
Engagement in social learning activities	
Joint cause analysis	
	Mich mit Kollegen/innen darüber austauschen ...
	... was zu der Fehlentscheidung geführt hat.
	... wie ich selbst zum Auftreten der Fehlentscheidung beigetragen habe.
	... ob meine Kompetenz lückenhaft ist.
	... ob etwas in der Zusammenarbeit in der Arbeitsgruppe zur Entstehung des Fehlers beigetragen hat.
	... ob mit der Kommunikation mit dem Patienten/der Patientin etwas nicht gestimmt hat.
	... wie das Arbeitsumfeld zur Entstehung des Fehlers beigetragen hat.
	... welche Rolle Zeitdruck gespielt hat
	... welche Rolle meine Arbeitsbelastung gespielt hat.
	Den Fall bei einer Team-Besprechung ansprechen, um die Ursachen herauszufinden.
Joint strategy development	
	Erfahrene Personen auf meiner Station fragen, wie sie an meiner Stelle gehandelt hätten.
	Andere auf meiner Station um Rat fragen, wie ich es in Zukunft besser machen kann.
	In einer Team-Besprechung Überlegungen anstoßen, was in Zukunft eine gute Strategie wäre, um solche Fehlentscheidungen zu vermeiden.
	Mit Personen aus der Arbeitsgruppe Vor- und Nachteile von verschiedenen Handlungsalternativen diskutieren.
	Mit meinem Vorgesetzten neue Richtlinien besprechen.
	Im Team Vereinbarungen über neue Vorgehensweisen und Richtlinien treffen.
	Personen aus meinem Team bitten, mich in ähnlichen Situationen zu kontrollieren.

Note. r = reverse scored.

A.3. Appendices for Study 3

Table 12: Items used in Study 3

Constructs and scales	*Items*	*Parcel*
Error orientation		
Estimation of errors as chance for learning		
	Dieser Fehler ist für mich sehr hilfreich, um meine Arbeit zu verbessern.	CL1
	Dieser Fehler liefert mir eine wichtige Information für die Durchführung meiner Arbeit.	CL2
	Dieser Fehler zeigt mir, was ich besser machen kann.	CL2
	Aus dieser Situation kann ich viel für die Bewältigung meiner Aufgaben lernen.	CL1
Error strain		
	Ich empfinde es als belastend, einen solchen Fehler zu machen.	ES1
	Es macht mir Angst, einen solchen Fehler zu machen.	ES1
	Ich schäme mich dafür, dass mir dieser Fehler passiert ist.	ES2
	Ich ärgere mich sehr.	ES1
	Ich mache mir während meiner Arbeit Sorgen, nochmals etwas falsch zu machen.	ES2
Covering up the error		
	Warum sollte ich diesen Fehler gegenüber anderen erwähnen, wenn er nicht weiter auffällt.	CE2
	Ich habe nur Nachteile davon, wenn ich mit meinen Kollegen/innen über diesen Fehler spreche.	CE1
	Für mich ist es von geringem Nutzen, wenn ich mit meinen Kolleg/innen über den Fehler rede.	CE2
	Es hat Vorteile, solche Fehler zu vertuschen.	CE1
	Ich behalte diesen Fehler lieber für mich.	CE2
Safe team climate		
Trust		
	Bei der Arbeit auf dieser Station besteht unter den Kollegen/innen ein vertrauensvolles Verhältnis.	TR
	Bei der Arbeit auf dieser Station geht man unter den Kollegen/innen fair miteinander um.	TR
	Bei der Arbeit auf dieser Station besteht unter den Kollegen/innen gegenseitige Achtung und Anerkennung.	TR
	Bei der Arbeit auf dieser Station hält man unter den Kollegen/innen zusammen.	TR
	Wenn jemand in meiner Arbeitsgruppe einen Fehler gemacht hat, kann er die anderen um Rat fragen, wie es weitergehen soll.	TR
Non-punitive orientation		
	Wenn jemand auf meiner Station einen Fehler macht, wird das häufig gegen diese Person verwendet. ^{r}	NPO
	Die Kollegen/innen auf meiner Station freuen sich, wenn ein Fehler nicht ihnen selbst, sondern jemand anderem passiert ist. ^{r}	NPO
	Wer auf meiner Station einen Fehler zugibt, bekommt ganz schön Ärger. ^{r}	NPO

(*Table continues*)

(*Table 12 continued*)

Constructs and scales	*Items*	*Parcel*
	Die Kollegen/innen auf meiner Station denken, dass uns Fehler zeigen, was wir besser machen können.	NPO
	Wer auf meiner Station einen Fehler macht, muss mit Disziplinarmaßnahmen rechnen. [r]	NPO
	Ich habe den Eindruck, dass ich vorsichtig sein muss, was ich Kollegen/innen gegenüber äußere. [r]	NPO
	Bei der Arbeit auf dieser Station bestehen unter den Kollegen/innen Konflikte und Spannungen. [r]	NPO
Engagement in social learning activities		
Joint cause analysis (general)		
	Mich mit Kollegen/innen darüber austauschen, ...	
	... warum ich diese Fehlentscheidung getroffen habe.	GCA1
	... was zu der Fehlentscheidung geführt hat.	GCA2
	... wie ich selbst zum Auftreten der Fehlentscheidung beigetragen habe.	x
Joint cause analysis (specific)		
	... ob meine Kompetenz lückenhaft ist.	SCA1
	... ob etwas in der Zusammenarbeit in der Arbeitsgruppe zur Entstehung des Fehlers beigetragen hat.	SCA2
	... ob die Kommunikation mit dem Patienten/der Patientin nicht gestimmt hat.	SCA3
	... wie das Arbeitsumfeld zur Entstehung des Fehlers beigetragen hat.	x
	Den Fall bei einer Team-Besprechung ansprechen, um die Ursachen herauszufinden.	x
Joint strategy development		
	Anderen im Team von dem Vorfall erzählen, damit ihnen nicht der gleiche Fehler passiert.	DS1
	Erfahrene Personen auf meiner Station fragen, wie sie an meiner Stelle gehandelt hätten.	DS1
	Andere auf der Station um Rat fragen, wie ich es in Zukunft besser machen kann.	DS2
	In einer Team-Besprechung Überlegungen anstoßen, was in Zukunft eine gute Strategie wäre, um solche Fehlentscheidungen zu vermeiden.	DS2
	Mit meinem Vorgesetzten neue Richtlinien besprechen.	DS2
	Im Team Vereinbarungen über neue Vorgehensweisen und Richtlinien treffen.	DS1
	Personen aus meinem Team bitten, mich in ähnlichen Situationen zu kontrollieren.	x

Note. Parcel = parcel to which an item was grouped; r = reverse scored; x = sorted out; CL = chance for learning; ES = error strain; CE = covering errors; NPO = non-punitive orientation; TR = trust; GCA = general cause analysis; SCA = specific cause analysis; DS = development of new strategies.

Table 13: Correlation matrix and descriptive statistics for the indicator variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 GCA1	—														
2 GCA2	.77	—													
3 SCA1	.22	.25	—												
4 SCA2	.20	.21	.54	—											
5 SCA3	.08	.08	.31	.40	—										
6 SD1	.37	.33	.34	.42	.18	—									
7 SD2	.26	.25	.35	.42	.24	.83	—								
8 CL1	.10	.12	.27	.21	.11	.24	.23	—							
9 CL2	.12	.15	.28	.17	.08	.19	.16	.86	—						
10 ES1	.07	.07	.26	.14	.13	.13	.14	.44	.46	—					
11 ES2	.06	.05	.27	.12	.12	.11	.11	.45	.46	.93	—				
12 CE1	-.28	-.28	-.09	.04	-.02	-.09	-.06	.03	.02	.07	.08	—			
13 CE2	-.47	-.41	-.18	-.08	-.07	-.28	-.21	-.07	-.07	-.04	-.01	.70	—		
14 NPO	.16	.15	.10	-.05	.09	.11	.15	.02	-.02	-.07	-.11	-.35	-.40	—	
15 TR	.14	.12	.15	.01	.10	.23	.28	.18	.11	.01	-.01	-.17	-.26	.69	—
M	2.02	1.99	3.41	3.79	3.26	2.57	3.07	2.41	2.33	2.66	2.94	5.33	5.04	2.21	2.22
SD	0.98	0.90	1.39	1.45	1.53	0.99	1.21	1.20	1.17	1.35	1.46	0.80	0.95	0.94	0.89
Skewness	1.16	0.91	0.09	-0.14	0.37	0.47	0.36	1.01	0.93	0.64	0.36	-1.19	-0.96	0.96	0.89
Kurtosis	1.57	0.94	-0.82	-0.86	-0.83	-0.09	-0.40	0.74	0.48	-0.49	-0.83	1.36	0.89	0.61	0.49

Note. $N = 276$; correlations greater than .118 are significant at $p < .05$. GCA = general cause analysis; SCA = specific cause analysis; SD = strategy development; CL = chance for learning; ES = error strain; CE = covering errors; NPO = non-punitive orientation; TR = trust; M = mean; SD = standard deviation.

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