Fostering Diagnostic Competence in Different Domains

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Kurzzusammenfassung

Diagnosekompetenz zu fördern ist ein wichtiges Ziel in der medizinischen und in der Lehramtsausbildung. Bisher ist unklar ob instruktionale Unterstützung von einer Domäne in die andere übertragen werden kann. In empirischen Studien in zwei medizinischen Domänen (Medizin und Pflege) und in der Lehramtsausbildung wurde untersucht ob Scaffolding mit Selbsterklärungsprompts und mit adaptierbarem Feedback Diagnosekompetenz in einer computerbasierten Lernumgebung mit fehlerhaften Lösungsbeispielen fördern kann. Die Ergebnisse zeigen Unterschiede zwischen den Domänen: während Scaffolding mit Selbsterklärungsprompts nachteilige Effekte in der Pflege- und in der Lehramtsausbildung hatten, zeigte sich dieser Effekt nicht in der medizinischen Ausbildung. Die Ergebnisse der drei Studien geben Hinweise, dass Scaffolding mit Selbsterklärungsprompts nicht unter allen Bedingungen von Vorteil ist und im Kontext des Fehlerlernens sogar nachteilig sein kann, zumindest in Domänen in denen weniger wissenschaftliches Wissen verfügbar und dessen Gebrauch als Beleg für praktisches Handeln weniger üblich ist.

Abstract

It is an important goal in medical and in teacher education to foster diagnostic competences. It is not clear if effective instructional support can be transferred from one domain to another. In empirical studies in two medical domains (medicine and nursing) and in teaching it was investigated if scaffolding by self-explanation prompts and adaptable feedback can foster diagnostic competence in an computer based learning environment using erroneous worked examples. The results show differences between the domains: while the scaffolding with self-explanation prompts was detrimental for learning of diagnostic competence in teacher and nursing education, they had no such effects in medical education. The results of the three studies suggest that scaffolding self-explanation may not be an advantage under all circumstances and may in fact even hinder learning in the context of learning from errors, at least in domains where less scientific knowledge is available and it is less used as evidence for practice.

Deutsche Zusammenfassung

Ein wichtiges Ziel in der Medizinischen- und in der Lehramtsausbildung ist es Diagnosekompetenz zu fördern. Bisher ist unklar inwiefern die Effektivität von instruktionaler Unterstützung zur Förderung von Diagnosekompetenz von der jeweiligen Domäne abhängt.

Die vorliegende Arbeit beginnt mit einer domänenspezifischen Analyse von Diagnosekompetenz aus Sicht der Medizin, Pflege und des Lehramts. Dabei wird Diagnosekompetenz als Kategorisierungsaufgabe eingeführt und Forschung zu Diagnoseprozessen, der Entwicklung von Diagnosekompetenz und deren Förderung jeweils aus fachspezifischer Sicht analysiert. Anschließend wird die fachspezifische Forschung verglichen und Ähnlichkeiten der Diagnosesituationen in der Medizin und in der Lehre erläutert. Ein wichtiger Unterschied zwischen den Domänen wird vorgestellt: die Verfügbarkeit von wissenschaftlichen Wissen und wie dieses zur Lösung von praktischen Problemstellungen angewandt wird. Daran anschließend werden Möglichkeiten der Operationalisierung von Diagnosekompetenz erläutert. Ein Modell das bereits erfolgreich in der Medizin eingesetzt wurde, wird vorgestellt und dessen Übertragbarkeit in die Pflege und in die Lehre diskutiert. Es wird erläutert warum Transfer von Fähigkeiten die im Unterricht gelernt wurden auf reale Problemlösungen nicht automatisch entsteht. Wie Lernumgebungen gestaltet sein sollten um Transfer Unterricht zum Diagnostizieren auf reale Diagnosesituationen wahrscheinlicher zu machen wird anschließen erklärt. Um Diagnosekompetenz auch langfristig zu fördern sind Befunde aus der Expertise Forschung wichtig. Diese werden beschrieben und es wird erläutert, dass Erfahrung ohne absichtsvolles üben nicht zu Expertise führt.

In Kapitel drei werden Fördermöglichkeiten für Diagnosekompetenz analysiert. Dazu wird zunächst der Zusammenhang zwischen Diagnosekompetenz und Problemlösen aufgezeigt. Die Vorteile eines fallbasierten Ansatzes zur Förderung von

Diagnosekompetenz werden diskutiert und Lernen mit fehlerhaften Lösungsbeispielen als vielversprechende Variante vorgestellt. Anschließende werden instruktionale Unterstützungsmöglichkeiten mit Selbsterklärungsprompts und mit adaptierbarem Feedback erläutert. Dazu wird zuerst ein Rahmenmodell von Scaffolding vorgestellt und empirische Befunde zu Selbsterklärungsprompts beim Lernen mit Lösungsbeispielen beschrieben. Effekte von unterschiedlichen Arten von Prompts werden analysiert. Die Befunde zu Selbsterklärungsprompts im Kontext von fehlerhaften Lösungsbeispielen werden als uneindeutig beschrieben und adaptierbares Feedback als zusätzliche Unterstützungsmaßnahme eingeführt.

Abgeleitet aus den theoretischen Überlegungen werden die beiden Hauptfragestellungen der Arbeit vorgestellt: Fragestellung 1) Inwiefern können Selbsterklärungsprompts und adaptierbares Feedback den Erwerb von Diagnosekompetenz beim Lernen mit fehlerhaften Lösungsbeispielen fördern? Fragestellung 2) Inwiefern gibt es Unterschiede in den Effekten von Selbsterklärungsprompts und adaptierbares Feedback auf den Erwerb von Diagnosekompetenz beim Lernen mit fehlerhaften Lösungsbeispielen in der Medizin, Pflege und im Lehramt?

Um diese Fragen zu beantworten werden drei empirische Studien in drei verschiedenen Domänen vorgestellt (Medizin, Pflege, Lehramt). Bei den Studien handelt es sich um konzeptuelle Replikationen. In allen drei Studien bearbeiteten Lerner fehlerhafte Lösungsbeispiele in einer Online-Lernumgebung. Die Lernenden werden dabei aufgefordert, sich in einen Famulanten (Medizin), einen Pflegeschüler (Pflege) oder in einen Lehrer im Praktikum (Lehre) hineinzuversetzen, der während der Arbeit mit Patienten bzw. mit Schülern diagnostische Fehler macht. Die beiden Faktoren Selbsterklärungsprompt (mit vs. ohne) und adaptierbares Feedback (mit vs. ohne) wurden experimentell variiert. Die Teilnehmer der drei Studien wurden randomisiert einer der vier Untersuchungsbedingungen zugeordnet. In der Bedingung mit Selbsterklärungsprompt werden die Lernenden aufgefordert, die Fehler zu analysieren. Von einem fiktiven erfahrenen Arzt (Medizin), einer fiktiven erfahrenen Pflegeperson (Pflegeperson) bzw. einer erfahrenen Lehrkraft (Lehre) wird Feedback angeboten. In der Bedingung mit adaptierbarem Feedback können die Lernenden das Level des Feedbacks an ihren

Wissensbedarf anpassen. Diagnosekompetenz wurde mittels unterschiedlicher Tests (MC Test, Key Feature- und Knowledge-Decomposition Aufgaben) operationalisiert. In einer vierten Studie wurden die Daten der drei Studien in der Medizin, Pflege und in der Lehre standardisiert und der Einfluss der Domäne analysiert.

Die Ergebnisse zeigen ein unterschiedliches Befundmuster je nach Domäne. Während adaptierbares Feedback keinen Effekt auf Diagnosekompetenz in der Pflege und in der Lehre hat, hat es einen positive Effekt auf den Diagnosekompetenzerwerb in der Medizin. Entgegen der Annahmen die aus den theoretischen Überlegungen abgeleitet wurden, hatten Selbsterklärungsprompts negative Auswirkungen auf den Erwerb von diagnostischem Handlungswissen in der Pflege und in der Lehre. Effekte von Selbsterklärungsprompts waren abhängig von der Domäne.

Im Kontext von Lernern mit Fehlern haben Selbsterklärungsprompts weniger positive Auswirkungen als theoretisch impliziert. Bis weitere Studien über die Wirkungsweisen von Selbsterklärungsprompts genaueren Aufschluss geben, können Selbsterklärungsprompts im Kontext des Fehlerlernens nicht empfohlen werden. Adaptierbares Feedback kann nur in Domänen empfohlen werden in denen Lernende mit dem Gebrauch von wissenschaftlichem Wissen zur Diagnosestellung vertraut sind.

Insgesamt gibt diese Dissertation Hinweise darauf, dass die Effektivität von instruktionaler Unterstützung zur Förderung von Diagnosekompetenz von der Domäne anhängig ist.

Contents

1 Introduction: Fostering Diagnostic Competence

Diagnostic competence is important in various domains. Diagnostic competence is often described as one of the core competences (Artelt & Gräsel, 2009; Banning, 2008; Charlin, Tardif, & Boshuizen, 2000). Diagnostic competence involves the analysis of complex situations such as classroom situations or the diagnosis of a patient's illness or state. The units of diagnoses and the goals differ between domains. In medicine, the goal is to diagnose the illness of a patient (Charlin et al., 2000). In nursing, the goal is to diagnose the impact of health limitations (North American Nursing Diagnosis Association, 1990). In education, a diagnosis can be concerned with how well a specific pedagogical methods works in the classroom (Vogt & Rogalla, 2009). Diagnostic competence has differences and similarities between the domains. Whereas processes underlying the development of diagnostic competence are described in a similar way, the availability of evidence, and how that evidence is used in daily practice is different in medicine compared to nursing and teaching. In fact, nursing and teaching have more similarities to each other (e.g. in the availability of evidence) than do medicine and nursing, despite the latter two both being medical domains. The described differences between domains may cause differences in the instructional support necessary to foster the development of diagnostic competences.

1.1 Aim of this Thesis

The aim of this thesis is to enhance the understanding of how to foster diagnostic competence in the domains medicine, nursing, and in teaching. The transferability of instructional support methods from one domain to another is analyzed. An often not appropriately addressed question in educational research is to what extent findings from one domain can be transferred to another. Even though there is much research on diagnostic competence in medicine, nursing, and in teaching, it is often not related to each other and not related to findings from educational research. A wasted potential in not transferring findings from one domain to another is possible. Research conducted so far had varied instruction in studies in different domains, and thus different results between domains might be confounded with the other varied variables. Besides complexity of task structure in fact, research findings seem to neglect differences between domains mostly. With this thesis the discussion on transferability of instructional methods is expanded.

2 Diagnostic Competence

Diagnoses are judgments of different units of analysis with the goal of classification. To diagnose is a cognitive skill (VanLehn, 1996) with the purpose to act accordingly. Diagnoses are based on data and derive from a process that is methodological and reflective (Helmke, 2010). While diagnosing, the integration of scientific knowledge and individual experience in practical situations is necessary (Abs, 2007; Wisniewski & Medin, 1994). For building categories scientific knowledge of attributes and their relationships is crucial (Rehder & Hastie, 2001; Wisniewski & Medin, 1994). Categories are built on the basis of underlying principles; for example, in medicine it can be on the basis of biomedical mechanism. The understanding of this mechanism can lead to a more comprehensive mental representation of categories (Woods, 2007).

Diagnostic competence plays a major role in various domains. Diagnostic competence involves the analysis of complex situations, such as a classroom situation or the diagnosis of a patient. The units of diagnosis and the goals differ between domains. A) In medicine the unit of analysis is a patient and his or her health limitations. The goal here is to identify a health limitation (Schwartz & Elstein, 2008) or the reasons for a health limitation (Berner & Graber, 2008). B) In nursing the units of analysis are also patients, but the goal somewhat differs from the goal in medicine. In nursing the goal is to identify the impact of health limitations (Evers, 1997). Therefore the individual reaction to a heath limitation is the priority (North American Nursing Diagnosis Association, 1990). C) In education a diagnosis focus on persons involved, such as the learner, the teacher or on learning material. A diagnosis can also be concerned with how well instruction works in the classroom: in education, the goal of diagnosis is often adapting the teaching to the diverse needs of learners (Vogt & Rogalla, 2009).

In the following paragraphs, diagnostic competence in the domains of medicine, nursing, and education is analyzed in more detail. Then, the differences and communalities of diagnostic competence in these domains are discussed. A possible operationalization as a basis for facilitating diagnostic competence in medicine, nursing, and in teaching is introduced. Afterwards it is described why it is so difficult to transfer knowledge and skills learned in a classroom to the real world and what can be done to make transfer more likely. To get a better idea on fostering diagnostic competence in the long run it is explained how and under what conditions expertise develops.

2.1 Diagnostic Competence in Medicine, Nursing, and in Teaching

2.1.1 Diagnostic Competence in Medicine

First the importance of diagnostic competence is described. Medical diagnoses get defined as categorization task with a high relation to further actions. Processes involved and a common theory for the development of diagnostic competence, the encapsulation theory, is introduced. Thereafter a dual and an integrated processing model are explained. The high amount of diagnostic error and the resulting need for instructional support for the development of diagnostic competence is analyzed. Empirical evidence on how to support the acquisition of diagnostic competence is presented. Last the operationalization of diagnostic competence is discussed.

Diagnostic competence is an important competence and can be described as a core competence of medical practice (Charlin et al., 2000). For patient-centered care, it is a central competence for a physician to derive a correct diagnoses in an organized and effective process (Mamede et al., 2012). The risks and costs of further diagnostic tests are balanced with the risk of premature closure (McSherry, 1997): that is accepting a diagnosis before final verification. Also, for patient safety, diagnostic competence or clinical reasoning is essential[1] (Croskerry, 2009). This holds true for all medical disciplines (Croskerry & Nimmo, 2011).

The goal of medical diagnosis is finding the appropriate course of action (Charlin et al., 2000). The appropriate course of action can be further diagnosis or treatment (Charlin, Boshuizen, Custers, & Feltovich, 2007). The diagnostic process is thus closely related to further action (Charlin et al., 2012). Medical diagnosis is a categorization task (Charlin et al., 2000). In medicine, the categories are diseases (Buckingham & Adams, 2000a). Attributes of an individual patient are matched to different classes and this way illnesses are identified. Diagnostic competence is a highly complex process with multiple facets (Charlin et al., 2012). The diagnostic process consists of gathering relevant information of a patient and his or her context, the activation of relevant knowledge structures, the generation of hypotheses, and a subsequent deliberate collection of data to confirm or refuse hypotheses. If a hypothesis is refused a new hypothesis needs to be generated. If a hypothesis is confirmed, it becomes the basis for further treatment (Charlin et al., 2012). The underlying mechanism and the necessary knowledge for these processes are not yet completely clear (Charlin et al., 2000).

[1] Diagnostic competence and clinical reasoning is used synonymously in this thesis.

In the following, a common theory is introduced that can give an insight into the development of diagnostic competence. Patel, Evans, and Groen (1989) showed that doctors thinking aloud while solving clinical cases rarely mention biomedical mechanisms. Biomedical knowledge is basic science knowledge on pathological mechanisms or processes causing diseases (Kaufman, Yoskowitz, & Patel, 2008) and is a form of conceptual knowledge. It is possible that the absence of biomedical knowledge in the think-aloud protocols is a result of a lack of awareness of these biomedical mechanisms, even though they influence diagnostic decisions indirectly (Woods, 2007). Woods (2007) regards the absence of biomedical knowledge as the foundation of the encapsulation theory. Through repeated confrontation with clinical cases knowledge gets encapsulated (Mamede et al., 2012); encapsulation means that biomedical knowledge gets closely linked to clinical features. Clinical knowledge is knowledge about factors that increase the likelihood of a disease, such as patient characteristics or environmental factors. It also includes associated symptoms or symptom patterns, the typical course, and diagnostic and treatment methods (Van De Wiel, Boshuizen, & Schmidt, 2000). Knowledge of a disease's symptoms is closely related to patient characteristics and conditions under which a certain disease emerges (Charlin et al., 2007; H. G. Schmidt & Rikers, 2007). The concepts in which a disease's symptoms are linked to patient characteristics build the cognitive representation of a disease, a so-called illness script (Schmidt & Rikers, 2007). Illness scripts are mental networks that contain clinical knowledge, with biomedical knowledge encapsulated and therefore underlying. Biomedical knowledge in an encapsulated form is still important for a coherent picture of a disease (Woods, 2007). An illness script also consists of links between different illnesses as well as of cases of an illness the physician previously experienced with a patient (Schmidt & Rikers, 2007).

After a common theory for the development of diagnostic competence was introduced, now a processing model is described. The processing model can give further insight into processes involved in diagnostic competence. The processes involved in diagnostic competence might show starting points for fostering diagnostic competence. A dual processing model with (a) non-analytical processing and (b) analytical processing is assumed for diagnosing in medicine. More recent approaches assume (c) integrated processing continuing both (e.g. Croskerry & Nimmo, 2011).

(a) Non-analytical processing: Non-analytical processing is sometimes called system one processing (Kahneman, 2011). Early in the diagnostic process the physician may recognize cues in the individual patient case. This activates one or more illness scripts (Charlin et al., 2012). An illness scripts functions as the basis for a hypotheses about the patient's illness. A hypotheses can lead the purposeful search for information that either confirms or excludes the hypotheses (Eva, 2004). For this type of processing, biomedical knowledge is not as relevant as for analytical processing (Woods, 2007). However, biomedical knowledge (encapsulated in the illness scripts) is still involved in generating meaningful hypotheses (H. G. Schmidt, Norman, & Boshuizen, 1990; Woods, 2007). Well organized illness scripts can save cognitive resources such as working memory capacity (Rikers, Loyens, & Schmidt, 2004).

(b) Analytical processing: Analytical processing is sometimes called system two processing (Kahneman, 2011) or described as hypothetico-deductive model (Schwartz & Elstein, 2008). If no suitable script can be found, an analytical process starts. During this process biomedical concepts are activated and within these concepts reasons for symptoms are analyzed (Boshuizen & Schmidt, 1992). However, the analytical diagnostic mode can also be activated deliberately, e.g., if an initial diagnosis from non-analytical processing proves to be wrong (Croskerry & Nimmo, 2011). Therefore physicians use biomedical knowledge when no script is present or in unfamiliar or complex cases (Charlin et al., 2000). Experts tend to use non-analytical processing, whereas novices tend to use analytical processing (Mamede, Schmidt, & Penaforte, 2008).

(c) More recent theoretical approaches propose an integrated model in which both analytical and non-analytical processing are integrated in circular moves (Croskerry, 2009; Eva, 2004). Eva (2004) states that the two approaches interact with each other and are relevant at different moments in the diagnostic process. Whereas the non-analytical processing is important at the initial state of the diagnostic process for building hypotheses, analytical processing is more predominantly involved in testing hypotheses or in complex, unfamiliar cases (Eva, 2004). The analytical approach is used as strategy to reduce cognitive biases that often occur (Croskerry & Nimmo, 2011). Integrated processing may also prevent overgeneralized heuristics (Tversky & Kahneman, 1974).

The acquisition of diagnostic competence is a difficult process. An indicator for this can the found in the high amount of diagnostic errors that are estimated to have a prevalence of 10-15% (Schiff et al., 2009). Diagnostic errors are often the result of the doctors' cognitive processes (Graber, Franklin, & Gordon, 2005). Errors can be due to different biases such as availability, base rate neglect, representativeness, confirmation bias, premature closure, or confirmatory search (Gigerenzer & Gaissmaier, 2011; Graber et al., 2005; McSherry, 1997; Norman & Eva, 2010). In particular for novices arriving at a correct diagnoses can cause major problems. In a study with medical students instead of building and testing hypotheses, students seemed to just accumulate data (Gräsel & Mandl, 1993). The problems were evident even if biomedical knowledge was sufficient. According to the process models on diagnostic competence, with sufficient biomedical knowledge, non-analytical processing would still rely on building of hypotheses and deliberately relating biomedical knowledge to the clinical features of the case. The problems in the diagnostic situations were on the application of biomedical knowledge to the diagnostic cases and more concerned with diagnostic strategy.

The development of diagnostic competence needs further support. There are few systematic studies on how to support students in developing diagnostic competence (Kassirer, 2010; Reilly, 2007). For learning diagnostic competence, early exposure to cases is recommended (Charlin et al., 2000). Cases are recommended to practice both non-analytical and analytical processing (Eva, 2004; Norman, 2005; H. G. Schmidt & Rikers, 2007). However, the building of scripts may be improved by instructional support (Charlin et al., 2000). It is not fully understood how to best support students while learning with cases (Mamede et al., 2012).

The first evidence for instructional support within integrated processing could be found even before integrated processing was formulated on a theoretical basis. In two studies with novices diagnosing electrocardiograms, students were instructed to first generate hypotheses and then gather evidence. This led to a reasonably higher amount of correct diagnoses compared to a condition in which students first listed all relevant information and then generated a hypothesis afterwards (Norman, Brooks, Colle, & Hatala, 1999). With a comparable instruction based on integrated processing, the improved accuracy of diagnoses could be replicated (Eva, Hatala, Leblanc, & Brooks, 2007). The effect became evident particularly for difficult and complex cases.

Another study with medical clerks took into account the familiarity of the cases (Chamberland, St-Onge, et al., 2011). The study yielded complementary results: diagnostic performance was fostered successfully by prompting students to self-explain. In this study, students were first asked to generate a hypothesis for a diagnosis and afterwards to find two main arguments for its support. As a last question, they were asked to list two alternative hypotheses. Students did not receive any feedback. In an assessment one week later, students benefited from the instruction to self-explain only while diagnosing less familiar cases. A later study found that self-explanation seemed to foster the application of biomedical knowledge to clinical cases (Chamberland et al., 2013). The greater a diagnostic challenge was, the more self-explanations were produced. More biomedical inferences were made in less familiar cases. From the results of these two studies it may be inferred that illness scripts for familiar cases might already have been sufficient. For the less familiar cases, the illness scripts were refined through the self-explanations of the cases. Biomedical knowledge was activated and linked to clinical knowledge. Knowledge encapsulation therefore was fostered by adding instruction to self-explain (Chamberland, St-Onge, et al., 2011; Chamberland et al., 2013).

Other studies found evidence for other assumptions of integrated processing that can be used for decision on how to support the development of diagnostic competence through e.g. varying the level of expertise (Mamede et al., 2010). Structured reflection improved expert physicians' diagnostic accuracy while diagnosing complex problems. Novices who already performed poorly in the beginning, at the generation of hypotheses, performed worse when deliberately reflecting about their diagnostic decisions. The authors explain this with the novices' confusion that is related to their fragmented knowledge base. For less complex tasks only, novices benefited from deliberately reflecting upon the cases; this is explained with knowledge available but not activated, as patterns might not have been recognized. Experts in contrast may be tempted to use non-analytic processing even in complex cases and profit from the deliberate use of analytical processing. A later study by Mamede and colleagues (2012) came to an interesting result. Here, a group that received instruction to practice a structured reflection only performed better in a delayed test and not in an immediate test on diagnosing clinical cases. In fact, in the immediate test, the worst performing group was the structured reflection group. The authors give two possible reasons for this delayed effect. The first reason is that reflection requires a lot of working memory capacity and thus leads to higher cognitive load and exhaustion of the learner (for more details on cognitive load please see 3.1.1 Cognitive Load). The second proposed reason is that the reflection initially confused learners due to the complexity of the diagnostic task. Nonetheless, the processing of deliberately relating hypotheses to evidence leads to an improvement of their illness scripts and improved performance afterwards.

To sum up the presented empirical evidence on how to support students in developing diagnostic competence, it can be said that cases seem to be a promising method (Charlin et al., 2000; Eva, 2004; Mamede et al., 2012; Norman, 2005; H. G. Schmidt & Rikers, 2007). There is also at least some empirical evidence on how to give instructional support to learners while working with diagnostic cases. The findings support the integrated processing model in which non-analytical and analytical processing are both involved simultaneously (Eva et al., 2007; Norman et al., 1999). Also, the increased importance of biomedical knowledge in non-familiar (Chamberland, St-Onge, et al., 2011; Chamberland et al., 2013), or complex cases (Mamede et al., 2010) could be found.

2.1.2 Diagnostic Competence in Nursing

The next section on diagnostic competence in nursing follows a similar structure than the former chapter on diagnostic competence in medicine. The chapter begins with a description of the importance of diagnostic competence. Diagnostic competence in nursing gets defined as categorization task with a high relation to further actions. Then the processes that are in involved are introduced. The transferability of encapsulation theory to nursing is discussed. Afterwards a dual processing model that is common in nursing and an additional integrated processing model that is known in medicine but not common in nursing is explained. Theoretical reflection and some empirical evidence on how to support the learning of diagnostic competence are presented.

Diagnostic competence is a core competence of nurses (Banning, 2008; Lee, Chan, & Phillips, 2006). It is crucial for patient care and becomes even more important with a currently increasing amount of co-responsibility of nurses for patients (Simmons, 2010). Poor diagnostic competences can be associated with the failure of noticing critical patient condition and thus may endanger patients (Aiken, Clarke, Cheung, Sloane, & Silber, 2003).

Nursing diagnoses are the diagnoses of conditions and behaviors relevant for the health of the patient that can be changed by nursing actions (Cholowski & Chan, 1992). Diagnostic or clinical reasoning in nurses is a categorization task in which patient conditions are identified on the basis of attributes of the patient and his or her specific environment (Buckingham & Adams, 2000a; Taylor, 1997). Similar to diagnostic competence in medicine, attributes of a patient are matched to different classes. Whereas in medicine the identification of an illness is the core, in nursing the goal is to recognize the resulting limitations of a disease (North American Nursing Diagnosis Association, 1990). Diagnosis in earlier approaches is described as clinical judgment and thus related to further action (e.g. Elstein, 1978). The process of clinical judgment involves the diagnosis and the planning, implementing, and evaluating of interventions (Tanner, 2006). In clinical judgment the development of standard approaches and practices is involved (ibid). This is excluded in diagnostic competence. In more recent work the focus is less on judgment and more on reasoning behavior (Kassirer, 2010). Nonetheless, reasoning is inseparable from judgments (Tanner, 2006) and further action (Elstein & Bordage, 1988; Simmons, 2010). The process to arrive at a diagnosis is diagnostic reasoning (Cholowski & Chan, 1992). Diagnostic reasoning, clinical judgment, clinical decision making, problem solving, and critical thinking are often used synonymously (Lee et al., 2006; Tanner, 2006). In nursing the term assessment is also used often (Crow, Chase, & Lamond, 1995). According to Crow, Chase, and Lamond (1995) assessment is different than diagnosis as it also includes planning and implementing further action. This, however, is in some contrast to how diagnosis is understood in this work, as the differentiation between the categorization and further diagnostic interventions or treatments seems rather artificial.

Diagnosing involves different processes such as collecting cues beginning with the first patient contact, processing the information, and implementing interventions (Levett-Jones et al., 2010). Noticing relevant cues is the basis of clinical reasoning (Tanner, 2006). Hypotheses are produced on the basis of cues early during the diagnosis, sometimes even before the first patient contact on the basis of documents (Taylor, 1997). The diagnostic process also involves weighing different hypotheses (Simmons, 2010). The process seems to be similar to the process in medicine (Simmons, Lanuza, Fonteyn, Hicks, & Holm, 2003). In nursing, underlying mechanisms and the necessary knowledge for these processes are again not yet completely clear.

In the following, it is analyzed to which degree the encapsulation theory can be transferred to the development of diagnostic competence in nursing. In medicine there is the theory of knowledge encapsulation and the development of illness scripts to explain how diagnostic competence develops from novices to experts (e.g. Schmidt & Rikers, 2007). A study by Offredy and Meerabeau (2005) found the first empirical evidence that scripts similar to illness scripts evolve in nurses. Prerequisites to a diagnosis were activated at the same time a hypothesis was built. The authors describe the process of script development in a way similar to how it is described in literature on illness scripts. Through extensive experience, relevant cues are linked to enabling conditions and experience from patient cases. Knowledge networks are built in which cues are related to hypotheses and interventions. Rule based reasoning is reduced (Buckingham & Adams, 2000b). These nursing scripts, as some authors refer to them, develop only after frequent exposure to patient cases (Greenwood, 2000). This makes the diagnosis of experienced nurses more accurate and less time consuming at least if confronted with familiar cases (Buckingham & Adams, 2000b). The processes described can be compared to the process of knowledge encapsulation and the building of illness scripts. Much like during encapsulation of knowledge in medicine, the underlying concepts become unconscious. The outcome variables in medicine (an illness) and in nursing (a patient state) get closely linked with clinical information derived from a patient case.

After the presentation of theoretical approaches on the development of diagnostic competence in nursing and its similarities to medicine, a dual processing model is introduced. A dual processing approach is already described and accepted in nursing on a theoretical basis, however empirical evidence is still missing (Tanner, 2006). Tanner (2006) describes analytical and intuitive processing. Diagnostic reasoning first starts with noticing cues followed by interpreting and responding to them. The interpretation of cues can come from intuition or from analytical processing (ibid). Intuition can be compared to non-analytical processing as described in medicine. The following proposed model uses the same differentiation that is already described in the model from medicine; however, the terms generally used in nursing may be different. A dual processing model with (a) non-analytical processing, (b) analytical processing and (c) integrated processing combining both will be further explained.

(a) During non-analytical processing, cues or patterns of cues activate knowledge (Buckingham & Adams, 2000a). Cues can come from patient information or from patients' context (Levett-Jones et al., 2010). Cues are interpreted and understood in relation to an existing knowledge network (see nursing scripts). Intuition is a commonly used term in nursing (Banning, 2008): it is described as the ability to grasp a situation immediately and knowing what to do. A characteristic of intuition is the limited ability to explain a decision (Thompson & Dowding, 2001). This inability to explain a decision could also indicate encapsulated knowledge. Intuition derives from experience with patient cases (Tanner, 2006). Intuition is often brought together with the recognition of patterns (Tanner, 2006). Thus, it is comparable to the non-analytic processing described earlier. With increasing expertise non-analytical processing becomes more and more important (Benner, Tanner, & Chesla, 2009). More experienced nurses tend to collect data and draw conclusions unconsciously; experienced nurses in familiar situations can respond intuitively (Cioffi, 2000). Novices instead have difficulties to recognize cues, they often miss important cues (O'Neill, Dluhy, & Chin, 2005). The collection or the noticing of relevant cues or cue patterns is prone to biases and thus to errors (Levett-Jones et al., 2010; O'Neill et al., 2005).

(b) Analytical processing involves having different hypotheses and using data to either confirm or reject them (Benner et al., 2009). Novices tend to use analytical processing; they match theoretical knowledge to the situation encountered (Tanner, 2006). Through the application of knowledge, nursing students build "practical" knowledge on how to apply that knowledge to practical situations (Tanner, 2006). Analytical processing is also used by experts if there is an unexpected development with the patient (Benner et al., 2009). The described processes are based on a five step model of expertise development by Dreyfus and Dreyfus (1980). In the first phase of skill acquisition abstract principles are applied to practical cases. With increasing experience the knowledge gets more differentiated (Benner et al., 2009). Later, experience becomes more important and non-analytical processing becomes dominant.

(c) In medicine recent approaches propose an integrated model in which both analytical and non-analytical processing are integrated in circular moves (Croskerry, 2009; Eva, 2004). In the following, it is explored how an integrated model could also be of value in nursing. Non-analytic processing such as pattern recognition or generating hypotheses using heuristics enables quick decisions, but they are prone to errors (Buckingham & Adams, 2000b): That is why both analytical and non-analytical processing seem to be important (Lee et al., 2006). A combined approach in which analytical processing is combined with non-analytical processing based on experience seems promising (Greenwood, 2000). In medicine, the integrated approach proposes two types of processing (analytical and non-analytical) that are important at different stages in the diagnostic process (Eva, 2004). Non-analytical processing is more important early in the diagnostic process for building hypotheses, and the analytical processing more important later for testing hypotheses or in complex unfamiliar cases (ibid). Analytical processing in medicine reduces cognitive biases (Croskerry & Nimmo, 2011). Whether the same is true for nursing is so far not researched, but promising in order to reduce errors in diagnoses.

Diagnostic competence is so far not taught in education of prospective nurses adequately (Kuiper & Pesut, 2004; Levett-Jones et al., 2010; Murphy, 2004). A reason could be that studies on instructional support for the acquisition of diagnostic competence are still rare; quantitative studies are particularly difficult to find. Claims based on theoretical reflection are common. In the next section, first theoretical reflections on diagnostic competence and its support are presented followed by empirical research on how to support the development of diagnostic competence is presented.

To develop diagnostic competence, scientific knowledge and clinical experience are crucial and should be fostered (Higgs, Burn, & Jones, 2001). Experience alone seems to be insufficient, as otherwise nurses with experience should all have adequate reasoning skills. Deliberate practice is key to clinical reasoning skills (Levett-Jones et al., 2010) (see *chapter 2.4 Expertise, page 25*). Through adding a reflective element learning can be enhanced (Atkins & Murphy, 1993). Reflection can help to improve clinical knowledge (Glaze, 2001) and clinical reasoning (Murphy, 2004). Problem-based learning with authentic cases to train diagnostic reasoning is recommended (Dutra, 2013; Profetto-McGrath, 2005; Taylor, 1997). Through learning with cases, non-analytical and analytical processing can be fostered. A computer system with patient cases was adapted from medicine, but it was used only in a pilot study and primarily for the assessment of clinical reasoning skills and not for learning (Forsberg, Georg, Ziegert, & Fors, 2011). In medicine, evidence suggests that cases are a promising method (Charlin et al., 2000; Eva, 2004; Mamede et al., 2012; Norman, 2005; H. G. Schmidt & Rikers, 2007) particularly if the instructional support is adequate. This may also be true for nursing but there is a lack of empirical research in nursing to support this claim.

It is likely that nursing students tend to have similar problems applying their knowledge to practical situations than medical students have. In a study with nursing students, evidence could be found that knowledge of underlying (in this case biomedical) knowledge was crucial for high quality diagnoses in inexperienced nurses (Cholowski & Chan, 1992). However, another component that was named logical reasoning also had an equally large influence. Therefore, if biomedical knowledge was present, it was still not a guarantee for the correct application to the case. The problems encountered by the nurses were thus on the application of scientific knowledge to the patient cases.

2.1.3 Diagnostic Competence in Teaching

This chapter on diagnostic competence in teaching has again a similar structure than the other two chapters on diagnostic competence in the two medical domains. First the importance of diagnostic competence in teaching is described. Diagnostic competence in teaching gets defined and differentiated from e.g. evaluation. Diagnostic competence is again described as classification task that has different units of analysis in teaching such as relatively stable individual variables of the learner such as intelligence, interest or anxiety (Spinath, 2005), diagnosis of the accuracy of students' performance in written or oral tasks (F.-W. Schrader, 2009), or the interpretation of classroom situations. Research on diagnostic competence and how to support it is described following the differentiation of units of analysis.

The need for diagnostic competence in teachers is universal among countries (Klug, Bruder, Kelava, Spiel, & Schmitz, 2013). Diagnostic competence is one of the core tasks of a teacher (Artelt & Gräsel, 2009; F.-W. Schrader, 2011). Decisions or classifications about students are made every 2-3 minutes while teaching (Shavelson & Stern, 1981). Teachers make diagnostic judgments about students more often than can be done with objective testing (Südkamp, Kaiser, & Möller, 2012). As learners differ in various characteristics such as prior knowledge, academic ability, interest or motivation, these classifications are valuable for a teacher in order to adapt their own teaching to the diverse learning needs of an individual learner (Vogt & Rogalla, 2009). Diagnostic competence in these regards is crucial for planning and teaching.

Diagnostic competence in education is the characteristic of a person to plan, implement, and evaluate his pedagogical actions according to the learning results of a learner (F.-W. Schrader, 2009). Diagnosing in teaching situations has the goal to use methods to develop competences of a learner or a class and to optimize the used methods regarding the present and the desired state of the competences (Helmke et al., 2012). Evaluation, in contrast to diagnostic competence, has another unit of analysis. Whereas in evaluation the focus is on a general and more comprehensive judgment, e.g. the success of a whole program, in a diagnosis the unit of diagnosis is more focused on an individual level, e.g. the teaching of a single teacher (Ingenkamp, 2008).

Diagnosing in medicine and in nursing has been described as a categorization task in which patient attributes are matched to either an illness or a patient state. In teaching the attributes and the categories are less clear (Ophuysen, 2010). In education, diagnostic competence is a broadly used concept. The attributes that are classified vary by the unit of analysis. The unit of analysis can be various individual characteristics of the learner such as skill level, emotional and motivational states, current performance, or how well a pedagogical concept is implemented in a classroom.

Diagnostic competence research is comprised of research of (a) relatively stable individual variables of the learner such as intelligence, interest or anxiety (Spinath, 2005), (b) diagnosis of the accuracy of students' performance in written or oral tasks (F.-W. Schrader, 2009, 2011) and, (c) the interpretation of classroom situation (Stürmer, Könings, & Seidel, 2013).

(a) So far not very well researched is diagnosing of personal characteristics that are relevant for learning and performance e.g. intelligence or motivation. In a study by Spinath (2005), performance attributes were enriched by motivational and affective attributes. Students completed tests on intelligence, self-report of academic ability, learning motivation, and anxiety. For these characteristics their class teachers were asked to diagnose the results. The accuracy of the diagnoses overall had low correlation with the objective tests. The correlations between the diagnostic accuracy of the different characteristics were also low. Spinath (2005) draws the conclusion that a general ability to correctly diagnose performance characteristics and motivational variables is unlikely to exist.

(b) A common research topic in the field of diagnostic competences in education is the accuracy of the diagnoses of students' performance. In fact the accuracy of diagnosing students' academic achievements has been the focus of empirical studies from 1970 until today on (Klug et al., 2013). Closely related is diagnosing of task difficulty as it is an estimation of students' future performance in a specific task. The diagnosis of learning material is researched sin relation with diagnostic competence. It is of importance, as a teacher needs to find adequate task for the skills level a student has. Empirical studies on this unit of analysis are presented in the following sections.

Research on diagnostic competence often looks at correlations between performance or ability tests and the diagnostic result of a teacher (Anders, Kunter, Brunner, Krauss, & Baumert, 2010). A meta-analysis on the accuracy of teachers' judgment of students' academic achievement investigated this relationship using 75 studies. The correlation identified was positive and high ($r = .63$) (Südkamp et al., 2012).

In laboratory studies, Südkamp, Möller, and Pohlmann (2008) used an approach with a simulated classroom. In a computer-based simulation, teachers immersed themselves into the role of a teacher of a class. Subjects could interact with the learners and ask questions. Afterwards subjects were asked to diagnose the performance of the simulated students. The results showed an influence of the reference group. Whereas the performance overall was rated better than it really was, the variance of performance was underestimated. The weak and middle students were rated better. The strong students were rated worse than they really were. Another indicator that accuracy depends on the level of performance of a class was found in a study in which teachers were asked to estimate the mathematical fluency of students (Eckert, Dunn, Codding, Begeny, & Kleinmann, 2006). Whereas teachers were only able to identify students with basic addition skills, they could not correctly diagnose students with mastery level (ibid). The accuracy was thus very dependent upon the performance level of students.

In other studies, also in the domain of mathematics, an underestimation of task difficulty and therefore an overestimation of students' performance was found (Hosenfeld, Helmke, & Schrader, 2002; Lehmann et al., 2000). Similar results were demonstrated for reading skills (Feinberg & Shapiro, 2009). In a study that included different domains such as geography or biology and different class levels evidence was found that teachers seem to have difficulties in sufficiently diagnosing the difficulty of tasks (McElvany et al., 2009). In contrast to the other presented studies, teachers here underestimated the ability of their students.

There might be a difference in the diagnosis of different characteristics. Whereas student performance can be assessed up to a certain degree, the diagnosis of other relevant variables such as motivation is rather poor. Research on the accuracy of student performance show that teachers can diagnose the performance of students on a middle skill level comparatively well, but weak students are often not correctly diagnosed. The performance of a class is often overestimated and subsequently the difficulty of tasks underestimated. An open question is how can a learner benefit from that kind of diagnosis (Klug et al., 2013)? There still is a need for diagnoses that can allow for improvement of teaching (Abs, 2007).

Having in mind the goal of diagnosis in education to develop competencies of learners, the accuracy of diagnosing students' current or future performance is hardly enough. Rather, it can be seen as a prerequisite of choosing appropriate instruction. In an empirical study, teachers with high diagnostic competence could select tasks with a higher cognitive level of activation (Anders et al., 2010) and therefore could foster the learning of their students better. To monitor the effect of instruction used, teachers need to interpret classroom situations (Stürmer et al., 2013).

(c) Diagnosing classroom situations is crucial for achieving learning goals and providing sufficient instructional support to the learner. In fact, the competence to assess the impact of instruction while teaching and to explain it on the basis of scientific knowledge is a central competence for a teacher (Borko, 2004; Darling-Hammond & Youngs, 2002). However, systematical quantitative research on this feature is still rare (Cochran-Smith & Zeichner, 2005). In a meta-analysis by Seidel and Shavelson (2007) domain specific components of teaching had a main influence on the effectiveness of teaching. Interesting in that regard is the results of a recent study by Kersting and colleagues (2012). Here the subject matter knowledge of teachers had an effect on student learning. This relationship was fully mediated by the usage of high quality instruction by the teacher. The important thing could be that teachers with more subject matter knowledge were able to find more suitable instruction for the learners. They could adapt their teaching better. Higher instructional quality enables the learner to actively follow the provided instruction (Anders et al., 2010). Therefore teachers with high diagnostic competence might select tasks with a higher cognitive level of activation (Anders et al., 2010).

Closely related to the diagnoses of classroom situations on the basis of scientific knowledge is the concept of *professional vision* that focuses on the impact of instruction (van Es & Sherin, 2008). Professional vision is very much comparable to the informal or implicit diagnoses that happen during teaching (F.-W. Schrader & Helmke, 2001). These informal diagnoses are the basis for micro-adaptations of instruction during teaching (F.-W. Schrader, 2011). Professional vision is concerned with the ability to notice and interpret classroom situations (Stürmer et al., 2013). The process involves first noticing important features and directing the attention to them. Second, knowledge-based reasoning takes places (van Es & Sherin, 2008). During this process the instructional event is analyzed based on prior knowledge. In other studies these ability is called reflecting about classroom events (Blomberg, Sherin, Renkl, Glogger, & Seidel, 2013). Blomberg and colleagues (2013) describe three levels. On the first level *Description* teachers need to identify relevant events. On the second level *Evaluation* the consequences of an instructional event on the learning of students is crucial. During the third level *Integration* the specific case information is related to professional, and thus scientific knowledge.

To learn professional vision teachers need to apply declarative knowledge of domain general pedagogical principles to authentic classroom situations and put them in relation to instructional events (Stürmer et al., 2013). In previous studies on professional vision, video recordings of classroom situations were successfully used for the training of experienced math teachers (Sherin & van Es, 2009; van Es & Sherin, 2008). In video clubs teachers discussed recordings of their own teaching. However, these studies had small sample sizes and were more of a qualitative nature. Two other studies were concerned with the early development of professional vision (Stürmer et al., 2013) and the ability to reflect about classroom events (Blomberg et al., 2013). Both studies used a quasi-experimental design in which pre-service teachers attended different university courses. All of the courses improved professional vision (Stürmer et al., 2013). The study by Blomberg and colleagues (2013) showed that a highly structured approach enabled students from the beginning on to use expert-like strategies such as integration. However, after a period of three months and faded guidance, the use of expert strategies decreased again.

Professional vision and reflecting about classroom events are both concerned with deliberate classifications of instructional events in classroom situations based on professional scientific knowledge about teaching and learning. Therefore, both concepts can be subsumed under the term diagnoses of instructional situations. Both studies on the development of diagnostic competence of instruction in pre-service teachers had small sample sizes and, due to their quasi-experimental design, limited process data that could give insight into the development of diagnostic competence.

The processes on the development of professional vision were so far not related to the integrated processing approach from the medical domain. However, to explore this relation might be promising. It might be that first, through non-analytical processing, cues in the classroom are noticed, and then unconsciously related to networks of existing knowledge and initial hypotheses are generated. In a second step, analytical processing could take place, in which hypotheses are tested based on professional knowledge about teaching and learning. An integrated processing model is thus also conceivable for teaching.

2.1.4 Differences and Similarities of Diagnostic Competence in the Domains

In the following chapter first similarities and differences in diagnostic competence research in medicine, nursing and in teaching are analyzed. Then another feature, the evidence that is available in a domain, gets introduced and compared between the two medical domains and teaching. Similarities between the diagnostic situations are discussed. Last it is explained how knowledge is applied to cases in medicine, nursing and in teaching.

Similarities and differences between the research on diagnostic competence in the medical domain and in teaching exist. In medicine research mainly focuses on the process of diagnostic competence. Quantitative experimental studies give evidence for specific features of integrated processing. In nursing qualitative studies are dominant. As in medicine, the processes during diagnosing are the main research interest. Integrated processing is less well studied than it is in medicine. In teaching, however, the processes during diagnosing are not investigated systematically. Research distinguishes much more than in the medical domain between the units of analysis. Quasi-experimental studies are prevalent, particularly for the diagnosis of instruction. More quantitative studies in teaching that also give an insight into involved processes are lacking. In medicine and nursing, research could benefit from more differentiation by the units of analysis, e.g. a diagnosis in which results of an imaging methods are the main source of information, compared to a diagnosis in which different laboratory findings and complex patient interviews are involved.

The processes of how diagnostic competence develops are comparable to those described by Kolodner (1992) in her case-based reasoning approach. In case-based reasoning, experience from earlier cases is used for solving problems in new cases. Experiences need to be reflected upon, as the application to new cases requires the learner to apply the gained knowledge to a new case; therefore, adaption may be necessary. Also, a learner might benefit from knowledge if a specific strategy that worked well in an earlier case will also work in the new case. Thus, conditional knowledge on the rationale of a procedure and of its prerequisites may be important.

One important feature of diagnosis is not well addressed by research so far: what evidence is available in a domain to justify a practice, and how is it applied to work on practical cases or other social practices?

Medical research as well as research in education has a broad scope. In medicine there are research studies on small entities, such as in molecular biology, and also research on individual patients and their progression (Roehl, 2006). This is similarly true for research in education: here, studies of very specific processes as well as studies on educational systems can be found (Riehl, 2006). Nonetheless, the availability of evidence for justifying practices is different. In order to compare the domains regarding this feature the evidence-based movements are introduced. 'Evidence-based' is defined as decisions based on proven information. The outcome is controlled empirically (Altrichter, 2010). Although these processes are similar in the domains, the domains vary in the kind of evidence available and how it is used in practice. First, differences in the availability of evidence for the justification of practices in (a) medicine, (b) nursing and (c) education are described.

(a) In medicine, the evidence-based medicine movement started about 60 years ago (c.f. Sackett, Rosenberg, Gray, Haynes, & Richardson, 1996). In evidence-based medicine, individual clinical expertise is integrated into the best current evidence from systematic research to provide individual care for a patient (ibid.). The basis of evidence-based medicine is randomized clinical trials. Physicians were not able to, or at least felt not able to, read original studies (Sniderman, Lachapelle, Rachon, & Furberg, 2013). Therefore, experts wrote clinical guidelines in which findings from randomized clinical trials were summarized and formulated into guidelines with a strong procedural focus (Sniderman et al., 2013). For most common diseases, clinical guidelines based on systematic literature review are available; however, these guidelines are also under critique due to their development and adherence (Timmermans & Mauck, 2005). Evidence is sometimes from outdated studies or incomplete, inconclusive, or completely absent (Sniderman et al., 2013). Even knowledge gained from high quality studies can be conflicting (Ioannidis, 2005; Pereira & Ioannidis, 2011). Also, it is so far unclear how to apply knowledge gained in studies to an individual patient and at the same time consider the individual characteristics and history of a patient. The previous findings indicate that there is a structured discussion on the availability on knowledge to justify a practice and at least an expert committee can agree on guidelines.

(b) Evidence-based nursing emerged later in the late nineties (French, 2002). It is not as well followed up as the evidence-based movement was in medicine. French (2002) describes a search in MEDLINE conducted 2001 revealed 5612 papers on evidence-based medicine, only 47 papers showed for evidence-based nursing. A similar search in 2013 by the author of this thesis revealed 56438 papers on evidence-based medicine, and only 3552 on evidence-based nursing. Inadequate evidence for practices in nursing is still common (Higgs et al., 2001; Thompson & Dowsing, 2001). In nursing qualitative studies are dominant and randomized clinical trials rare (Higgs et al., 2001). Empirical evidence is not available for all decisions (Thompson & Dowding, 2001). Medicine and nursing are both inexact sciences and evidence often ignores the individual patient characteristics or environmental factors but the nature of professional practice is that the correctness of a practice is very much content dependent (Higgs et al., 2001). Evidence-based nursing also includes integration of best available evidence and experience (Profetto-McGrath, 2005).

The use of findings from research in professional practice is vital for patient care and for nursing as a profession (Hornet, & Kearney, 2001). Scientific evidence is hardly used in daily practice (Hutchinson & Johnston, 2004; Ousey & Gallagher, 2007); it is often ignored and instead practices are shaped by following traditions (Gennaro et al., 2001). As large scale studies and daily practice with individual patients are fundamentally different, diagnostic skills are necessary to use available evidence in an intelligent way (Benner et al., 2009). In a large survey, nurses were asked about facilitators for using research findings in daily practice. Advancement of education was seen as a great facilitator (Hutchinson & Johnston, 2004). Transfer from instructional situations in the classroom to practical application with patients needs to be trained, and an understanding of the importance of evidence needs to be created by educators (Ousey & Gallagher, 2007).

(c) In education, the scope of high quality research is also limited, and for many decisions there are only single studies right up to no available findings (Slocum, Spencer, & Detrich, 2012). Even if evidence is available for an educational situation, experts have different ideas on how to best implement a specific theory or how to make use of an empirical finding (Robinson, 1998). Another indication for the different conclusions experts draw from empirical findings is that projects in which a synthesis of findings in education had been tried came to different conclusions (Slavin, 2008). Nonetheless, a discussion on evidence-based practice and data-driven decision making in education, respectively, has started (Groccia & Buskist, 2011; Mandinach, 2012). Groccia and Buskist (2011) define evidence-based teaching as “the conscientious, explicit, and judicious integration of best available research on teaching techniques and expertise within the context of student, teacher, department, college, university, and community characteristics” (p. 8). What can be seen from this definition is that, the same as in medicine and in nursing, the integration of scientific evidence and one’s own expertise is important for professional actions. Therefore, scientific evidence is seen as one source of information that has its own value, as does individual experience (e.g. Hammersley, 2007; Mandinach, 2012). Teachers have difficulties using scientific knowledge gained during their own professional education in the classroom afterwards (Cochran-Smith & Zeichner, 2005; Korthagen, 2007; Spencer, Detrich, & Slocum, 2012). Decisions on pedagogical methods are often based on traditions or on personal preferences instead of reflections about the rationale of a method (Spencer et al., 2012) or on empirical evidence.

However, it is a challenging and not yet well understood task for medical practitioners, nurses, and teachers to use scientific evidence together with individual experience in practical situations.

Now that the availability of evidence in medicine, nursing, and in education has been discussed, the situations to which this evidence needs to be applied is described. Diagnostic decisions need to be made in medicine, nursing, and teaching under, in some features, similar situations. The situations in which diagnostic decisions are made are described as (1) complex with a multitude of aspects to be considered, (2) with uncertainty as not all necessary information is available and (3) dynamically changing.

(1) The diagnostic situation in nursing and medicine is complex (Higgs & Jones, 2008; Kramer et al., 2013; O'Neill et al., 2005). In taking care of a patient there are also a multitude of aspects that need to be considered, such as information from different organ systems or the psychosocial environment of patient. The same is true for the diagnosis of teaching situations (F.-W. Schrader & Helmke, 2001). Teachers need to consider a multitude of aspects when they adapt a pedagogical approach to a classroom situation and implement it (Doyle, 2006). If a teacher wants to foster learning of a whole class and not only of a single student, it is necessary to monitor students' learning processes in a class simultaneously. This can be regarded as rather complex information, as each student may differ with respect to learning prerequisites.

(2) Complete rationale decisions are only possible with knowledge of all relevant information. Knowledge of all relevant information is not generally the case in medicine (Croskerry & Nimmo, 2011), nursing (Ebright, Patterson, Chalko, & Render, 2003), or teaching (Doyle, 2006). Of the large amount of information available on patients, the nurses or medical practitioners are only aware to a limited degree. Teachers are also not aware, or are only aware of a fragment of the information they would need to create an optimal learning situation, e.g. a teacher may know the last grade of a student in a subject, but a teacher may not know about the learner's motivational state. Decisions under uncertainty are common but prone to biases (Tversky & Kahneman, 1974)

(3) In the medical domain, information is dynamically changing as the patient state may change during the diagnostic process (Higgs & Jones, 2008). This has even greater influence in nursing as changes in the patient state can be regarded as different diagnoses

in nursing (Simmons, 2010). The situation in teaching is also dynamically changing, as students' knowledge as well as other variables related to learning can change during every interaction (Mandinach, 2012).

Teachers and medical practitioners are knowledge workers (Riehl, 2006). That is, in the daily practice, scientific evidence or knowledge can give valuable hints for decisions to be made. Scientific knowledge, however, still needs to be reflected upon in a specific case scenario; individual circumstances of the case need to be considered. A central ability for a teacher is to make use of scientific knowledge in concrete situations and also to know which knowledge is relevant in a specific situation (Zottmann, Goeze, Frank, Zentner, F. Fischer, & Schrader, 2012). In the case of the application of a pedagogical method, teachers need to use theoretical concepts and empirical findings on, e.g., problem-based learning for implementing and reflecting upon a lesson in a classroom. In nursing, knowledge also needs to be evaluated and used in a specific situation (Higgs et al., 2001). How to use scientific evidence is, however, not an easy task and requires skills that are not available in all learners (Profetto-McGrath, 2005). These skills need to be practiced (DiCenso, 2003).

In medicine, research often has a larger impact on practice than in education (Riehl, 2006) or nursing. The lack of use of evidence in nursing and education might be due to a lack of a social practice to do so. Whereas in medicine it is common to discuss with colleagues why a procedure is appropriate for a specific patient on the basis of scientific evidence, this is not a daily practice in nursing (Greenwood, 2000). It is also uncommon in education to discuss the use of a pedagogical method in relation to a learning goal and a specific class with individual students on the basis of scientific knowledge. The lack of using scientific evidence could also be due to differences in the professional training (Buckingham & Adams, 2000b).

To sum up, the assumed availability of evidence, and how that evidence is used, is different in medicine compared to nursing and teaching. In fact, nursing and teaching have more similarities to each other than do medicine and nursing with regard to the availability of evidence, despite the latter two both being medical domains. The described differences between domains may cause differences in the instructional support necessary to foster the development of diagnostic competences.

2.2 Operationalization of Diagnostic Competence

A common operationalization in cognitive oriented competence models is based on the differentiation between *conceptual knowledge* of concept and their interrelations and *procedural knowledge* as the ability to execute actions to solve a problem (Rittle-Johnson, Siegler, & Alibali, 2001). In studies, conceptual knowledge is often measured through multiple-choice questions without the necessity of application of knowledge to cases. Procedural knowledge is often measured through problem solving in cases (Booth, Lange, Koedinger, & Newton, 2013). If conceptual knowledge is measured only through multiple-choice questions that are focusing on facts there is a danger that the context dependence of professional knowledge is not considered enough (Borko, 2004; Seidel & Prenzel, 2007). An understanding of underlying principles is not always connected to successful problem solving and reciprocally e.g. students who were able to solve problems in physics were not able to explain the underlying principles (Hestenes, Wells, & Swackhamer, 1992) or medical students with sufficient knowledge on biomedical concept were not able to solve patient cases (Gräsel & Mandl, 1993). In addition to the presented concepts on diagnostic competence and the common operationalization in competence models (Rittle-Johnson et al., 2001) a possibility to asses diagnostic competence that explicitly takes application of conceptual knowledge to cases into account was developed by Stark, Kopp and M. Fischer (2011). Here, diagnostic competence is not defined by analytical and non-analytical processing but moreso by the types of knowledge involved. The authors defined diagnostic competence as consisting of three interrelated kinds of knowledge (Stark et al., 2011). It is conceptualized as beeing of (1) declarative-conceptual knowledge, and additionally (2) practically oriented kinds of knowledge that are (2a) strategic and (2b) conditional knowledge (Paris, Lipson, & Wilson, 1983; van Gog, Paas, & Van Merriënboer, 2004). (1) Declarative-conceptual knowledge is knowledge of basic concepts and objects in a domain. In medicine this is comparable to biomedical knowledge e.g. that heart failure can be caused by coronary heart disease. In relation to generally used terms it can be compared to conceptual knowledge. (2) Practical knowledge is comprised of knowledge about procedures, problem-solving strategies, goals and the rationale of a procedure (Paris et al. 1983; van Gog et al. 2004). It can be compared to procedural knowledge (Rittle-Johnson et al., 2001). In contrast to declarative-conceptual knowledge it is organized around cases and has a clear focus on solving practical problems. To understand why practical knowledge is further differentiated into strategic and conditional knowledge the reflections of Paris, Lipson, and Wixson (1983) are relevant. It is emphasized that there is a difference between performing an action and understanding why and under what conditions it can or should be performed. They further state that conditional knowledge is important for activating declarative-conceptual knowledge in a specific context. Therefore, a further differentiation for practical knowledge is made. The component (2a) strategic knowledge is knowledge about procedures, problem-solving strategies and heuristics, e.g., "Ms. Miller shows symptoms of heart failure." The doctor decides to conduct an echocardiography. (2b) Conditional knowledge is knowledge on the principles or the rationale of a procedure and of its goals, e.g., to ensure the correct diagnosis of Ms. Miller's heart disease, an echocardiography needs to be conducted to analyze the reason, the type, and the intensity of the syndrome. Only then causal therapy or further diagnostics are appropriate. It is likely that practical knowledge is in fact also part of a well-organized illness script. However, there it is not included in research on illness scripts so far. Therefore assumptions can only be made cautiously. The additional component, conditional knowledge, seems to be important in medical diagnosing because overgeneralized heuristics are a frequent cause for diagnostic error (Berner & Graber, 2008). Also problem solving is not enough as only measure for learning outcomes. Also important is the understanding of underlying principles (Richey & Nokes-Malach, 2013). Conditional knowledge could potentially integrate analytical processing if used in instruction. The described model has already been used successfully to foster diagnostic competence in medical students (Stark et al., 2011).

The diagnostic competence model from Stark, and colleagues (2011) adds practical knowledge components to existing diagnostic competence approaches. So far the model has only been used to foster diagnostic competence in medicine (Stark et al., 2011), but it may also be promising for fostering diagnostic competence in nurses or in teachers. If the diagnostic competence model (Stark et al., 2011), could be used in medical, nursing, and teacher education it might give an insight in facilitating diagnostic competence across domains.

2.3 Transfer

To facilitate the acquisition of diagnostic competence, it is necessary to understand why it is so difficult to transfer knowledge and skills learned in a classroom to the real world. Therefore transfer of knowledge is analyzed in the next sections.

To have an impact in the field of action of a learner is crucial for learning. New knowledge should not only change behavior and thinking in a learning situation, but also in real life. In the following positive and negative transfer is introduced. A model to describe transfer using a content and a context component is explained. Then the relation of transfer and the way something is learned is analyzed.

Transfer is using knowledge and abilities in a situation different than the learning situation (Mähler & Stern, 2010), e.g. to learn about concepts on learning and teaching and to apply these concepts later in the classroom to diagnose specific pedagogical methods (Stürmer et al., 2013). Inadequate transfer to the real world is a common problem of instructional situations (van Gog et al., 2004). Transfer, with the goal of fostering diagnostic competence, means that, e.g., physicians or nurses should be able to diagnose a real patient and not only a patient in the learning situation.

Positive transfer means that new knowledge makes problem solving easier. However, it can also happen that new knowledge is obstructive for solving problems: this is known as negative transfer (Pennington & Rehder, 1995). Negative transfer can happen if, for example, problem-solving strategies are taught in isolation: learners with insufficient prior knowledge often cannot tell if the prerequisites for the application of a rule are given in a certain context. If a rule or strategy is applied without prior checking of prerequisites it is called overgeneralization e.g. learners studying a programming language might use a superficial rule that ignores contextual features (Corbett & Trask, 2000), or learners in geometry use visual superficial features such as an angel looks the same in a diagram to inference that two angle are same (Aleven & Koedinger, 2002). In diagnosing how a pedagogical concept is used in a classroom situation, a teacher might use cooperative learning without reflection about the task to be learned or how he or she needs to further structure the cooperation.

Positive transfer can be differentiated by how far learned knowledge can be transferred. Barnett and Ceci (2002) developed a framework for the classification of transfer. The taxonomy involves a (A) *content component*, which describes what should be transferred and a (B) *context component*, which involves the question where and when knowledge is transferred. The content component further differentiates complexity of transfer based on (A1) *learned skill*, which can range from a concrete procedure (e.g. how to take a specific diagnostic test such as how to auscultate a patient) to a general principle such as how to diagnose one’s own pedagogical methods in a classroom. The content component also contains the (A2) *performance change* to be achieved: a problem could be solved faster (e.g. a teacher can immediately tell if students benefit from his / her instruction) or better (the teacher can tell if students benefit from his / her instruction more accurate) or in a new way (the teacher can tell if students benefit from his / her instruction by using observation instead of formal test). The third content component differentiates complexity of transfer based on the (A3) *memory demand*; this can be recognizing that the individual only performs what he or she learned in a similar situation to the learning situation. In more complex cases the individual has to choose between different alternatives. The learner needs not only to know what he does, but also why. A learner has to know under which conditions a strategy can be used.

In the context dimension, the following aspects are considered to be influential factors: first, the (B1) *domain*, that is, the totality of available knowledge in a specialist field, is judged. Near transfer would be a transfer situation e.g. when a physician diagnoses a patient with cardiac failure in the learning situation and later in a real life situation. Far transfer would be if a physician diagnoses a patient with cardiac failure in the learning situation and later in a real life situation he should diagnose a patient with depression. The second context dimension (B2) is the *physical place.* Near transfer could be an online training at work, whereas far transfer might be a seminar that is outside the school where a teacher is employed. Also an important factor is the (B3) *temporal context*. An example for near transfer would be the application of the learned skill during the next day and an example for far transfer the application after a year. Another dimension is the (B4) *functional context*. Near transfer would be if a task is already planned as similar to a real life task and transfer is intended; an example could be to have a rich diagnostic situation with context information embedded in a realistic story. Far transfer would be if the task in the training is only for an academic purpose without the intention for immediate transfer. The (B5) *social context* represents another dimension on which transfer is evaluated within the context dimension. Near transfer would be if, for example, a teacher diagnoses classroom situations by himself or herself in the training and later in school as well. Far transfer would be if a teacher diagnoses a classroom situation in a group during the training situation, but diagnoses individually later in the classroom. The last dimension is the (B6) *modality*. Near transfer would be if a patient case were presented as realistically as possible, for example with simulated patients. Far transfer would be if a specific diagnostic skill such as auscultation is learned by reading a text, whereas in real life, the skill needs to be performed on a patient. This is in line with the approach from Greeno, Moore, and Smith (1993), which states that the context influences cognitive processes.

Whether something can be transferred from training to real life is dependent upon how it is learned. The number of empirical studies on transfer is huge. However, Barnett and Ceci (2002) could not identify a single study in which far transfer occurred spontaneously. In particular, if no further instructional support is provided, far transfer is not likely (Barnett & Ceci, 2002). The findings from Stark and colleagues (1999) point to a similar direction. In different domains and in different types of tasks, transfer was more likely if the same problem was considered in different contexts, e.g., to diagnose the same disease in different patients. The effect of multiple contexts only showed in a training if instructional support was provided. Transfer problems can also occur in tasks with a similar structure and similar context features. Often, analogies from different content areas are built by the learner that cannot be used to effectively solve a problem (Alexander & Murphy, 1999). Activating suitable knowledge is a challenging task. To sum up, it can be said that transfer to the real world does not occur automatically; a specific design of a learning task is important in order to enable successful transfer. The next section covers further important considerations for fostering diagnostic competence in the long run. The relationship to the previously described development of diagnostic competence is reported.

2.4 Expertise

In this chapter first three major streams of research in expertise are described. Whereas in the first phase differences of experts and novices were of main research interest, in the second phase descriptive models of expert development in different domains emerged. Now it is investigated how expertise develops over many years. Expertise development models in medicine, in nursing, and in teaching are described. This is followed by a description of an expertise model that also includes the perspective how expertise can be fostered. Then the difference between routine and adaptive experts is explained and related to learning opportunities involving experience from cases. Finally it is explained why experience without deliberate practice will not lead to expertise.

During the last 30 years, expertise was investigated mainly in three major strands with different core themes. Following Alexander, Murphy and Kulikowich (2009), in the first phase the emphasis was on how knowledge is perceived, internalized, saved and used. Experts were found to have more heuristic strategies than novices. Experts also understand the underlying problem structure and can divide between surface and deep structure; e.g., compared to novice teachers, expert teachers have another, more advanced, perception and assessment of teaching situations (Berliner, 2001). Another findings is that experts use more time to analyze a problem and plan their further actions compared to novices. A domain general problem solving ability is hard to find (Gick, 1986).

In the next phase of expertise research, knowledge and problem-solving strategies were investigated, domain specifically (Alexander et al., 2009) and descriptive models on the development of expertise emerged. Results of different studies on expert knowledge are described in the following. Experts have a larger and better-structured knowledge base. They have more domain knowledge and they can use that knowledge better than novices (Kolodner, 1983). Based on experience, knowledge structures are reorganized. Experts can hence recognize domain relevant patterns more quickly (Reimann & Chi, 1989); e.g., expert physicians and nurses can recognize patterns more easily (c.f. non-analytic processing, see *chapter 2 Diagnostic Competence*). Expert teachers can also better recognize patterns in classroom situations (Hammerness et al., 2005). This may also be the reason why experts are able to change their cognitive processing strategy depending on their specific goals (Krolak-Schwerdt, Böhmer, & Gräsel, 2009). Furthermore it has been shown that the knowledge of an expert is organized around a few crucial concepts in a domain (Alexander, Murphy, & Woods, 1996).

In the third strand it is currently investigated how knowledge develops over many years in longitudinal studies and which emotional factors influence this development. The domains have expanded to more complex and ill-structured domains such as medicine or teaching (Alexander et al., 2009). Current research is more concerned with the question of which contexts and which type of instruction can support the development of expertise. In the following paragraphs models on expertise development in medicine, in nursing and a more recent model in teaching are described afterward a current domain general model that also considers affective variables is presented.

In medicine, the processes from (1) novice, to (2) intermediate, to (3) expert are described as the following. *(1) Novices:* Their knowledge is organized in complex causal networks. In these networks, diseases can be explained by pathophysiological mechanisms. When a novice is working on a clinical case he or she is likely to focus on single symptoms and their relation to pathophysiological mechanisms (H. Schmidt & Rikers, 2007). *(2) Intermediate*: With more experience with clinical cases, the biomedical knowledge gets encapsulated. Illness scripts start to develop (for an explanation see 2.1 Diagnostic Competence in Medicine, Nursing, and in Teaching

Diagnostic Competence in Medicine). The focus of attention shifts from single symptoms to patterns of symptoms (H. Schmidt & Rikers, 2007). In contrast to experts, intermediates make references to underlying principles (Boshuizen & Schmidt, 1992). (3) *Experts:* Experts have more and better developed illness scripts with more meaningful relations in between them (H. Schmidt & Rikers, 2007). Diseases are linked to experience with individual patients. A shift from biomedical to clinical knowledge takes place during the clerkship when they gain more experience with real patients (Boshuizen & Schmidt, 1992).

A recent model in nursing based on the work by S. Dreyfus and Dreyfus (1980) describes five stages of expertise (Benner et al., 2009): (1) during the *novice* stage, rule-based behavior while diagnosing patients is common. Novices have difficulties noticing relevant knowledge. (2) With more expertise, *advanced beginners* are better able to recognize relevant cues. Prototypical cases are built. Novices and advanced beginners can be compared to the novice stage in medicine. (3) During the third stage *competence*, initial hypotheses are generated in a non-analytical way. Underlying concepts are becoming unconscious in routine cases. This stage is comparable to the intermediate stage in medicine. (4) During the *proficient* stage, a nurse can respond intuitively and knows what to do immediately after diagnosing. Pattern recognition has already been developed. However, he or she still uses rule-based reasoning in order to reduce errors. (5) In the last stage, *expert*, the nurse also knows how to best achieve a specific goal. Nurses can respond intuitively and at the same time have a comprehensive understanding of the diagnostic situation. The proficient and experts stages in nursing are comparable to the expert stage in medicine. Thus, it can be concluded that in both medical domains, expertise development is described in a similar way in current research.

A five stage model based on an earlier description of Benner's model (1982) was also adapted for teaching (Berliner, 1994). The processes from novice to expert are very much comparable to these described in nursing. However, not all teachers reach the last stage, expert (Berliner, 2001). Although the three domains have these detailed stage models, all of them lack a comprehensive model how expertise development can be fostered.

A current model that describes the development of expertise independently from a domain is the *Model of Domain Learning (MDL)* (Alexander, 1997; Alexander et al., 2009). The MDL considers cognitive and affective factors and describes the interaction of subject-matter knowledge and affective factors. Alexander and colleagues (2009) describe that expertise develops in three steps (1) *acclimation*, (2) *competence,* and (3) *proficiency*. (1) During acclimation the learner does not have much relevant knowledge in a domain. In this phase the learner gains basic knowledge that is not very well connected and also incomplete. This is related to the problem of novices being unable to distinguish between relevant and non-relevant knowledge (Alexander et al., 1994). An individual in this stage has problems to solve a problem in an efficient way. During problem solving, individuals have difficulties distinguishing between features that are relevant to the problem and features that are not relevant. Deep-level strategies such as elaboration are rare. Interest is bound to the context during this stage. An individual might lose interest in a specific topic again, if the context is complex. (2) During the next phase, competence, individuals develop better-connected knowledge and can identify relevant knowledge. This allows to solve problems related to familiar tasks. Interest is less context-dependent, but is more determined by the content and its relevance for the task. (3) In the phase of proficiency, learners have well developed knowledge that is also well connected. In this phase of expertise the relationship between interest and knowledge becomes more obvious. Only through high individual interest, learners engage themselves in gaining knowledge even after the level of competency. Learners encounter new problems, develop new strategies to solve them and hence generate new knowledge. Deep-level strategies are used. The described Model of Domain Learning gained empirical support from studies in different domains and in different age groups (including adults) (Alexander et al., 2009). The MDL could also provide valuable insights in medicine and in teaching.

Even with enough opportunities to gain experiences, not every learner becomes an expert, and even if expertise is achieved, the level of performance can stagnate or even decrease (Ericsson, 2006). After a certain skill level is reached and daily tasks can be solved sufficiently, cognitive processes usually become automatized. Through automatization the skill is deprived of deliberate modification. This is called arrested development (ibid). In order to continuously develop a skill, top experts are able to counteract automatization with deliberate practice (Ericsson, 2006). Deliberate practice is experienced as being mostly exhausting and unpleasant. The Model of Domain Learning with the interaction of motivation, interest, and skill development could explain why some experts are still able to develop theirs skills continuously.

However, several questions have not been answered so far: How can prospective physicians, nurses and teachers be supported in learning to diagnose patient cases or classroom events? In the next section instructional approaches are introduced that can be used for the design of a learning environment to foster diagnostic competence are introduced. To support the learning of diagnostic competence a case-based approach may train learners how to use declarative-conceptual knowledge to solve cases. This could lead to knowledge encapsulation (Boshuizen, Schmidt, Custers, & Van de Wiel, 1995) in which existing declarative-conceptual knowledge gets enriched with experience from cases. Learners may therefore be able to build strategic and conditional knowledge. The encapsulated knowledge may comprise scientific knowledge and the experience from the cases.

3 Instructional Support for the Acquisition of Diagnostic Competence

In the following chapters research on instructional support is discussed. First, learning with cases is introduced. Ways to make learning with cases also promising in an early phase of skill acquisition are explained. Erroneous worked examples and accompanying scaffolding possibilities are introduced. It is explained how these approaches can be used for the design of a learning environment to foster diagnostic competence.

3.1 Learning with Cases

In this chapter, first diagnostic competence and its relation to problem solving and problem-solving strategies are described. Then, the advantages of a case-based approach to fostering diagnostic competence are discussed. This is followed by a presentation of worked examples as an instructional method, particularly in an early phase of skill acquisition. Finally, possible advantages of including errors into worked examples are considered.

Diagnosing a patient or a classroom situation can be regarded as a form of problem solving. The problem in a diagnostic situation is to find the appropriate course of action in a given situation; for a teacher, for example, this could be modifying a pedagogical method due to the needs of the learner. Van Merriënboer (2013) distinguishes between three types of problem solving methods: (1) Weak methods for solving unfamiliar problems or in domains were the learner is less knowledgeable. (2) Strong methods for solving very specific routine problems with strategies that are specific for a situation. (3) Knowledge-based methods are used for problems that contain factors unknown to the individual and require the learner to make judgments based on available knowledge. Strong problem solving methods are similar to non-analytical processing. Knowledge-based methods in contrast are similar to analytical processing (see *chapter 2. Diagnostic Competence)*. Real life problems are often ill-structured (Jonassen & Hung, 2008). Van Merriënboer (2013) argues for real life problems, a mixture of strong and knowledge-based methods is the general case. Strong and knowledge-based methods need to be practiced to gain strong skills to solve real life problems (van Merriënboer, 2013) such as diagnosing a patient. To learn strong and knowledge-based methods at the same time, the use of authentic cases has been shown to be in particularly helpful (Merrill, 2013; van Merriënboer & Kirschner, 2013). Cases are also recommended in medical education (Charlin et al., 2000; Eva, 2004; Mamede et al., 2012; Norman, 2005; Schmidt & Ricers, 2007), in nurse education (Dutra, 2013; Profetto-McGrath, 2005; Taylor, 1997) and in teacher education (Borko, 2004; Seidel & Prenzel, 2007). Simulated cases present a good opportunity to expose learners to both typical and also to atypical cases (Graber, 2009).

The use of authentic problems is a key element in problem-based learning (Hmelo-Silver, 2004). In various studies, problem-based learning was also shown to be effective for fostering learning of complex skills (Dochy, Segers, Van den Bossche, & Gijbels, 2003). Other approaches, such as case-based reasoning, also suggest learning from authentic cases is key to learning (Kolodner, 1992, 2006).

How cases for fostering diagnostic competence could look is analyzed in the following. The previous thoughts on transfer using Barnett's and Ceci's (2002) framework made clear that transfer of knowledge to the real world is more likely if learning situations and real life situations are alike; for example, for a doctor it would be best to learn how to diagnose patients with cardiac failures with real patients in the same situation is he or she will have to perform diagnoses later on. Regarding the content component of transfer, diagnostic competence can be seen as a complex skill, in which the correct strategy needs to be identified and not merely recognized, as another patient might have many different attributes than the patient used for training. Hence the content component indicates rather far transfer from the training to the real-life situation. Regarding the context component, to design for near transfer, it seems best to design cases in a way that they deal with cardiac failure in the learning session to prepare the learner for diagnosing cardiac failure also later in real situations. Furthermore, learning situation and real life application should not be too different from each other. For doctors in training, cases could be used that are close to what they will be doing in the near future, such as doing a clinical clerkship. Having realistic narrative patient cases in which a patient presents him or herself in a realistic way could also improve transfer to real life.

Looking at novices as a specific type of learner, it has been found that they usually are not able to solve a problem or a case by themselves with strong methods and thus may use weak methods if confronted with a problem without sufficient support (van Merriënboer, 2013). Using only weak strategies the learner is unlikely to gain an understanding of the underlying domain principles (Renkl, in press). The focus of novices' attention is likely to be on reaching the goal of solving the given problem, instead of on understanding its underlying principles (ibid). An explanation why novices in particular have difficulties with problem solving can be found in the cognitive load theory. The cognitive load theory is explained in the next chapter. Then it is explained how a case based approach can be enriched with instructional support with the goal to let also novices profit from it.

3.1.1 Cognitive Load

Cognitive load can be divided into three different types of loads (a) intrinsic load, (b) extraneous load and (c) germane load (van Merriënboer & Sweller, 2010).

(a) Intrinsic load depends on the interactivity of elements in the learning material: That is, the intensity of intrinsic load is defined by the aspect single elements of the learning materials can be understood without understanding the other elements or if the elements cannot be understood without understanding the other elements as well. Van Merriënboer and Sweller (2010) describe the example of learning vocabulary as low interactive because vocabulary words can also be learned independently from each other. Learning grammar is in contrast described as highly interactive, as many elements need to be processed simultaneously. When facing new information, the working memory capacity reaches its limits early on, as without the ability for organizing the new information beforehand, the possible ways to combine the different elements are numerous (van Merriënboer & Sweller, 2010). Intrinsic load cannot be reduced by instruction, but only by schema construction of a learner. To reduce the number of elements, larger knowledge structures, called schemata are built during the learning process. Building chunks by combining elements to larger knowledge units, including the combination of new elements into schemata and acquisiation of information that is already schematized by other individuals, is an important process for schema construction (van Merriënboer & Sweller, 2010). As novices do not have sufficient schemata, they can experience much higher intrinsic load than an intermediate or expert would. However, other authors assume that intrinsic load might also be influenced by instruction, for example by sequencing (de Jong, 2010).

b) Extraneous load can be directly influenced by instruction. Intensity of extraneous load depends on the intensity of guidance during the problem solving process and on the way how information is provided to the learner (van Merriënboer & Sweller, 2010). problem solving can induce high extraneous load, particularly in novices (Renkl, in press).

c) Germane load results from actual learning: that is from the construction or further advancement of schemata (van Merriënboer & Sweller, 2010). However, there are hints that germane load can sometimes be too high leading to an impairment of learning (de Jong, 2010). Cognitive load as a general theoretical concept is under critique due to difficulties in clearly differentiating the three types of load (de Jong, 2010). Some authors, such as Kalyuga (2011), argue for only two type of loads, that are intrinsic and extraneous load, due to lack of empirical possibilities to prove all three types. The measurement of cognitive load also causes major problems (de Jong, 2010).

As novices might use weak problem solving strategies if confronted with a realistic problem, instead of relying on knowledge-based strategies, designing learning situations as problem solving situations might not be the best solution. Empirical studies offer hints that learning as open problem solving in open learning environments without instructional support does not have positive effects on learning (Kirschner, Sweller, & Clark, 2006). Other authors additionally state that with adequate guidance, learning environments with complex cases can increase learning (Hmelo-Silver, Duncan, & Chinn, 2007). A possible way to let novices learn from realistic problems is to provide guidance using worked examples (van Gog, Paas, & Sweller, 2010).

3.1.2 Learning with Worked Examples

In the following, learning with worked examples and the relation to cognitive load is described. Afterwards different kinds of worked examples are introduced and their usefulness for fostering diagnostic competence is analyzed.

Worked examples are composed of a problem formulation, solution steps (which may be more of less detailed), and a final solution. There is evidence for the effectiveness of worked examples in well-structured domains (e.g. in mathematics) (Renkl &, 2010; Stark, 1999, 2001) and also in complex domains (e.g. in argumentation or legal case reasoning) (Nievelstein, van Gog, van Dijck, & Boshuizen, 2013; Schworm & Renkl, 2007). The worked example effect can be explained with the cognitive load theory (Kalyuga, 2011; Sweller, Van Merriënboer & Paas, 1998). For the elaboration of a worked example, less cognitive capacity of the working memory is demanded than problem solving. This effect can be assumed to last until the learner has gained sufficient expertise and therefore acquired enough cognitive schemata to lead his or her problem solving processes (van Merriënboer, 2013). As a result, more cognitive capacity is available for the construction of schemata; that is, to build meaningful relations between prior knowledge and new information (Kalyuga, 2011). If learners already have much prior knowledge, an expertise reversal effect can occur while learning from worked examples (Kalyuga, Ayres, Chandler, & Sweller, 2003). An expertise reversal effect occurs if an instructional method is no longer beneficial for learners with a higher level of knowledge (Kalyuga & Renkl, 2010). Before learners can start to benefit more from problem solving than from learning with worked examples they need to acquire knowledge on the domain principles (Renkl, in press). In complex domains there are studies in which no expertise reversal effect was found for learning with worked examples: for instance, with legal case reasoning (Nievelstein et al., 2013), whereas in other complex domains such as literacy interpretation an expertise reversal effect was found (Oksa, Kalyuga, & Chandler, 2010).

Different types of worked examples can be distinguished: (1) product-oriented worked examples, (2) process-oriented worked examples and heuristic worked examples and (3) double-content worked examples. (1) In classic *product-oriented* worked examples it is shown how a goal-state can be reached. (2) In *process-oriented* worked examples, the strategic knowledge on heuristics and problem-solving strategies applied to reach the goal is included in addition; also the rationale of a solution is also explained (van Gog et al., 2004). Process-oriented worked examples are promising in order to increase transfer (van Gog, Paas, & van Merriënboer, 2008; van Gog et al., 2004). A similar concept is that of *heuristic worked examples* (Hilbert, Renkl, Kessler, & Reiss, 2008). Similar to process-oriented worked examples, problem-solving strategies are added but only for non-recurrent skills (ibid). Therefore they can be regarded as a special type of process-oriented worked examples. Heuristic worked examples were effective in learning to prove (ibid). (3) Another form of worked examples to foster complex skill are *double-content worked examples* (Schworm & Renkl, 2007). To foster the development of e.g. argumentation skills it is required to have two levels of content that is argumentation itself (*learning domain)* and also the domain from which the problem is taken e.g. genetics (*exemplifying domain)* (Schworm & Renkl, 2007). Further, in argumentation no algorithmic solution can be provided. Double-content examples were successfully used to foster argumentation (Schworm & Renkl, 2007) and collaboration (Rummel, Spada, & Hauser, 2009; Rummel & Spada, 2005).

For the diagnosis of patients and also for the diagnosis of a classroom situation it seems that there is no algorithmic solution available, as these kinds of problems can be regarded as highly complex and ill-defined (see *chapter 2.1.4* Differences and Similarities of Diagnostic Competence in the Domains). Accordingly, using the principles from process-oriented examples might be beneficial to foster diagnostic competence. Thus, knowledge on heuristics and problem-solving strategies (strategic knowledge) and also of the rationale of a solution (conditional knowledge) should be included. Similar to the double-content examples for argumentation or collaboration, in diagnosing there is also an exemplifying domain where basic features have to be understood, e.g., while diagnosing a patient with symptoms of cardiac failure basic declarative-conceptual knowledge on the cardiovascular system needs to be understood. However, it seems that the distinction between the exemplifying and content domains is less clear and much more interwoven.

An assumption of worked examples is the principle that learners can also learn by observing others problem solving (Sweller, 2010). That individuals can also learn from others' cases is also assumed in the case-based reasoning approach (Kolodner, 2006) and in the social learning theory (Bandura, 1977). Learning from others was so far investigated from a cognitive perspective in research on worked examples and from a social learning perspective in research on modeling examples (van Gog & Rummel, 2010). Van Gog and Rummel (2010) contrast worked examples to modeling examples by describing the solution to a problem of worked example as didactically motivated. In modeling examples the model can also be a peer who shows natural behavior and commits errors while solving a problem. Worked examples are generally presented in a text-based format whereas modeling examples often uses some kind of live or captured observations (van Gog & Rummel, 2010). In both perspectives it is assumed that learners need to actively process the example cases and build on cognitive representations (ibid). Learning from worked examples and learning from observation share common features, such as reliance on cases (Renkl, in press). Both strive to build activities that let the learner build relations between the cases and the underlying principles. Renkl (in press) states that in several studies worked examples and observational learning are conceptually connected (Chi, Roy, & Hausmann, 2008; Craig, Chi, & VanLehn, 2009; Gholson & Craig, 2006). In these studies, a learner observes another learner trying to perform a skill while the observed learner is tutored. As the learner that is observing is not addressed personally it can be regarded as a case of vicarious learning (McKendree, Stenning, Mayes, Lee, & Cox, 1998).

It might also be beneficial to connect principles from worked examples and observational learning to foster diagnostic competence. Using a fictitious peer in a worked example format could have the advantage of increased transfer performance, as the situation of a peer doing an internship at a school or a medical clerkship in a hospital is much closer to a situation a student will encounter soon. Another potential advantage would be that misconceptions and typical errors could be integrated more authentically. Through including a fictitious expert, strategic and conditional information can be added into the worked examples.

To achieve meaningful learning in the form that new knowledge is integrated into existing knowledge structures, active processing of learning material is necessary (Eysink & de Jong, 2012). Accordingly, the effectiveness of worked examples is dependent upon the self-explanation activity of a learner (Atkinson, Renkl, & Merrill, 2003; Chi & Bassok, 1989; Hausmann & VanLehn, 2007; Renkl, 1997). Self-explanation means to generate explanations after being confronted with learning material (Chi, 2000). With regard to worked examples, that is, if a learner can and does explain the solution steps to him or herself. Self-explanations are not complete but rather fragmented, incorrect, and incomplete and thus show what a learner did and did not understand (Chi, 2000). Incorrect self-explanation can also promote learning if detected and resolved (Chi, 2000). Conati and VanLehn (2000) in contrast state that only correct and high quality self-explanation are beneficial for learning, at least for learners who are not very good at monitoring their own learning process. Accordingly, if an incorrect self-explanation cannot be detected because a learner has insufficient monitoring skills, it might not be advantageous for learning.

Self-explanations are necessary to gain understanding (Nokes, Hausmann, VanLehn, & Gershman, 2011), and can improve transfer (Atkinson et al., 2003; Hilbert et al., 2008). Differences exist in the success of learners due to qualitative differences in their self-explanation activity (Chi, Bassok, Lewis, & Reimann, 1989; Renkl, 1997); for example successful learners anticipate the next solution step and connect underlying principles within the case (Renkl, 1997).

Without support, the cognitive capacity freed through instruction based on worked examples is not used for self-explanation by all learners (Renkl, 1997; Stark, 1999). Instead, learners often process worked examples passively or superficially (Renkl & Atkinson, 2010). Self-explanation activities can be fostered indirectly through the design of the worked examples (Renkl, in press). A promising method to help learners use this capacity for learning is include errors into worked examples (Booth et al., 2013; Große & Renkl, 2004, 2007; Stark et al., 2011). For worked examples that are conceptually connected to observational learning by using a peer as fictitious model, this can easily be realized.

3.1.3 Learning with Erroneous Worked Examples

To include errors into worked examples may not only have the advantage of increased self-explanation activity, but processing errors themselves may have some advantages for learning. In different learning theories learning from errors is included. In the experience-based learning model the analysis of errors is seen as a central mechanism for learning (Kolodner, 1983). Errors can lead to reflections and therefore trigger deep understanding (VanLehn, 1999). Learners reach a point in problem solving at which their present knowledge is not sufficient anymore: they cannot find the solution to a problem and start to elaborate on the problem. This can lead to relations between existing declarative-conceptual knowledge and case information and thus may improve strategic and conditional knowledge. The mechanism for learning described by VanLehn (1999) is not due to conducting an error oneself, but rather to trying to overcome it. A learner does not need to conduct an error by him or herself, but rather only needs to perceive an error (VanLehn, Siler, Murray, Yamauchi, & Baggett, 2003). Errors in learning material can increase the likelihood that a learner processes also the correct procedure in more detail, foster elaboration and therefore deeper understanding (VanLehn et al., 2003; VanLehn, 1999). Processing why a specific procedure leads to a wrong solution can help to replace faulty knowledge (Booth et al., 2013).

In other approaches, conducting an error oneself is seen to prepare learners for future learning (Kapur & Bielaczyc, 2012). In the productive failure approach, learners start with problem solving without much guidance, before an instructional event. The likelihood for failure is accordingly high. This kind of delayed instruction can lead to better problem-solving performance and transfer (Kapur & Bielaczyc, 2012; Kapur, 2013). In a quasiexperimental study in a school on the topic of probability, learning from one's own failure (productive failure) was compared to learning from the failure of others (vicarious failure). The productive failure learners outperformed the learners from the vicarious learning group in understanding of underlying concepts and transfer tasks (Kapur, 2013). In addition, they were more engaged and put more mental effort into understanding the canonical solutions (ibid). Kapur (2013) states that one's own failure is superior because generating failure prepares learners for better understanding of the underlying structure and for noticing critical features (Kapur, 2013). A possible way to engage students in the explanations of the error made by others might be to use prompts to let learners self-explain the errors.

Recent studies indicate that it is in fact not conducting an error oneself, but other processes such as thinking about underlying structure of the learning material that drives learning with errors. Approaches that guide learners through invention processes and accordingly reduce the experience of failure showed benefits for learning (Holmes, Day, Park, Bonn, & Roll, in press; Loibl & Rummel, in press). What can be drawn from the discussion on the underlying mechanism involved with learning from errors is that it is crucial to process the errors actively.

Analyzing an one's own error makes a problem-solving situation more complex, and a learner who is already challenged to solve a problem may not have the additional capacity to learn from the error. Using worked examples may reduce cognitive load compared to problem solving and leave enough capacity to process an error (Renkl & Atkinson, 2010). Learning with erroneous worked examples might free cognitive capacity while at the same time increasing the ability to evaluate and justify procedures (McLaren et al., 2012). To include errors in worked examples might therefore be a promising method to help learners learn from errors without demanding too much of their cognitive capacity. Similar to normal worked examples, erroneous examples also consist of a problem that is solved stepwise. In addition, errors in one or more steps are included (Adams, McLaren, Mayer, Goguadze, & Isotani, 2013; Tsovaltzi, McLaren, Melis, & Meyer, 2012). There are several studies that used erroneous worked examples that came to mixed results. The empirical evidence is presented in the following paragraphs.

Comparing correct with incorrect worked examples was beneficial for learning and retention for learning decimals (Durkin & Rittle-Johnson, 2012; Rittle-Johnson et al., 2001). The errors included in the worked examples were based on common misconceptions. The authors traced the positive effect of erroneous worked examples back to learners being better able to explain why a certain misconception was wrong. Directly letting learners explain why an incorrect solution was incorrect was also beneficial for learning in mathematics. It increased learning compared to only explaining why a solution was correct (Huang, Liu, & Shiu, 2008; Siegler & Chen, 2008). Explaining why an erroneous procedure is wrong can help to prevent this error in the future (Durkin & Rittle-Johnson, 2012; Siegler, 2002).

Looking for results that can give additional insight into the mechanism that increase learning with erroneous worked examples leads to studies by Isotani's and colleagues (2011) and McLaren and colleagues (2012). In a study conducted in middle-school in different classes with the topic of decimals, a condition with interactive erroneous worked examples was compared to a condition with worked examples and to a problem solving condition (Isotani et al., 2011). No effect of the three conditions on learning was found. Students were not provided with prompts to find and correct the errors. In a later study (McLaren et al., 2012) in which the multiple-choice menu for the explanations was simplified and the learners were also asked to provide problem-solving strategies that corrected errors, the students in the erroneous worked example condition outperformed their fellow students in a delayed posttest. No effect was found in an immediate posttest. This effect is attributed by the authors to deep generative learning processes that are more challenging and had been shown to lead to delayed learning gains (R. Schmidt & Bjork, 1992).

In studies on students working with probability estimation by Große und Renkl (2007; 2004) learners with high prior knowledge could profit from the integration of errors into worked examples in far transfer tasks. For methodological reasons errors in this study were not explained to the learners in the learning environment. In the Große & Renkl (2002) study, only learners with high prior knowledge profited from the errors. To benefit from error in worked examples learners need to actively process why a solution procedure was incorrect (Große & Renkl, 2007; Siegler, 2002). Self-explanation during erroneous worked examples that occurs without further prompting can be at the costs of principle-based self-explanation that can be considered important for learning from worked examples (Große & Renkl, 2007).

In studies from medicine, the successful use of erroneous worked examples to foster diagnostic competences has been reported (e.g. Klopp et al., 2013; Kopp et al., 2009; Stark et al., 2011). Here, the errors were explained in different levels of elaborations. The learners with elaborated feedback and integrated instructional errors gained the most knowledge. Just knowing the correct procedure was not enough to exploit the full potential of the errors (Stark et al., 2011). The explanation of why a procedure was incorrect and what the correct procedure was improved learning in two studies on two different medical domains. It was also found that not every learner benefited from the detailed feedback given after the errors. Later in the learning session the detailed feedback even had negative cognitive and motivational effects (Stark & M. Fischer, 2008).

A more recent study found evidence for the high demand of learning with worked examples and the importance of instructional support. In Tsovaltzi et al.'s (2012) studies standard fraction exercises were compared to interactive erroneous worked examples in which typical errors of fractions were implemented. In one of the conditions the erroneous worked examples were enriched with instructional support. After presented with an erroneous step, students were prompted to pick the erroneous step from a list of prepared alternatives and correct the error afterwards. Afterwards the learners got feedback. The correct solution was given in all conditions. The more advanced students' problem solving skills and conceptual understanding were enhanced by the erroneous worked examples only if the examples were enriched with additional support. The less advanced students did not profit as much from the erroneous worked examples compared to general problem solving (Tsovaltzi et al., 2012).

Learning from incorrect solutions is particularly challenging (Große & Renkl, 2007): for example identifying incorrect mathematical solutions is more difficult than identifying correct solutions (Reiss, Hellmich, & Thomas, 2002). The presented studies show that errors themselves might be a good possibility to enhance learning from worked examples. To simply include errors into worked examples may not be enough to learn from the errors as learners might not understand why an error is wrong (Stark et al., 2011). To fully use the potential of erroneous worked examples, sufficient scaffolds are necessary (Durkin & Rittle-Johnson, 2012). Providing scaffolding, for example by marking an error (Große & Renkl, 2007), by prompting to find the error using a limited set of alternative answers (Tsovaltzi et al., 2012), or by providing additional instructional explanation in the form of elaborated feedback (Stark et al., 2011) can increase learning. Errors with instructional help for how to learn from an error in safe environments can be beneficial for learning also with adult learners (Heimbeck, Frese, Sonnentag, & Keith, 2003). In the next section scaffolding for erroneous worked examples is discussed.

3.2 Scaffolding in Erroneous Worked Examples

Scaffolding enables a learner to carry out tasks or achieve goals that he or she would not have been able to reach without scaffolding (Quintana et al., 2004; Wood, Bruner, & Ross, 1976). Elements of the learning material are taken over by a system, a peer, or a teacher so the learner only has to carry out the steps within his or her reach (Wood et al., 1976). In computer supported learning, scaffolds can be fixed. Learners then have to monitor their learning by themselves, and use provided scaffolds if needed (Puntambekar & Hubscher, 2005). Fixed scaffolds may consist of a fixed set of questions or prompts on the learning material (Azevedo, Cromley, Winters, Moos, & Greene, 2005).

A framework that might help to identify promising scaffolds through analyzing activities is introduced in the following. Chi (2009) provides a framework in which (a) active, (b) constructive and (c) interactive activities are differentiated and possible cognitive processes during those activities are described. (a) Being active is described as physically doing something e.g. clicking on a link to ask for further explanation. The goal of active activities is to engage learners. Active activities can activate existing knowledge. New knowledge can be added into existing knowledge gaps. (b) During constructive activities, output is produced, e.g. in generating self-explanations. The output contains, information that has not been presented in the learning material. Constructive activities can be induced through prompts. Constructive activities can help to build meaningful relationships between new and existing knowledge (ibid). (c) Interactive activities are concerned with talking to another individual and referring to what was said by the other individual. Interactive activities can induce similar processes to constructive activities, but in addition, shared understanding can be achieved. Chi (2009) describes active activities as more promising for learning than passive and constructive activities as more promising than active activities.

To learn from an error, learners need to be aware of the error and they need to be able to explain the error (Schank, 1999). Not every learner may be able to do this without instructional support. In order to learn from an error learners need sufficient prior knowledge (Große & Renkl, 2007). In particular, learners with low prior knowledge need support when learning with errors (Renkl, in press). Through scaffolding it could be that learners with low prior knowledge can also profit from erroneous worked examples as in the study by Stark et al., (2011). From the previously described studies, two particularly promising scaffolds can be identified: letting learners self-explain the error and providing learners with help to identify the underlying principles of an error, for example through elaborated feedback. In contrast to presenting erroneous worked examples, these two scaffolds would be considered active and constructive activities (Chi, 2009). Providing learners with an active activity could be possible through letting learners decide how much help they need in order to understand the underlying principles of an error. Such a scaffold can be implemented through adaptable feedback in which the learner can adapt the level of additional instructional explanation he or she needs (Leutner, 2002). Through the inclusion of self-explanation prompts in the learning material, a constructive activity could also be included. Interactive activities are difficult to include, as to increase transfer performance, diagnosing a patient or a classroom situation might be better learned individually and not with a learning partner, due to the fact that a cooperative diagnosis is not the general case for diagnosis of, e.g., classroom situations in the real world for a teacher. In the next two sections scaffolding through self-explanation prompts and through adaptable feedback is analyzed in more detail.

3.2.1 Self-Explanation Prompts

To foster learning from erroneous worked examples, additional instruction including scaffolds to self-explain the content of the worked examples could be an easy to implement and promising method. This scaffolding can be realized through prompts. Prompts are a form of scaffolding that direct the attention of the learner to important aspects of an activity during the learning process (Quintana et al., 2004). Prompts aim at inducing strategies that the learner is capable of but do not show spontaneously without being prompted (Pressley et al., 1992).

A method to foster self-explanation activity while studying worked examples is to give additional instructions to self-explain (Atkinson et al., 2003). In less complex domains such as in early business management training, the positive cognitive and metacognitive effects of self-explanation prompts have been found (e.g. Stark, 1999). This effect was also found for less complex tasks in physics (Chi et al., 1989) and in biology (Chi, De Leeuw, Chiu, & LaVancher, 1994). In more complex domains such as in argumentation (Schworm & Renkl, 2007), chess (de Bruin, Rikers, & Schmidt, 2007), and in diagnostic competence in medicine (Chamberland, St-Onge, et al., 2011; Chamberland et al., 2013), a positive effect of self-explanation prompts was shown. In contrast, in language acquisition where the proceduralization is more important, self-explanation prompts did not increase learning (Mwangi & Sweller, 1998).

Self-explanation prompts are also beneficial if provided by a computer. In a computer-based learning environment learners were asked to type in self-explanations while reading materials (Hausmann & Chi, 2002). In a first experiment, no prompts were given, and the amount of self-explanation was low. In a second experiment, content-free prompts were provided. The prompts were as effective as prompts from a human tutor (Hausmann & Chi, 2002).

Prompted self-explanation is beneficial in comparison with other instructional methods. Compared to additional practice, self-explanation is slightly beneficial, with regard to procedural and conceptual knowledge in mathematics (McEldoon, Durkin, & Rittle-Johnson, 2012). Self-explanation prompts in combination with worked examples are promising in comparison to other instructional methods. Eysink and colleagues (2009) compared different instructional approaches to each other with regard to the learning outcomes. Self-explanation-based instruction and inquiry learning were higher in their outcomes than hypermedia learning and observational learning (Eysink et al., 2009). The self-explanation-based learning environment combined worked examples with generating self-explanations. While studying worked out examples the learners were prompted to self-explain the underlying principles and why certain procedures were used in worked out steps. Learner showed better-organized knowledge and better transfer of knowledge to new problems (Eysink et al., 2009). In a later study, think-aloud protocols were used to get an insight in the learning processes involved (Eysink & de Jong, 2012). Elaboration was shown more often in self-explanation and in inquiry learning environments. In hypermedia learning and observational learning environments there was more superficial processing. Self-explanation prompts in combination with worked examples were tested with success. However, the prompts were not the only factor varied in this study.

If the benefit of generating self-explanations is just the additional attention a learner pays to the solution steps in the worked examples needs to be analyzed. In a study in which self-explanation was beneficial even if learners were paraphrased underlying principles of a worked example showed that this is not the case (Hausmann & VanLehn, 2007). Accordingly the benefit of self-explanation is not just attention but has an additional value.

The additional value of self-explanation prompts in worked examples compared to other methods such as building analogies is confirmed by another study. To foster learners' knowledge of domain principles, worked examples that were either enriched with self-explanation prompts or with prompts to build analogies were compared to a group of learners that read worked examples and solved practice problems afterwards (Nokes-Malach, VanLehn, Belenky, Lichtenstein, & Cox, 2013). In near transfer tasks the reading and the self-explanation groups were better than the groups that built analogies during the learning phase. It is possible that the analogies group focused on understanding underlying principles instead of on procedural aspects. The authors state that if the analogies groups focused on declarative knowledge, this group should be better on an intermediate and on a far transfer test as declarative knowledge, is assumed by the authors to be more flexible. However, in the intermediate transfer test, no differences between the groups were found. In the far transfer task, the self-explanation and the analogies groups were best. Self-explanation prompts that prompt learners to make connections between underlying principles and cases can lead to knowledge that can also be transferred (Nokes-Malach et al., 2013). Similar results showed in medicine: here the diagnostic performance was fostered successfully by prompting students to self-explain (Chamberland, St-Onge, et al., 2011; Chamberland et al., 2013). In an assessment one week later, students benefited from the instruction to self-explain while diagnosing less familiar cases. A later study found that self-explanation prompts fostered the application of biomedical knowledge (comparable to declarative-conceptual knowledge) to clinical cases (Chamberland et al., 2013).

In erroneous worked examples, self-explanation prompts lead to mixed results. Erroneous worked examples combined with self-explanation prompts were beneficial with regard to conceptual knowledge gains compared to explaining only correct solutions of algebra problems (Booth et al., 2013). However, there was no effect on procedural knowledge measured through isomorphic problems and transfer problems. This may provide further evidence to Nokes-Malach's and colleagues (2013) statement that building analogies and self-explaining worked examples might lead the learner to concentrate on conceptual understanding instead of on procedural knowledge.

Another open question is what exactly should be prompted, and what the underlying mechanism is that makes prompts beneficial for learning. Several studies can give hints about this question. In a study with double-content worked examples Schworm and Renkl (2007) varied different types of self-explanation prompts. The prompts were either directed to the domain to be learned (argumentation) or to the exemplifying domain (stem cell research). Additionally, in one condition no prompts, and in another condition, both kinds of prompts were given. Self-explanation prompts on the domain were beneficial, also in combination with prompts on the exemplifying domain. Prompts only on the exemplifying domain were not beneficial for learning. This result can be interpreted to mean that in addition to active processing, the focus of attention on domain principles is also crucial for the effectiveness of prompts.

Focused prompts that direct the attention of the learner to a specific aspect of the learning material appear to be particularly beneficial (Berthold & Renkl, 2010). In the case of learning with erroneous worked examples, self-explanation prompts that specifically focus on the identification and explanation as well as on the conclusions of errors are encouraging because they are a method to let a learner self-explain the errors. Explaining why an incorrect solution is incorrect is beneficial for learning (Curry, 2004; Siegler, 2002). In addition, another benefit could be that prompts might be a good possibility to engage learners in the explanation of errors made by others. This might help to overcome the benefits of errors committed by the learner him or herself (Kapur, 2013) and could potentially make it possible to also learn successfully from others' errors.

With respect to the complex patterns of the effects of prompts, two complementary studies are reported. In the first study, prompts that aimed to focus learners' attention on declarative-conceptual knowledge covered in the learning material had mixed effects on different kinds of knowledge (Berthold, Röder, Knörzer, Kessler, & Renkl, 2011). The prompts in this study targeted deep understanding of underlying principles without relation to the case presented. Tax-law students with these prompts gained more declarative-conceptual knowledge, but in fact were hindered in learning procedural knowledge. In order to assess procedural knowledge, learners were presented with small case vignettes and asked what they would advise a client and why. Therefore it is similar to the practical knowledge explained earlier *(*see *2.1 Diagnostic Competence in Medicine, Nursing, and in Teachingn Diagnostic Competence in Medicine, page 21).*

Findings from a second study by Berthold, Eysink and Renkl (2009) showed another possibility for how to support learners in focusing their attention with prompts. In this study learners were asked to explain a mathematical operation based on theories and to explain why they performed the particular operation. After the prompts, assistance was provided either in form of preformulated phrases or the answer format was open. Both kinds of prompts fostered procedural knowledge and conceptual knowledge. Additional assistance after the prompts in particular fostered conceptual knowledge. In this study procedural knowledge was assessed again via cases in which the solution to problems had to be provided. Therefore, it is comparable to the strategic knowledge previously introduced. In the conceptual knowledge items of the knowledge test, the focus was on understanding why a solution procedure was applied. It is thus comparable to conditional knowledge *(*see *2.2* Operationalization of Diagnostic Competence*, page 20).*

These two studies illustrate that prompts are not automatically advantageous for all of the knowledge types that are relevant for diagnostic competence and can even have negative effects. For example in the study by Berthold, Röder, Knörzer, Kessler and Renkl (2011), the declarative-conceptual oriented prompts had negative effects on practical knowledge aspect but positive effects on declarative-conceptual knowledge, whereas in the study by Berthold, Eysink and Renkl (2009), prompts focusing on the explanation of underlying principles in relation to the case of application had positive effects on practical knowledge. Different prompts seem to have different effects on different types of knowledge. For this reason it is crucial not to focus prompts exclusively on declarative-conceptual aspects of the learning material. In order to foster diagnostic competence it might be to the best advantage to prompt learners to think about practical knowledge that is what a correct solution to the case might be and why. This could also support the encapsulation of knowledge (see *chapter 2.1 Diagnostic Competence in Medicine, Nursing, and in Teaching Diagnostic Competence in Medicine, page 4*) and therefore foster the integration of scientific knowledge and of one's own experience.

Integrating errors into worked examples might be a promising method, but it could also increase cognitive load due to the high demand of analyzing errors. That is also the case with self-explanation prompts. Self-explanation prompts and errors in worked examples could increase cognitive load to a level, that is detrimental for learning, as has been demonstrated in other studies in which self-explanation prompts combined with other methods had negative effects. In heuristic worked examples on mathematical proving, self-explanation prompts were beneficial (Hilbert et al., 2008). In combination with gaps to be filled in by the learner, they had negative effects. The processing of both could have impaired learning (Hilbert et al., 2008). In another study, self-explanation prompts were not beneficial for learning in combination with multiple-representational solutions (Große & Renkl, 2006). Self-explanation prompts were also not beneficial in combination with modular worked examples (Gerjets, Scheiter, & Catrambone, 2006). While learning with a complex learning task, self-explanation prompts could overload cognitive capacity due to high processing demands, particularly if prior knowledge is low (Berthold et al., 2011; Renkl, in press). Even if self-explanation prompts are advantageous for self-explanation activity they may increase intrinsic cognitive load as they can increase the interactivity of element due to the prompted involvement of domain principles (Kalyuga, 2011). With more expertise, the declarative-conceptual knowledge may be better connected with cases of application, and therefore the cognitive load may decrease over time.

Hints that point in this direction can be found in a study in two different populations (high school students and psychology students) (Berthold et al., 2011). Whereas self-explanation prompts had a double–edged effect in the high school students (Berthold & Renkl, 2009), they were beneficial for psychology students (Berthold et al., 2009). The authors refer to this study and provide an explanation for this finding that considers at the learning prerequisites of the two populations (Berthold et al., 2011). They state that psychology students may have better learning prerequisites, as their prior knowledge is much higher. Thus, they may have experienced a lower intrinsic load from the learning material and were able to use the freed cognitive capacity for self-explanation activity.

In another study, the influence of prior knowledge was evident. Self-explanation prompts in an experiment by Große and Renkl (2007) had no positive effect in combination with erroneous worked examples or in combination with general correct worked examples. In a second experiment, correctly solved and incorrectly solved worked examples were provided. The errors were not highlighted and learners had to find the errors by themselves. Learners were instructed to think-aloud while learning with the worked examples. It was found that incorrect solutions fostered elaborations on errors but reduced principle-based self-explanations (Große & Renkl, 2007). It could be that the attention shifted away from underlying principles simply through including prompts and without providing additional support through feedback. The researchers also found a high correlation between correct self-explanations and transfer performance (Große & Renkl, 2007). Errors in the solution procedure were only beneficial if learners could find adequate self-explanations which in turn are related to prior knowledge (Große & Renkl, 2007). Not all learners can self-explain on a sufficient level (Berthold et al., 2009). A problem with freely formulated self-explanations is that students might have an illusion of understanding the worked example steps and thus are not engaged enough in self-explanation activity (Conati & VanLehn, 2000; Renkl, 2002): learners overestimate their level of understanding (Dunlosky & Lipko, 2007; Dunlosky & Rawson, 2012). As a result, learners stopped studying and thus did not achieve high learning outcomes. Overconfidence can be very harmful for learning (Dunlosky & Rawson, 2012). Self-testing combined with learning material that includes key terms to be learned can be effective means against overconfidence if the learner actively compares his or her own solution with the additionally provided ones (Dunlosky & Rawson, 2012). To reduce illusions of understanding and to overcome knowledge gaps, the combination of self-explanation prompts with additional instructional explanation in the form of feedback may be beneficial (Gerjets et al., 2006). For learning from errors in particular this could be true, as it is important to be aware and to understand the error in order to learn from it (Ohlsson, 1996; Schank, 1999). But, of course, not every learner is able to understand every error. Depending on prior knowledge and metacognitive abilities, learners may in fact not even detect an error.

A combination with feedback is more promising as not all self-explanations are correct. However, learners can also learn from incorrect self-explanations as they may trigger later self-explanations (Chi, 2000). Aleven and Koedinger (2002) stand against this statement and found that, in contrast to Chi's study (2000) in which 75 % of the self-explanations were correct, in a more complex learning task such as in their own study the correct self-explanations are much less. Therefore, even if incorrect self-explanations, can trigger further self-explanation, they can remain incorrect. In a complex learning task such as diagnosing a patient or a classroom situation were the danger of incorrect self-explanation is high it may be beneficial to include feedback.

3.2.2 Adaptable Feedback

Feedback follows after instruction and can have major influences on learning (Hattie & Timperley, 2007). Feedback is information provided by an agent such as by a computer-based learning environment or by a learner him or herself. That is, feedback can come from an external source or internally from a learner (ibid). Feedback in an instructional setting is considered to be all information provided after a learner has responded to a stimuli that informs a learner about his or her actual state of performance (Narciss, 2013).

For feedback reception metacognitive skills are crucial (Narciss, 2008). Metacognition is knowledge and monitoring of one's own cognitive processes (Flavell, 1979). Feedback aims at reducing the discrepancy between a current and a desired state (Hattie & Timperley, 2007).

Feedback can help to detect errors or knowledge gaps, and give strategically useful information (Narciss et al., 2014). Feedback in instructional contexts can sometimes not clearly be distinguished from instructional explanation (Hattie & Timperley, 2007), as also instructional explanation should be relevant for the misunderstandings of a learner to foster elaboration (Webb & Mastergeorge, 2003). An example for the difficulty to distinguish feedback and instructional explanation is *revising* instructional explanation. Whereas standard instructional explanation provides learners with basic understanding of a topic, revising instructional explanation targets gaps and flaws in already gained knowledge (Wittwer & Renkl, 2008).

Effective feedback relates to three questions and also to dimensions of learning. The questions to be answered by feedback are (1) What progress is being made toward the goal? (2) What activities need to be undertaken to make better progress? and (3) What are the goals? (Hattie & Timperley, 2007). The dimensions of learning involve task performance, understanding of a task, metacognitive processes, and self. Related to diagnostic competence, the first and second questions correspond to strategic knowledge, as they involve problem-solving strategies and heuristics in relation to a specific case. The third question corresponds to conditional knowledge, as it is about the goals of a procedure and of its rationale. Therefore, to foster diagnostic competence, it might be beneficial to structure feedback with regard to these dimensions.

To make the erroneous worked examples promising for learners with low prior knowledge in addition to learners with high prior knowledge, feedback in which the error is explained and linked to the theoretical background could be important. However, instructional explanation failed to improve learning in several studies.

Instructional explanation can be beneficial in helping students apply their existing knowledge to new cases and also can fill gaps in knowledge (Wittwer & Renkl, 2008). Even though a meta-analysis showed that providing instructional explanation had a positive effect on conceptual knowledge, a negative effect on problem solving skills in math and no effect in science or learning science (Wittwer & Renkl, 2010) were found. Compared to worked examples with prompts to self-explain they were not beneficial. In three experiments on electrical circuits that used worked examples, withholding instructional explanation was beneficial (Richey & Nokes-Malach, 2013). Richey and Nokes-Malach (2013) have hypothesized that instructional explanation may discourage constructive behaviors.

Revising instructional explanation that targets gaps and flaws (Wittwer & Renkl, 2008), and is very much comparable to feedback, failed to enhance learning in several studies (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001; Schworm & Renkl, 2006). Sánchez and García-Rodicio (2013) note that instructional explanation has not been marked as corresponding to the learners' misunderstandings in the previously mentioned studies. Thus, the additional information may have been experienced as redundant to the learning material. Their own studies show an advantage of explicitly marking instructional explanation as corresponding to errors or misconceptions of leaners (ibid).

There could be various reasons why instructional explanation and feedback failed to be beneficial for learning, such as the prior knowledge of the learners. A study on how to foster diagnostic competence in medicine (Stark et al., 2011) and other studies (e.g. Strijbos, Narciss, & Dünnebier, 2010) showed that elaborated feedback is not beneficial for every learner. Instructional explanation of the rational of a procedure is valuable for learning in the beginning: however, it can become redundant during learning and should be faded out after some time (van Gog et al., 2008). The redundancy of the explanations could cause an expertise reversal effect (ibid), as with more expertise learning may even be hampered by additional explanations (Kalyuga et al., 2003). That these unnecessary explanations and redundancy can also be detrimental for learning is also supported by other authors (Kalyuga & Renkl, 2010). A hint in that direction could be that feedback with a fixed format given after self-explanation prompts had negative effects (Gerjets et al., 2006). An possible reason for this could be that the instructional explanations were not well adapted to the prior knowledge of learners (Wittwer & Renkl, 2010), and they may not been given at the time a learners needed them (Renkl, 2002).

Feedback given to learners if they are at an impasse and cannot self-explain on their own seems especially helpful (Renkl, 1997; Stark, Gruber, Mandl, & Hinkofer, 2001; Stark, 1999). But learners, even if they are formally at the same educational level, may differ substantially with respect to prior knowledge. An automated adaptive feedback that is specifically tailored to the needs of the individual learners would be the best solution. To be adaptive, a tutor has to monitor the understanding of the learner (Chi, Siler, & Jeong, 2004). Even human tutors with high conceptual understanding of the content domain fail to diagnose students' false beliefs and knowledge deficits accurately and accordingly, have difficulties adapting their instructional explanation to the learners' needs (Chi et al., 2004).

To give adaptive feedback after an error would required knowing exactly what the error was in order to decide on the adequate instructional support (Aleven, Stahl, Schworm, F. Fischer, & Wallace, 2003). But in a complex field such as in education or in medicine, the generation of the knowledge base that would be needed to analyze the learners' understanding automatically is currently out of reach (M. Fischer et al., 2008).

Accordingly, it is difficult to adapt instructional explanation to the needs of the learners automatically, particularly in complex domains (Aleven et al., 2003).

A possibility for adaptive feedback would be to let learners choose their self-explanations from a set of multiple-choice questions. This procedure was effective in some studies (Atkinson et al., 2003; Conati & VanLehn, 2000) but had no effect in others (Gerjets, Scheiter, & Schuh, 2005). However, such a procedure is only of limited use, as a wrongly chosen self-explanation only contains limited information about the misconceptions a learner might have.

A possible way to implement some adaptability is to let learners decide on the extent of feedback they need (Leutner, 2002). Help on demand in combination with self-explanation prompts and worked examples can be beneficial for learning (Renkl, 2002). On-demand help is help that the learner actively requests e.g. by clicking on a hyperlink (Aleven et al., 2003). Instructional explanation on demand can benefit learners with low prior knowledge without harming the learning of those learners with high prior knowledge (Renkl, 2002). Through letting learners decide about the level of detail of the feedback, the autonomy of the learner is fostered and therefore the conditions for intrinsic motivation are improved (Deci & Ryan, 1993). Learner control in computer-based environments can increase interest and motivation and may also help the learner to adapt the learning environment to his or her cognitive needs (Scheiter & Gerjets, 2007). In addition, to let learners decide on the level of feedback by clicking on a link is an active activity as learner is physically doing something (Chi, 2009). Being active may activate existing knowledge so that new knowledge can be added easier (ibid). Having learners decide on the help they need may also provide them the opportunity to find their own explanations (Anderson, 1993).

If feedback is structured with regard to the previously described types of knowledge the learner may also have the opportunity to focus on the knowledge he or she needs. For example, after deliberately relating prior knowledge to case information, a learner might recognize a wrong procedure (question 1), but it could still be the case that he or she does not know how to proceed (question 2) or what the goal of procedure is (question 3). With an adaptable feedback method the learner would not have to scan through all the information, but could decide upfront if further explanations about a certain type of diagnostic knowledge are necessary.

Learner control poses high demands on the learner (Scheiter & Gerjets, 2007). The effectiveness adaptability, that is to let learners decide on, e.g. the level of feedback they need, requires a certain level of metacognitive competence, which is missing in some learners (Stark & Mandl, 2002; Stark et al., 2008). Learner-controlled adaption in which the learner actively chooses instructional activities can be beneficial, but learners often lack the metacognitive ability to decide on the most beneficial activity for learning (Narciss, 2008). For example, it was shown that feedback on demand was not used very often (Corbett & Anderson, 2001). Adaptability, accordingly, can also be problematic because learners with low prior knowledge are often bad help seekers (Aleven et al., 2003). In computer-based learning environments help seeking consists of five steps. The steps are (1) becoming aware of the need for help. Self-monitoring skills are crucial (Aleven et al., 2003). (2) The decision to seek help, which may be less influenced by help-seeking costs in computer supported leaning, e.g. by the risk of being seen as incompetent. To let a learner simply click on a link to ask for help might further reduce help seeking costs. (3) The identification of a source for help, which in case of an adaptable feedback measurement is very easy. (4) Making use of provided help. In computer-based learning environments the help may not always be tailored at students needs. Accordingly, the learner needs to filter the information provided and judge the usefulness for the problem at hand. (5) Learners evaluate the help-seeking process (Aleven et al., 2003). Help-seeking activities are not easy processes and from the five steps it gets obvious why help seeking can increase cognitive load (Aleven et al., 2003). Even though in a computer-based learning environment that provides adaptable feedback that might be less important as, for example, the step two and three are less demanding than in other setting such as in a classroom. Learners tend to overestimate their understanding (Chi et al., 1994) and thus refrain from seeking help in the first place. It is possible that learners who need additional explanations the most, are the least prone to ask for them, in some cases because they do not even know they need it (Gräsel, F. Fischer, & Mandl, 2001; Narciss, Proske, & Koerndle, 2007).

One of the reasons why the combination of adaptable feedback with self-explanation prompts is promising is that the combination of both might help learners to realize their need for additional explanation. In the next section the prospects of a combination of self-explanation prompts and adaptable feedback are analyzed.

3.2.3 Interaction of Self-explanations Prompts and Adaptable Feedback

In the following, the three main benefits of the combination of the two instructional support methods, self-explanation prompts and adaptable feedback, are explained: (1) reducing illusions of understanding, (2) provision of learners that cannot find adequate self-explanations with the underlying principles of a problems, and (3) fostering active processing of instructional explanations in form of feedback. Then empirical evidence for the positive effects of self-explanation prompts and adaptable feedback is presented. Finally, possible limitations are analyzed and design recommendations are introduced.

(1) Learners tend to overestimate their understanding. They often have illusions of understanding (e.g. Chi et al., 1994). An illusion of understanding can lead to shallow processing of provided additional explanations (Wittwer & Renkl, 2008). Learners with poor metacognitive skills may have problems to monitoring their own understanding and may refrain from actively elaborating on instructional explanations (Hofer, 2004). The passive use of instructional explanations could be fostered by self-explanation prompts before instructional explanations (Renkl, 2002). Self-explanation prompts may support learners in realizing their need for additional explanation, and hence assist students with weaker learning prerequisites in seeking help.

(2) Learners can have difficulties self-explaining the underlying principles of a solution in a worked example (Berthold et al., 2009; Renkl, 2002). Inadequate self-explanation can impair learning (Berthold et al., 2009). For those learners in particular the combination of self-explanation with instructional explanation is recommended (Renkl, 1999, 2002). One might have the idea to not let learners self-explain the solution steps, but instead provide them with additional instructional explanation. A meta-analysis by Wittwer and Renkl (2010) showed that this would not be an adequate solution. Instructional explanations had only minimal effects and were not beneficial compared to generating self-explanations.

(3) Learning material is often processed in a passive way (Berthold & Renkl, 2010; Pressley et al., 1992). Instead of deliberately relating new knowledge to prior knowledge, learners often simply summarize presented content (Roelle, Berthold, & Renkl, in press). Just adding feedback may not be enough to benefit learning, as learners need to actively process it (Narciss, 2008; Timmers, Braber-van den Broek, & van den Berg, 2013; Wittwer & Renkl, 2008). Particularly in the case of erroneous worked examples there is a danger that learner do not process errors and their to underlying principles to a sufficient degree. Delaying feedback can promote error-detection and error-correction skills (Mathan & Koedinger, 2005). However, simply delaying feedback may not be enough to help learners detect and correct an error (Corbett & Anderson, 2001). Additional support may be necessary, e.g. by prompting learner to actively process the errors. Prompts to process instructional explanations added to effectiveness of worked examples (Berthold & Renkl, 2010). A recent study showed that prompts that induced focused processing of instructional explanation were beneficial (Roelle et al., in press). This relation was fully mediated by the inferences a learner made to the central principles provided in the instructional explanations. Accordingly, prompts can be of great use in order to enhance the active processing of instructional explanation.

Empirical evidence for the positive effect of a combination of self-explanation prompts and feedback is presented in the following. Aleven and Koedinger (2002) enriched an existing computer-based cognitive tutor in a physics classroom with self-explanation scaffolds. Students chose from a predefined list the underlying principle of their problem solving steps and were provided with feedback afterwards. The self-explanation prompts combined with the feedback had a positive effect on learning (Aleven & Koedinger, 2002). Another study that combined similar self-explanation scaffolds and feedback came to similar results. Additionally, this study introduced a fading procedure in which steps of a worked examples were faded in favor of problem solving by the learner him or herself. Self-explanations prompts for identification of underlying principles of each problem step in combination with feedback improved near and far transfer (Atkinson et al., 2003). Self-explanation prompts and instructional explanation can also benefit learning in case the instructional explanation helps to reduce faulty self-explanation (Rittle-Johnson, 2006). The learners with self-explanation prompts outperformed their fellow students in a delayed posttest after 2 weeks. The beneficial effect of feedback and self-explanation was also be found in another study that incorporated the explanation of incorrect solutions (Curry, 2004).

A possible limitation of the benefits of the combination of instructional explanation and additional instructional explanation is that instructional explanation can suppress self explanation (Chi, 2000; Richey & Nokes-Malach, 2013). Choosing from adaptable feedback is an active activity, but it could discourage constructive behavior such as self explanation (Richey & Nokes-Malach, 2013). On-demand help has shown to be effective (Renkl, 2002) but it can also decrease self-explanation activity of learners (Schworm & Renkl, 2006). Koedinger and Aleven (2007) refer to this as the assistance dilemma. They state that only as much instruction as is needed to understand the learning content should be given. Other authors specify that only as much additional instructional explanation or feedback as necessary should be provided (Conati & VanLehn, 2000; Renkl, 1999, 2002).

Another limitation could be that self-explanations prompts combined with erroneous worked examples might already induce a high level of cognitive load. If feedback also needs to be adapted to one’s own knowledge and a complex task needs to be solved, that could in fact lead to a level of cognitive load that is detrimental for learning. An indication may be found in a study in which students in a didactically-oriented program performed best if provided with self-explanation prompts only. Learners from a subject matter-oriented program performed best if self-explanation prompts were combined with additional instructional explanation (Hilbert, Schworm, & Renkl, 2004). The authors concluded that the combination of self-explanation prompts and instructional explanation is beneficial for students with better prior knowledge.

Instructional explanation thus should only be provided if a learner cannot self explain on his or her own (Renkl, 2002). To optimize learning from self-explanation and instructional explanation, Renkl (2002) formulated principles: (1) As much self-explanation as possible and only as much instructional explanation as needed. (2)

Feedback should be provided. (3) Provision of instructional explanation on demand of the learner. (4) Instructional explanation should be as minimal as possible. (5) The degree of elaboration of instructional explanation should be adapted to the prior knowledge of the learner. (6) Instructional explanation should focus on principles. In learning with worked examples, that is how principles can be used to solve cases. Help on demand in combination with instructions to self explain worked examples can be beneficial for learning (Renkl, 2002).

There are some studies that might give design advice for the benefit of the combination of self-explanation prompts and adaptable feedback. After a study in four different schools Conati and VanLehn (2000) conclude that intense scaffolding of self-explanation using prompts and feedback is beneficial at an early learning stage. In a more advanced stage, less intense scaffolding with prompts only is more beneficial (Conati & VanLehn, 2000). This result is indicative for the benefit of providing self-explanation prompts and feedback. It can also be concluded that feedback may be more beneficial if a learner can adapt it to his or her needs.

The combination of instructional explanation with self-explanation prompts was worse than withholding instructional explanation. The prompts in this study were given after the instructional explanation (Richey & Nokes-Malach, 2013). Given that result, it might be better to provide the prompts *before* the instructional explanation. Thus, the instructional explanation can help mark the character of marking misconceptions of a leaner (Sánchez & García-Rodicio, 2013).

In the previous chapter possible benefits of instructional support of erroneous worked examples with self-explanation prompts and adaptable feedback and their combination was analyzed. In the next section, open questions concerning these support measures are discussed.

4 General Research Questions

The aim of this thesis is to enhance the understanding of how to foster diagnostic competence in the domains of medicine, nursing, and in teaching. In the previous chapters a promising approach using erroneous worked examples was introduced. An open question now is how to best scaffold learning from errors in worked examples with the goal of fostering diagnostic competence. Two scaffolding methods were introduced in the last chapter: self-explanation prompts and adaptable feedback.

Self-explanation prompts can enhance worked examples. Research on self-explanation prompts in erroneous worked examples so far has come to mixed results. If self-explanation prompts focusing on errors can foster diagnostic competence is not known, but a positive influence is anticipated from a theoretical perspective. Another open question is on what self-explanation prompts should focus, particularly in case of erroneous examples.

Adaptable feedback is a form of feedback that opens up the possibility to let the learner decide how much feedback he or she needs in order to understand the learning content. To make feedback adaptive has certain advantage, but could also hinder learning, as a learner needs adequate help-seeking skills that are not present in all learners. Therefore, the second general research question is:

The combination of self-explanation prompts and adaptable feedback has three major benefits: (1) reducing illusions of understanding, (2) provision of learners that cannot find adequate self-explanations with the underlying principles of a problems, and (3) fostering active processing of the feedback. However, there are also limitations, as the additional instruction could also suppress the self-explanation activity of the learners. Accordingly, the first general research question of this thesis is:

General Research Question 1:

To what extend can self-explanation prompts and adaptable feedback enhance the acquisition of diagnostic competence while learning with erroneous worked examples?

Diagnostic competence has been studied in medicine, in nursing and in teaching. Research shows similarities as well as differences between diagnostic competences in those domains. Processes of diagnostic competence development can be connected to research on expertise development. A major difference in diagnostic competences in the domains is the kind of evidence that is available and how it is used in practice. In medicine for example research has a larger impact on practice than in education (Riehl, 2006) or nursing. In medicine to discuss with colleagues about procedures on the basis of scientific evidence is daily practice, whereas this is not the case in nursing or teaching. Regarding the use of evidence, nursing and teaching have more similarities to each other than medicine and nursing. These differences between the domains may yield differences in the instructional support necessary to foster the development of diagnostic competences. Even though there is a large body of research on fostering diagnostic competence within subject domains, a systematic approach that also compares instructional methods across domains is still missing. Most research so far could not compare scaffolding across domains systematically. Therefore, the second general research question is:

General Research Question 2:

To what extent is the effect of self-explanation prompts, adaptable feedback, and their combination for the acquisition of diagnostic competence while learning with erroneous worked examples different in medicine, nursing, and teaching?

These research questions require replication studies using material and designs as similar as possible in the domains medicine, nursing, and in teaching. An important aspect of research comparing diagnostic competence between different domains is that diagnostic competence needs to be operationalized similarly. Research conducted so far had varied instruction in studies in different domains, and thus different results between domains might be confounded with the other varied variables. Besides complexity of task structure in fact, research findings seem to neglect differences between domains mostly.

In the following chapters three studies are presented in which diagnostic competence of prospective physician, nurses and teachers is fostered with an erroneous worked example approach. The two scaffolding method (self-explanation prompts and adaptable feedback) are varied systematically in this studies. In a last study theses three conceptual replication studies are compared to each other. In the last chapter results and their implications are discussed from a general perspective.

5 Study 1: Fostering Diagnostic Competence in Medicine

5.1 Context

5.1.1 Diagnostic Competence in Medicine

Diagnostic competence is a core competence of medical practice (Charlin et al., 2000). To derive a correct diagnoses in an effective process is a central competence for every physician (Mamede et al., 2012). For patient safety, diagnostic competence is crucial in basically all medical disciplines (Croskerry & Nimmo, 2011; Croskerry, 2009). Medical diagnoses are a categorization task. The diagnostic process in medicine is highly complex (Charlin et al., 2012). In order to arrive at a correct diagnosis a physician has to gather information on a patient and his or her state. The physician's knowledge gets activated and patient characteristics are matched to illnesses (Charlin et al., 2000). Diagnosing is closely related to further action (Charlin et al., 2012). A medical diagnoses has the goal to make a decision on how to proceed with further diagnosis or treatment (Charlin et al., 2007).

In recent approaches on the processing of diagnostic situations, diagnostic competence is described with an integrated model with analytical and non-analytical processing involved (Croskerry, 2009; Eva, 2004). Non-analytical processing are particularly important in an early stage of diagnoses for building hypotheses, whereas at a later stage of the diagnosis for testing hypotheses or in complex, unfamiliar cases analytical processing is more important (Eva, 2004).

The development of diagnostic competence in medicine is often described with knowledge encapsulation and building of illness scripts (Woods, 2007). During knowledge encapsulation, biomedical knowledge gets associated to clinical features. Symptoms of a disease get related to patient characteristics and contextual features (Charlin et al., 2007; H. G. Schmidt & Rikers, 2007). The concepts in which biomedical knowledge and clinical features are associated with each other are called illness scripts (Schmidt & Rikers, 2007). During the development of expertise in an early stage knowledge is getting organized in causal networks (H. Schmidt & Rikers, 2007). With more experience with patient cases, in an intermediate stage knowledge gets encapsulated and illness scripts start to develop (for an explanation see *chapter 2.1.1* Diagnostic Competence in Medicine*, page 3).* Patterns can be recognized easier (H. Schmidt & Rikers, 2007). Later in the expertise development, physicians make only few references to underlying biomedical principles, and diseases are directly linked to experience from patient cases (Boshuizen & Schmidt, 1992). The stage model of expertise in medicine (see chapter *2.4 Expertise)* (H. Schmidt & Rikers, 2007) lacks the perspective how expertise development can be fostered. Other more domain comprehensive expertise models such as the model of domain learning (Alexander, 1997; Alexander et al., 2009) show important factors of expertise development such as how learners use their experience.

However, even with enough experience, not every learner becomes an expert (Ericsson, 2006). After daily tasks can be solved sufficiently, cognitive processes usually become automatized. To continuously develop a skill, experts are able to counteract automatization with deliberate practice (Ericsson, 2006). A key element of deliberate practice is to reflect on the appropriateness of a procedure and how it could be improved. Therefore, besides the opportunity from cases also a reflective element seems to be important for expertise development.

Learning of diagnostic competence is a difficult process and there is a high amount of diagnostic errors. Error in the diagnostic processes are estimated to have a prevalence of 10-15% (Schiff et al., 2009). For novices diagnostic situations are challenging (Gräsel & Mandl, 1993). The application of biomedical knowledge and thus declarative-conceptual knowledge to patient cases can be a major problem particularly for novices. The development of diagnostic competence needs further support.

5.1.2 Facilitating Diagnostic Competence in Medicine

To support the learning of diagnostic competence a case-based approach may train learners how to use declarative-conceptual knowledge to solve cases. This could lead to knowledge encapsulation (Boshuizen, Schmidt, Custers, & Van de Wiel, 1995) in which existing declarative-conceptual knowledge gets enriched with experience from cases. Learners may therefore be able to build strategic and conditional knowledge. The encapsulated knowledge may comprise scientific knowledge and the experience from the cases. A case-based approach has the advantage that learners could gain experience with typical and also with atypical cases (Graber, 2009). Empirical evidence from research in medical education on how to support students in developing diagnostic competence, suggest that cases seem to be promising (Charlin et al., 2000; Eva, 2004; Mamede et al., 2012; Norman, 2005; H. G. Schmidt & Rikers, 2007). This is in line with deliberations on problem solving and how it can be learned (see chapter *3.1 Learning with Cases*).

The research on learning with cases shows, presenting learners with ill-structured real life cases without sufficient support, may lead particularly novices to the use of weak methods, without practice of strong or knowledge-based strategies (van Merriënboer, 2013). Worked examples are a possible way to let also novices profit from learning with cases and provide them with adequate guidance at the same time (van Gog et al., 2010). Without instructional support learners often process worked examples passively or superficially (Renkl & Atkinson, 2010). A promising method to help learners process worked examples actively is to include errors (Booth et al., 2013; Große & Renkl, 2004, 2007; Stark et al., 2011). Processing errors themselves may in addition have some advantages for learning (see chapter *3.1.3 Learning with Erroneous Worked Examples*). Simply including an error into a worked example might not be sufficient to learn from it, as it is crucial for learning from errors that a learner is aware of an error and can explain it (Schank, 1999). Particularly learners with low prior knowledge may need support when learning with errors (Renkl, in press). Through sufficient scaffolding it could be, that also these learners can profit from erroneous worked examples as in the study by Stark et al. (2011). Two particularly promising scaffolding strategies are: letting learners self-explain the error and letting learners decide on how much feedback they need to identify the underlying principles of an error.

5.2 Aims of this Study and Specific Research Questions

The aim of this study is to investigate the effect of scaffolding on fostering diagnostic competence in medicine during learning with erroneous worked examples. More specifically, scaffolding through self-explanation prompts, adaptable feedback and a combination of both is analyzed. In this study, from general research questions one specific questions and hypotheses are formulated.

(RQ1) To what extent can two scaffolding methods (self-explanation prompts and adaptable feedback) facilitate diagnostic competence?

Currently it is not known if self-explanation prompts focusing on diagnostic errors can foster diagnostic competence. A positive influence is anticipated overall on the basis of the theoretical assumptions outlined in chapter *3.2.1 Self-Explanation Prompts*. The second scaffolding method that is investigated is adaptable feedback. Letting prospective physicians decide how much feedback they need has certain advantages but could also hinder learning, as a learner needs adequate help-seeking skills that are not present in all learners. If the combination of self-explanation prompts and adaptable feedback is in particular positive for learning has not been systematically addressed by research so far.

The two methods may interact positively because the combination might reduce illusions of understanding, provide learners that cannot find adequate self-explanations with the underlying principles of a problem and might foster active processing of the feedback. But there might also be limitations as the additional instruction could suppress the self-explanation activity of the learners for instance.

(RQ2) What are the effects of self-explanation prompts targeting different kinds of knowledge on diagnostic competence in medical education?

Furthermore, the differential effect of prompts targeting different kinds of diagnostic knowledge on diagnostic competence has not been investigated systematically. It is expected that a prompt focusing on problem solving strategy and thus on strategic knowledge has a positive relation with the acquisition of strategic knowledge. A prompt that is more focused on understanding why a procedure is appropriate may lead to increased practical knowledge.

(RQ3) Can motivation be increased by the use of adaptable feedback in medical education?

One of the advantages of adaptable feedback and thus of letting learners decide about the level of detail in feedback can be, that the autonomy of the learner might be fostered and therefore the conditions for motivation are improved (Deci & Ryan, 1993). Motivation can improve learning (Deci & Ryan, 1993).

(RQ4) Are the effects of adaptable feedback on the acquisition of diagnostic competence mediated by metacognitive competence in medical education?

Metacognitive competence is necessary for successfully adapting feedback to one's own need. To decide on the usefulness of adaptable feedback for fostering diagnostic competence in future physicians it is necessary to know if only learners with a high metacognitive competence can profit from this adaptability.

(RQ5) What are the effects of two scaffolding methods (self-explanation prompts and adaptable feedback) on cognitive load in medical education?

(RQ6) Are the effects of self-explanation prompts on the acquisition of diagnostic competence mediated by cognitive load in medical education?

It is also unclear to what extent additional scaffolding might affect cognitive load. While learning a complex task such a to diagnose patients, self-explanation prompts could possibly overload cognitive capacity due to high processing demands (Berthold et al., 2011; Renkl, in press). To analyze this effect, it is investigated if cognitive load mediates the influence of self-explanation prompts on diagnostic competence in research question 6.

5.3 Method

5.3.1 Sample and Design

The study sample consisted of N=103 medical students from a German university that voluntarily participated in this study. Participants were all in the clinical years of the curriculum. On average the participants were 25.54 years old (*SD* = 3.27). Among them 49 % were male and 51 % were female. The data of 5 participants needed to be removed prior to the following analysis, as they did not follow the instructions e.g., they did not give answers to the self-explanation prompts. The resulting sample thus consisted of N=98 participants.

A 2 x 2 factorial design with the factors self-explanation prompts (with vs. without) and adaptable feedback (with vs. without) was implemented (see Table 1). The subjects were randomly assigned to one of the four experimental conditions.

Table 1: *Design of the study in medicine*

Adaptable feedback	Self-explanation prompts	
	With	Without
With	25	25
Without	25	23

5.3.2 Learning Environment

The case materials were text-based worked examples. The learners worked individually in a computer-based learning environment. They were asked to immerse themselves with a fictitious student apprentice working with an experienced doctor. The fictitious student apprentice was diagnosing patients during that time. While diagnosing the fictitious student apprentice commits errors. For an example see Figure 1. The context of the error is: *“Mr. Drexel collapsed earlier. An ECG did not show any conspicuity besides some supraventricular extrasystole”*

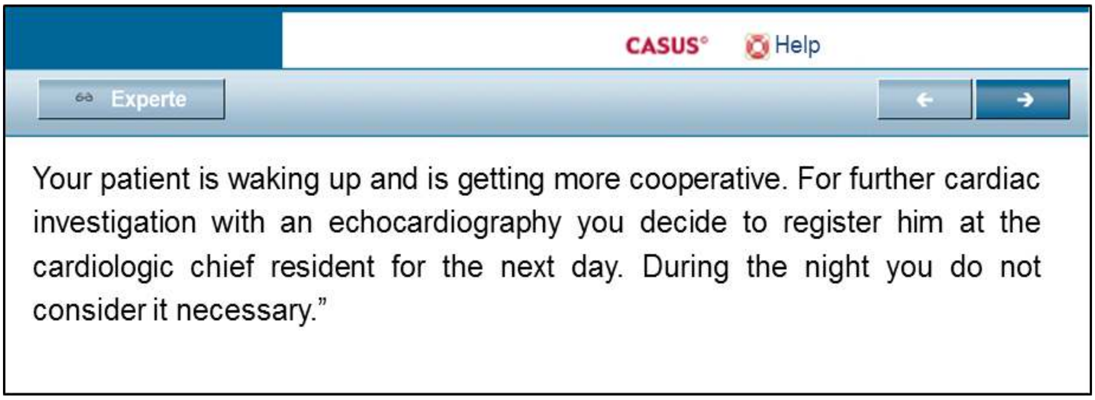

Figure 1: *Error of the fictitious medical student*

In the condition with self-explanation prompts students were prompted to think about the errors afterwards. The experienced physician in the worked examples gave feedback after each erroneous step of the fictitious student apprentice. The worked examples including the errors were developed and improved by experienced physicians. The erroneous worked examples were implemented into the computer-supported learning environment 'CASUS' (M. Fischer, 2000). For an example case see Appendix A.

5.3.3 Procedure

First, an explanation of the purpose and the procedure of the study took place by the experimenter. Then each participant watched a short video in which the learning environment was explained. Subsequently participants filled out a questionnaire for demographic and other control variables such as prior knowledge and metacognitive competence. Afterwards the medical students continued with the prior knowledge test on diagnostic competence on the computer and solved six key feature and six knowledge-decomposition tasks. This was followed by an individual learning phase in which the learner studied three of the already described worked examples in the online learning environment. After the individual learning phase students filled out process questionnaires in which cognitive load and motivation was assed. Hereafter, online posttests for strategic and conditional knowledge were administered. Finally a paper-based posttest for declarative-conceptual knowledge was completed by the learners. For an overview on the procedure and the duration of the steps see Table 2.

Table 2: *Procedures and durations*

Procedure	Planned Duration in Minutes (minutes cumulated)	
Introduction by experimenter	10	(10)
Video	5	(15)
Pretest Paper-based	10	(25)
Pretest Online	40	(65)
Individual learning phase 1	90	(155)
Process questionnaire time 2	5	(160)
Posttest Paper-based	10	(170)
Posttest Online	40	(210)

5.3.4 Experimental Conditions

Self-explanation prompts

After the erroneous step of the fictitious student apprentice, learners in the condition with self-explanation prompts students were prompted to think about the error. Three prompts were given successively (see Table 3 for examples).

Table 3: *Self-explanation prompts used in the learning environment*

Name of the prompt	Self-explanation prompt in the learning environment
1. Error-recognition prompt	*What can you criticize on this procedure and what would be the correct procedure?*
2. Problem-solving prompt	*Which problem solving strategy could have been applied to prevent the error?*
3. Knowledge-decomposition prompt	*What is the theoretical background for the correct behavior or what are the goals of the correct behavior?*

The first self-explanation prompt targeted on the recognition of the error, whereas the other two were focused on practical knowledge and targeted on the relation of scientific knowledge to cases of application. The second prompt focused on strategic knowledge *(see chapter 2.2 Operationalization of Diagnostic Competence, page 20)* and was thus more related to problem solving. The third prompt focused on conditional knowledge and required the learner to justify the correct behavior with the theoretical background based on scientific knowledge. Learners had to type their analysis after each prompt. For a screenshot see Figure 2.

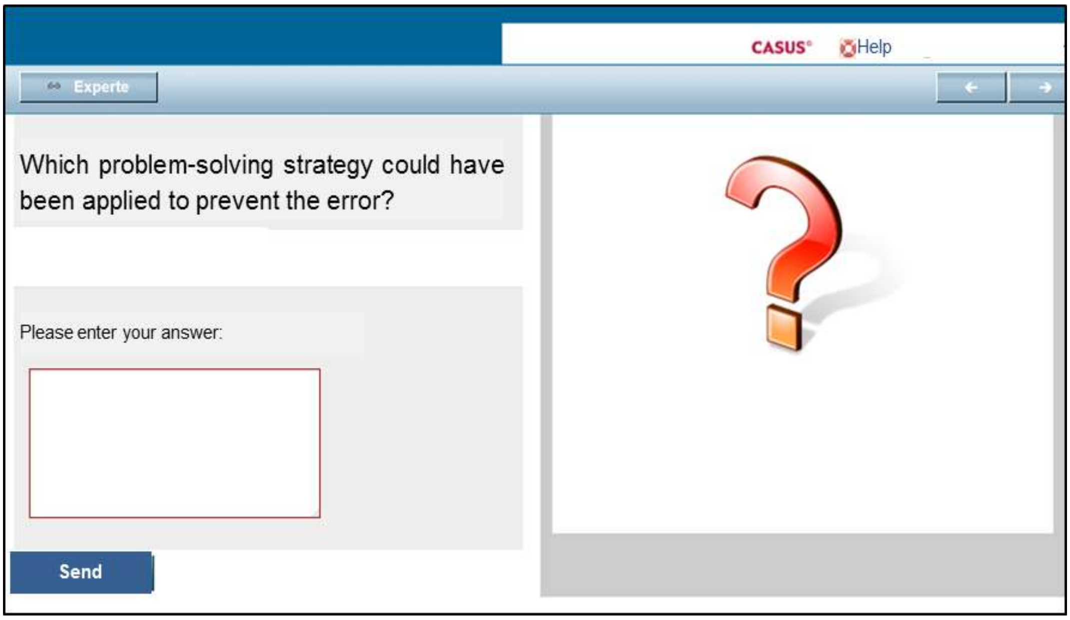

Figure 2: *Screenshot of the self-explanation prompt*

Adaptable Feedback

After the erroneous step of the fictitious student apprentice and depending on the condition after the prompts all learners got feedback from an experienced physician. For subjects in the condition with adaptable feedback, additional information was provided on three levels: The first level marked the error and included information or the right procedure to be taken. Level one feedback targeted on the recognition of the error and on the current progress being made. It answers the question "what progress is being made toward the goal?" (see Hattie & Timperley, 2007). An example is:

> *"You need to take Mr. Drexel's complaints seriously. That is in particular important as the frequency of syncopes increased. You should extent your diagnostic immediately."*

Feedback on level two additionally gave hints on problem-solving strategies and heuristics. Therefore it answers the question "what activities need to be undertaken to make better progress?" (see Hattie & Timperley, 2007). As the problem-solving prompt it targeted on strategic knowledge. An example is:

"In situations like that you should get a better idea over the LF function to exclude a heart valve defect using auscultation and an echocardiography. In addition you need to decide if the patient needs to go to intensive care. You should talk through the situation with the patient."

Level three feedback contained the theoretical background and the goals of the procedure. It answers the question "What are the goals?" (see Hattie & Timperley, 2007). As the knowledge-decomposition prompt is targeted on conditional knowledge. An example is:

"A relevant cause for slowly progressive dyspnea can be a dilative cardiomyopathie. […] Clinically, progressive left-heart failure with exertional dyspnea is leading in this case. […] In addition cardiac arrhythmias occur often. Those can reach from a single primarily ventricular extrasystole, to an absolute arrhythmia at auricular fibrillation up to a ventricular arrhythmia that acts on the circulation."

All learners in the adaptable feedback condition received feedback on level one automatically since recognizing an error as such is a central prerequisite for learning from it. Less advanced students should be enabled to identify the error as well. Feedback on levels two and three was only provided if learners clicked on a link to request it. Only then a new window opened in which the level two respectively level three feedback was given. For an example see Figure 3.

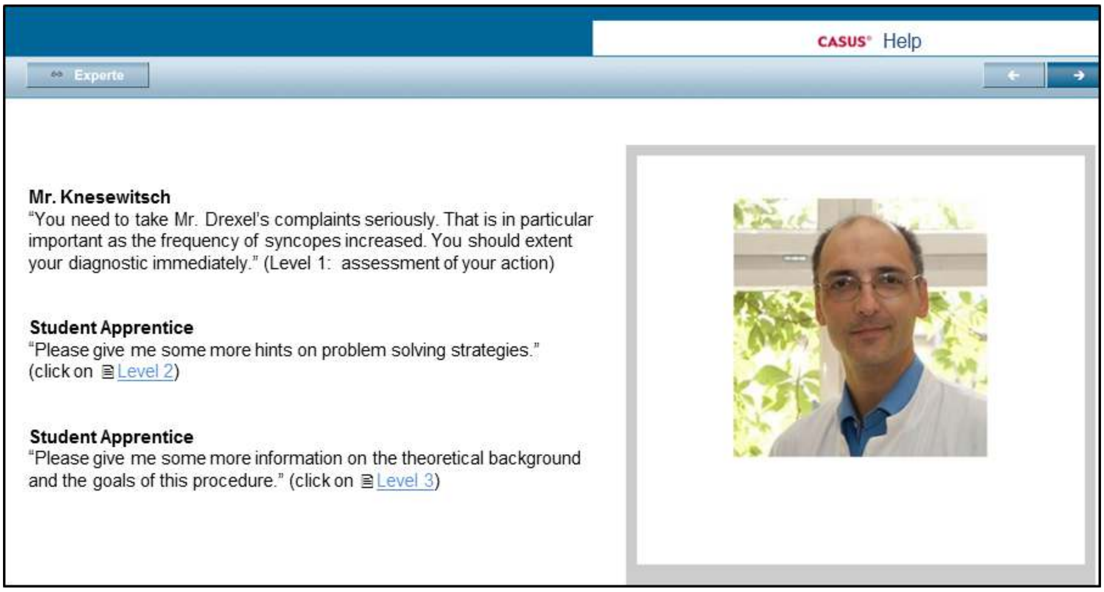

Figure 3: *Screenshot of the adaptable feedback*

Subjects without adaptable feedback received feedback, in which information on all three levels was provided simultaneously. This feedback can be regarded as elaborated feedback (Narciss, 2008).

5.3.5 Data Sources and Instruments

Pretest

Prior Diagnostic Competence: During the pretest prior diagnostic competence was assessed using the conceptualization of Stark and colleagues (2011) that differentiates (a) declarative-conceptual knowledge and (b) practical knowledge (consisting of strategic and conditional knowledge) *(see chapter 2.2 Operationalization of Diagnostic Competence, page 20)*. As professional knowledge is bound to contexts and situations (Borko, 2004; Seidel & Prenzel, 2007) an assessment of practical knowledge should make the application of knowledge to cases necessary to include situational and contextual features.

(a) Prior *declarative-conceptual knowledge* was measured through a 21 item multiple-choice questionnaire on cardiac failure (for an example item see Table 4). In the multiple-choice questionnaire zero to four answers were correct in every question. Learners received one point for every correctly marked or correctly not marked answer. During scale formation, nine questions had to be removed to increase the internal consistency. Maximum points that could be achieved were 48. Cronbach's α for the remaining 12 items was .55 (see Table 9). The test on declarative-conceptual knowledge can be found in Appendix B Test for Declarative-Conceptual Knowledge in Medicine.

Table 4: *Example item multiple-choice test to assess declarative-conceptual knowledge in medicine*

Which of the following description(s) is/are compatible with level III of the New York Heart Association (NYHA) classification?	
❍	no complaints at rest
❍	shortness of breath while rising or sitting
❍	anginose symptoms during daily gardening
❍	breathing pause after two staircases

(b) Practical knowledge was measured using key feature tasks (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) for conditional knowledge.

Strategic knowledge was measured with six key feature tasks. Three key feature tasks each were about one patient. After a short case vignette of a patient, learners had to derive consequences for further actions. An example can be seen in Table 5:

Table 5: *Example key feature tasks to assess strategic knowledge in medicine*

Initial patient vignette 1 *Ms. Weimer is 76 years old. She presents herself in the emergency department with dyspnea that is progressive since a few days ago and with an edema at the lower leg. The dyspnea also occurs during walking around her apartment. She denies a retrosternal feeling of pressure. She tells that her body weight increases slowly during the last weeks even though she is not eating more food.*
Question 1 *On which finding should you look in particular during the physical examination?*
Continued patient vignette 2 *During the examination you auscultate distinct, moist, inspiratory crackles in particular in the basal parts of the lungs on both sides. Radiological it shows a distinct pulmonary venous stasis in particular at left-ventricular heart enlargement. Echocardiographical a left-ventricular reduced pumping function can be shown.*
Question 2 *Which diuretic would you give to the patient?*
Continued patient vignette 3 *You give Ms. Weimer furosemide 40mg intravenously and decide to treat her in the hospital.*
Question 3 *Which other medication should you give to Ms. Weimer while she is treated in the hospital?*

The answers were rated by two raters and for each key feature task up to three points could be achieved. The more a student was able to relate scientific knowledge to the case the more points he or she got. The maximum score was 18 points. The intra-class correlation coefficient (ICC) was used for calculating the inter-rater agreement for the key feature tasks. The ICCs for the different key feature tasks all reached excellent values (ICC > .90). The ICCs can be seen in Table 7. The strategic knowledge test can be found in Appendix C .

Conditional knowledge was measured with six knowledge-decomposition tasks (Holmes et al., in press). Three knowledge-decomposition tasks were about one patient. A short patient vignette was presented. In addition it was described how a physician reacted on that situation. Students were asked why the reaction of the physicians can reach a correct solution based on their scientific knowledge. To correctly answer these items a deep and fine grained understanding is necessary (Holmes et al., in press). Knowledge-decomposition tasks were successfully used in different studies on invention activities to assess learning outcomes (Holmes et al., in press; Roll, Aleven, McLaren, & Koedinger, 2011). An example for a knowledge-decomposition task can be seen in Table 6. The strategic knowledge test can be found in Appendix C .

Table 6: *Example knowledge-decomposition tasks to asses conditional knowledge in medicine*

Initial patient vignette 1 *Your next patient on the ward round is Mr. Block, an eighty-year-old patient with heart failure. He moans, "in earlier times I could at least walk without problems and only had shortness of breath and palpitation climbing stairs. But now walking around outside and in my apartment causes problems and carrying a shopping bag is not possible anymore. Immediately I get dizzy and I cannot breath. I then think I might die instantly." You immediately recognize that you patient is very worried. The patient lives alone, and from his medical history a cardiologic clarified heart failure and an arterial hypertonia is known. There is no thyroid disease.*
Question 1 *Why does it make sense to ask for a thyroid disease?*
Continued patient vignette 2 *You explain to Mr. Block that a physical examination is necessary for the diagnostic and therapeutic assessment of his anamnestic NYHA III level.* *At the examination you find:* • *RR 155 / 99 mmHg, pulse 96 / min* • *distinct ankle edema on both sides* • *congested jugular veins* • *3. heart sound / translocated apical impulse* • *basal pulmonary crackles* *Upon request Mr. Block explains that he gained weight. He took the medication against his heart failure regularly. You cannot find signs of a thyroid disease. You do also not have the impression that he has an acute heart ischemia. As a next step you plan further lab diagnostic (blood glucose, hemogram, GPT, sodium, potassium, BNP, CK, CK-MB, troponin I, TSH, creatinine, and urin analysis) and an ECG.*
Question 2 *Please explain why an ECG makes sense?*
Continued patient vignette 3 *In the ECG the Sokolow-Lyon index is with S in V1 + R in V5>3,5 mV increased. The lab diagnostic is to a large extent normal. In the echocardiography typical sings of an advanced systolic heart failure show. The heart failure seems to have deteriorated*

since the last examination. The medication needs to get adjusted to the new situation. In addition you explain to Mr. Block basic behaviors such as to weight himself on a daily basis.
Question 3 *Why is the daily management of weight meaningful?*

Again, answers were rated by two raters and again up to three points could be achieved. The maximum score was 18 points. The ICCs for the different knowledge-decomposition tasks for conditional knowledge ranged from good (ICC = .64) to excellent values (ICC = .96). For ICCs see Table 7.

Table 7: *ICCs in the key feature and knowledge-decomposition task in the pretest in medicine*

Item	ICC
Pre key feature task 1.1	.97**
Pre key feature task 1.2	.95**
Pre key feature task 1.3	.94**
Pre key feature task 2.1	.91**
Pre key feature task 2.2	.96**
Pre key feature task 2.3	.96**
Pre knowledge-decomposition task 1.1	.95**
Pre knowledge-decomposition task 1.2	.96**
Pre knowledge-decomposition task 1.3	.96**
Pre knowledge-decomposition task 2.1	.96**
Pre knowledge-decomposition task 2.2	.64**
Pre knowledge-decomposition task 2.3	.91**

Note ** = $p < .01$, * = $p < .05$

The Cronbach's α for the key feature tasks and for the knowledge-decomposition tasks were low (key feature tasks, Cronbach's α = .37; knowledge-decomposition tasks, Cronbach's α = .46). The aggregated prior diagnostic competence had satisfactory Cronbach's α (see Table 9, page 71). It consisted of 14 MC-test items (7 items needed to be removed in order to increase internal consistency), six key feature tasks and six knowledge-decomposition tasks Maximum score of prior diagnostic competence was 92 points.

Metacognitive competence: Metacognitive competence was assessed with a questionnaire containing 27 items. An example item is "*If I do not progress during studying, I think about alternative strategies to study*.". The questionnaire has been successfully applied in previous studies (Krause, 2007; Stark, Tyroller, Krause, & Mandl, 2008). The questionnaire is oriented on different scales (e.g., the Motivated Strategies for Learning Questionnaire from Pintrich, Smith, Garcia, and McKeachie (1993). The responses were on a 6-point Likert scale. Answers were ranging from one (fully disagree) to six (fully agree). For metacognitive competence the score was computed based on the mean of the responses on all items (Cronbach's $\alpha = .92$; see Table 9). The test can be found in Appendix L Test for Metacognitive Competence.

Process data

Cognitive load: Cognitive load was assessed with an eight item subjective rating scale ranging from 1 (very easy) to 7 (very difficult) (Paas & Kalyuga, 2005). An example item is *''How easy or difficult do you find it to work with the learning environment?"*. With the sample of this study, it was not possible to differentiate different cognitive load aspects, as the sub-scales proposed by Paas and Kalyuga (2005) could not be replicated. For cognitive load the score was computed based on the mean of the responses on all items. Cronbach's α was satisfactory (see Table 9). The test can be found in Appendix M Test for Cognitive Load.

Motivation: Motivation was assessed with a questionnaire using 11 items from a questionnaire developed by Prenzel, Eitel, Holzbach, Schoenheinz, and Schweiberer (1993). The questionnaire is based on the self-determination theory (Deci & Ryan, 1993). An example item is "*So far I experienced myself as curious and inquisitive during studying in the learning environment*.". The items were answered using a rating scale ranging from zero (almost never) to three (very frequently). For motivation the score was computed based on the mean of the responses on all items. Cronbach's α was satisfactory (see Table 9). The test can be found in Appendix N Test for Motivation.

Processing time: The learning environment logged the time spent on each step (e.g., time spent on the three different prompts) while learners were studying the worked example. The time a learner spent watching a learning content in the computer-based learning environment can be interpreted as processing time of the presented content (Sánchez & García-Rodicio, 2013). Thus more time spent on the elaboration of a specific content can be regarded as an indicator for more intense processing (Sánchez & García-Rodicio, 2013)

Posttest

Diagnostic Competence: During the posttest diagnostic competence was assessed. Diagnostic competence consisted of (a) declarative-conceptual knowledge and (b) of practical knowledge aspects (see page 64).

(a) Declarative-conceptual knowledge in the posttest was assessed through a multiple-choice questionnaire. Nine items needed to be removed to increase internal

consistency. Some items from the multiple-choice questionnaire from the pretest are contained also in the post test. Maximum score was accordingly 52 points. Cronbach's α for the remaining 12 items was .56 (see Table 9). The test can be found in Appendix B Test for Declarative-Conceptual Knowledge in Medicine.

(b) Practical knowledge was again measured through key feature (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) (see page 64).

Strategic knowledge: In addition to the six key feature tasks used in the pretest additional 12 key feature tasks about four patients were used. Key Feature tasks make problem solving necessary and can be compared to problem-solving tasks used e.g. by Richey and Nokes-Malach (2013). The transfer taxonomy by Barnett and Ceci (2002) *(see chapter 2.3 Transfer, page 22)* can be used to classify learning task according to their need of transfer knowledge (Nokes-Malach et al., 2013). Key feature tasks here assess near transfer of content as the execution of prior problem solving procedures introduced in the worked examples need to be applied. The key feature tasks were similarly structured then the worked examples and required the application of knowledge to a similar problem with different surface features. Again, answers were rated by two raters and again a maximum of three points per key feature task could be achieved. The ICCs for the different key-feature tasks ranged from good (ICC = .73) to excellent values (ICC = 1.00). The ICCs can be seen in Table 8. Maximum score was 54 points. Cronbach's α was low (see Table 9). The strategic knowledge test can be found in Appendix C .

Conditional knowledge: In addition to the six knowledge-decomposition tasks used in the pretest additional 12 knowledge-decomposition tasks about four patients were used. Following again the transfer taxonomy by Barnett and Ceci (2002) *(see chapter 2.3 Transfer, page 22)* the used knowledge-decomposition tasks are intended to assess intermediate transfer of content as an individual not just performs what he or she learned in a similar situation to the learning situation but also needs to reflect on different alternatives. Hence a learner not only needs to know what he or she does, but also why. A learner has to know under which conditions a strategy can be used. Tasks in which deep conceptual understanding is necessary are considered even far transfer by some authors (Nokes-Malach et al., 2013; Richey & Nokes-Malach, 2013). Answers were rated by two raters and up to three points could be achieved in every task. The ICCs for the different key-feature tasks ranged from good (ICC = .66) to excellent values (ICC = .97). The ICCs can be seen in Table 8. Maximum score was accordingly 54 points. Cronbach's α was good (see Table 9). The conditional knowledge test can be found in Appendix D Test for Conditional Knowledge in Medicine.

For the aggregated measure practical knowledge (36 Items) consisting of the key feature tasks and of the knowledge-decomposition tasks the Cronbach's α was .76, and the maximum score 108.

Table 8: *ICCs in the key feature tasks and in the knowledge-decomposition tasks in the posttest in medicine*

Item	ICC
Post key feature task 1.1	.97**
Post key feature task 1.2	.95**
Post key feature task 1.3	.98**
Post key feature task 2.1	.73**
Post key feature task 2.2	.92**
Post key feature task 2.3	1.00**
Post key feature task 3.1	.92**
Post key feature task 3.2	.85**
Post key feature task 3.3	.94**
Post key feature task 4.1	.95**
Post key feature task 4.2	1.00**
Post key feature task 4.3	.93**
Post key feature task 5.1	.97**
Post key feature task 5.2	.96**
Post key feature task 5.3	.98**
Post key feature task 5.3	.93**
Post key feature task 5.3	.85**
Post key feature task 5.3	1,00**
Post knowledge-decomposition task 1.1	.90**
Post knowledge-decomposition task 1.2	.95**
Post knowledge-decomposition task 1.3	.90**
Post knowledge-decomposition task 2.1	.66**
Post knowledge-decomposition task 2.2	.88**
Post knowledge-decomposition task 2.3	.95**
Post knowledge-decomposition task 3.1	.90**
Post knowledge-decomposition task 3.2	.80**
Post knowledge-decomposition task 3.3	.94**
Post knowledge-decomposition task 4.1	.97**
Post knowledge-decomposition task 4.2	.97**
Post knowledge-decomposition task 4.3	.95**
Post knowledge-decomposition task 5.1	.84**
Post knowledge-decomposition task 5.2	.82**
Post knowledge-decomposition task 5.3	.77**
Post knowledge-decomposition task 6.1	.91**
Post knowledge-decomposition task 6.2	.73**
Post knowledge-decomposition task 6.3	.94**

Note ** = $p < .01$, * = $p < .05$

Bivariate correlations were calculated using Pearson's product-moment correlation between strategic and conditional knowledge was moderate (r = .41, p < .01). The correlation between declarative-conceptual knowledge and conditional knowledge was also moderate ($r = .34$, $p < .01$). The correlations between declarative-conceptual knowledge and strategic knowledge was low ($r = .12$, $p = .225$).

Table 9: *Instruments, internal consistencies. Medicine*

Measures	Cronbach's α
Pretest	
Prior diagnostic competence	.69
Declarative-conceptual knowledge	.55
Strategic knowledge	.37
Conditional knowledge	.46
Metacognitive competence	.92
Process	
Cognitive load	.79
Motivation	.78
Posttests	
Diagnostic competence	
Declarative-conceptual knowledge	.56
Practical knowledge	.76
Strategic knowledge	.51
Conditional knowledge	.85

5.3.6 Statistical Analysis

The alpha level of .05 was used for the statistical analyses. Partial eta^2 was used as a measure of effect size; values of about .01 are considered as weak effect size, of about .06 as medium, and of about .14 or higher as large (Cohen, 1988). Bivariate correlations were calculated using Pearson's product-moment correlation: values of.01 are considered small, of about .30 as medium, and of above .50 as large (Cohen, 1988). In addition MANCOVAs, ANCOVAs, ANOVAs and t-tests were used. Post-hoc comparisons were conducted using linear independent, pairwise and Bonferroni-adjusted contrasts. In case of unequal variances a Kruskal-Walis test with follow-up Man-Whitney tests were applied. For the two mediation analysis in research questions four and six the causal steps strategy by (Baron & Kenny, 1986) and the products of coefficients approach (MacKinnon, Fairchild, & Fritz, 2007; Preacher & Hayes, 2008; Sobel, 1986) was used. According to the causal steps strategy, a variable (e.g., metacognitive competence) is a mediator of the effects of an independent variable (e.g., adaptable feedback) on a dependent variable (e.g., diagnostic competence) if four conditions are met: (a) the independent variable (adaptable feedback) must affect the dependent variable (diagnostic competence). (b) the independent variable (adaptable feedback) must affect the potential mediator (metacognitive competence), (c) the mediating variable (metacognitive competence) must affect the dependent variable (diagnostic competence) when both the independent variable (adaptable feedback) and mediating variable (metacognitive competence) are predictors of the dependent variable (diagnostic competence), and (d) the effect of the independent variable (adaptable feedback) on the dependent variable (diagnostic competence) should be substantially reduced (partial mediation) or zero (complete mediation) when the mediator is included as an additional predictor of the dependent variable (MacKinnon et al., 2007; Preacher & Hayes, 2008).

5.4 Results

5.4.1 Preliminary Analyses

No differences concerning in prior diagnostic knowledge ($F(3, 94) = 1.17$, $p = .33$), and metacognitive competence ($F(3, 94) = .55$, $p = .71$) were found between the four experimental conditions prior to the experiment. For descriptive values please see Table 10, page 73).

The correlations of prior knowledge with diagnostic competence were significant and high indicating a pre to posttest gain (for declarative-conceptual knowledge, $r = .37$, $p < .01$; for strategic knowledge, $r = .41$, $p < .01$; for conditional knowledge, $r = .40$, $p < .01$).

Regarding the effect of self-explanation prompts and adaptable feedback on time-on-task, the Levene's test for equality of variances was found to be significant for the present analysis ($F(3, 94) = 5.66$, $p < .01$) indicating unequal variances. In addition Hartley's variance ratio shows a value of $F_{max} = 7.94$ and is thus above the critical value (Pearson & Hartley, 1976), further indicating substantial differences in variance. Therefore a Kruskal–Wallis test, with follow-up Man-Whitney tests were applied. The experimental variation through self-explanation prompts (with and without) and adaptable feedback (with and without) were significantly affecting time-on-task ($H(3) = 64.18$, $p < .01$). Mann–Whitney tests were used to follow-up this finding. A Bonferroni correction was applied and so all effects are reported at a .025 level. Self-explanation prompts did affect time-on task ($U = 77$, $p < .01$). In contrast adaptable feedback had no effect on time-on-task ($U = 191$, $p = .41$). That is learners with self-explanation prompts learned longer than learners without, however, adaptable feedback had no additional effect on the learning time and also the two measures did not interact with each other regarding the learning time (for descriptive data see Table 10). Time-on-task was not significantly correlated to diagnostic competence (for declarative-conceptual knowledge, r = .02, p = .85; for strategic knowledge, r = .05, p = .61; for conditional knowledge, r = .13, p = .21).

Table 10: *Means and (SD) of prior diagnostic competence, prior declarative-conceptual knowledge, metacognitive competence, cognitive load, motivation, time-on-task, diagnostic competence, declarative-conceptual knowledge, practical knowledge, strategic knowledge, and conditional knowledge in medicine*

	With self-explanation prompts		Without self-explanation prompts	
	With adaptable feedback (n = 25)	Without adaptable feedback (n = 25)	With adaptable feedback (n = 25)	Without adaptable feedback (n = 23)
Prior diagnostic competence	52.96 (6.13)	52.04 (4.97)	54.34 (5.15)	54.35 (4.20)
Metacognitive competence	4.43 (.50)	4.63 (.48)	4.52 (0.64)	4.50 (.68)
Cognitive load	3.75 (.63)	3.81 (.63)	3.35 (0.77)	3.67 (.82)
Motivation	2.75 (.41)	2.67 (.53)	2.58 (0.57)	2.63 (.37)
Time-on-task	59.92 (22.08)	63.88 (21.44)	26.68 (10.08)	27.92 (7.83)
Diagnostic competence				
Declarative-conceptual knowledge	37.72 (3.68)	38.36 (3.89)	39.52 (3.34)	38.09 (5.29)
Practical knowledge	41.64 (5.71)	37.64 (5.17)	39.94 (5.32)	39.48 (5.33)
Strategic knowledge	21.84 (3.15)	20.06 (2.33)	21.42 (3.01)	20.91 (2.49)
Conditional knowledge	19.80 (3.59)	17.58 (3.67)	18.52 (3.44)	18.57 (4.04)

5.4.2 Effect on Diagnostic Competence (RQ1)

For descriptive data on the diagnostic competence measures in the four conditions see Table 10. To test if the combination of self-explanation prompts and adaptable feedback can facilitate learning of diagnostic competence, a MANCOVA with self-explanation prompts and adaptable feedback as independent variable, diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) as dependent variable and prior knowledge a covariate was conducted. The MANCOVA showed that the interaction between the self-explanation prompts and the adaptable feedback was not significant Wilks's λ = .94, $F(3, 91)$ = 2.01, p = .12. Further the MANCOVA showed no multivariate effect of self-explanation prompts on diagnostic competence (Wilks's λ = .99, $F(3, 91)$ = .43, p = .73) and of adaptable feedback on diagnostic competence (Wilks's λ = .95, $F(3, 91)$ = 1.61, p = .19).

The next steps in the analytic strategy addressed the different component variables of diagnostic competence. To test the effect of the two independent variables (self-explanation prompts and adaptable feedback) on the dependent variables declarative-conceptual knowledge, strategic knowledge, and conditional knowledge, three ANCOVAs with prior diagnostic competence as a covariate were calculated.

Declarative-conceptual knowledge: The first ANCOVA with self-explanation prompts and adaptable feedback as independent, declarative-conceptual knowledge as dependent variable and prior diagnostic competence as covariate showed a significant Levene's test ($F(3, 94) = 2.90$, $p < .05$) indicating unequal variances. Hartley's variance ratio in contrary shows a value of $F_{max} = 2.50$ and is thus under the critical value (Pearson & Hartley, 1976) indicating no substantial differences in variance. Still the results of this analysis should be interpreted with caution. The ANCOVA showed no significant interaction effect of self-explanation prompts and adaptable feedback on declarative-conceptual knowledge ($F(1, 93) = 2.27$, $p = .13$). As this analysis did not reveal an interaction effect, the main effects of self-explanation prompts and adaptable feedback on declarative-conceptual knowledge were tested while prior diagnostic competence was controlled. The ANCOVA showed no effect of self-explanation prompts ($F(1, 93) = .09$, p = .77) or adaptable feedback ($F(1, 93) = .19$, p = .73). Planned contrasts revealed no significant group differences between any of the groups.

Practical knowledge: Three ANCOVAs with self-explanation prompts and adaptable feedback as independent, prior diagnostic competence as covariate and strategic, conditional knowledge, or practical knowledge as dependent variable did not reveal a significant interaction effect of self-explanation prompts and adaptable feedback on strategic knowledge ($F(1, 93) = 1.08$, $p = .30$), conditional knowledge ($F(1, 93) = 2.13$, $p = .15$) and on the aggregated measure practical knowledge ($F(1, 93) = 2.59$, $p = .59$). As this analysis did not reveal an interaction effect, the main effects of self-explanation prompts and adaptable feedback were tested while prior diagnostic competence was controlled. No significant effect of self-explanation prompts on strategic knowledge ($F(1, 93) = .16$, $p = .69$), conditional knowledge ($F(1, 93) = .98$, $p = .33$) and practical knowledge ($F(1, 93) = .86$, $p = .36$) was shown. Also no significant effect of adaptable feedback on conditional knowledge ($F(1, 93) = 1.95$, $p = .17$) was shown. However, learner who learned with self-explanation prompts and with adaptable feedback ($M = 19.80$; $SD = 3.59$) acquired more conditional knowledge than learners with self-explanation prompts and without adaptable feedback *(*$M = 17.58$, $SD = 3.67$, post-hoc comparison $p < .05$). The ANCOVA did show a small significant effect of adaptable feedback on strategic knowledge ($F(1, 93) = 4.15$ $p < .05$, *partial* $\eta^2 = .04$) (see Figure 4) and on practical knowledge ($F(1, 93) = 4.41$ $p < .05$, *partial* $\eta^2 = .05$) (see Figure 5).

A Bonferroni correction was applied and so all effects are reported at a .025 level. The results showed that in the condition with adaptable feedback acquired more practical knowledge on a descriptive level ($M = 40.79$; $SD = 5.53$) than learners in the condition without adaptable feedback ($M = 38.52$, $SD = 5.28$, post-hoc comparison $p = .038$).

Learner who learned with self-explanation prompts and with adaptable feedback acquired more practical knowledge (M = 41.67; SD = 5.71) than learners with self-explanation prompts and without adaptable feedback (practical knowledge: M = 37.64, SD = 5.17, post-hoc comparison $p < .01$).

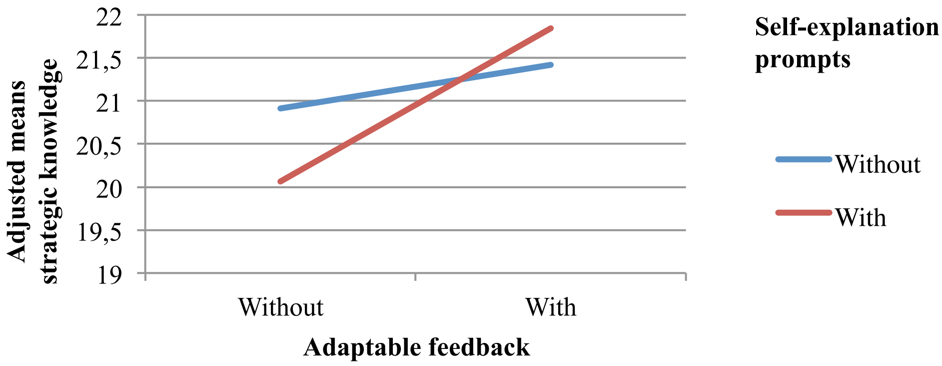

Figure 4: *Adjusted means of strategic knowledge in the four experimental conditions in medicine*

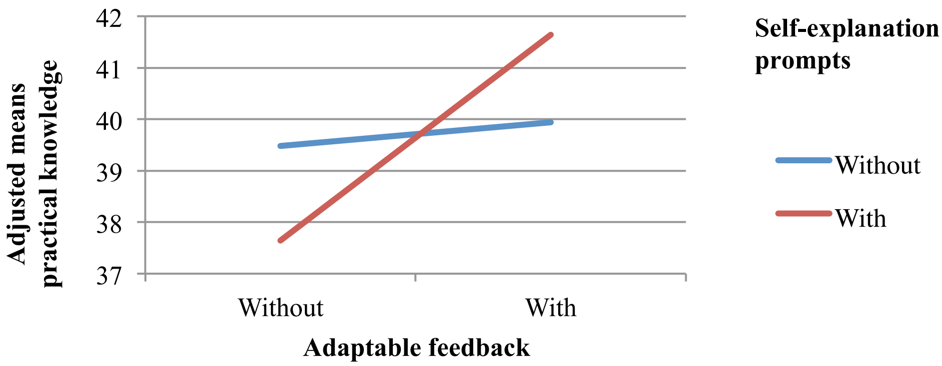

Figure 5: *Adjusted means of practical knowledge in the four experimental conditions in medicine*

To answer research question one it can be said, self-explanation prompts had no significant effect on diagnostic competence. Adaptable feedback had a positive main effect on strategic and practical knowledge but not on conditional knowledge. The combination of self-explanation prompts had no effect on diagnostic competence.

5.4.3 Type of Prompt (RQ2)

To analyze the relation of the three different prompts with the types of knowledge contained in the model of diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge), bivariate correlations were calculated using

Pearson's product-moment correlation. The two variables used for that calculation were (1) the automatically logged time a learner spent answering the three prompts and (2) diagnostic competence. The time the learner spent on answering the prompts is interpreted as processing time similar as in the study by Sánchez and García-Rodicio (2013). More time used for answering a specific prompt can be regarded as an indicator for more intense processing (Sánchez & García-Rodicio, 2013). There was no significant correlation between the time spent on the problem-solving prompt (see Table 11). There were significant, medium, positive correlations between the time spend on the error-recognition prompt and conditional knowledge ($r = .37, p < .01$) as well as on practical knowledge ($r = .35, p < .05$). There also were significant, medium, positive correlations between the time spend on the knowledge-decomposition prompt and conditional knowledge ($r = .38, p < .01$), and practical knowledge ($r = .36, p < .01$).

Table 11: *Correlations between time on the three prompts with diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) in medicine*

	Pearson's Correlation (two tailed)		
	Time on error-recognition prompt	Time on problem solving prompt	Time on knowledge-decomposition prompt
Declarative-conceptual knowledge	.10	.15	.09
Practical knowledge	.35*	.19	.36**
Strategic knowledge	.21	.17	.23
Conditional knowledge	.37**	.17	.38**

Note ** = $p < .01$, * = $p < .05$

In sum, the three self-explanation prompts had differentiated effects on diagnostic competence. Whereas the self-explanation prompt that targeted on problem solving was not positively associated with diagnostic competence, the self-explanation prompts that targeted on error-recognition and on conditional knowledge were positively related with the acquisition of conditional knowledge and practical knowledge.

5.4.4 *Effect of Adaptable Feedback on Motivation (RQ3)*

To analyze the effect of adaptable feedback on motivation an independent t-test with adaptable feedback as independent and motivation as dependent variable was calculated. The t-test showed no difference between those groups ($t(96) = -.202$, p = .84). That is the group with adaptable feedback ($M = 2.67$, $SD = .50$) was equally motivated than the group without adaptable feedback ($M = 2.65$, $SD = .46$). To answer research question three it can be said, that motivation could not be increased by the use of adaptable feedback.

5.4.5 Mediation by Metacognitive Competence (RQ4)

With respect to research questions four, a possible mediation of metacognitive competence between the potential effects of adaptable feedback on the acquisition of diagnostic competence was investigated. To test the potential mediation the causal steps strategy by (Baron & Kenny, 1986) and the products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986) is used (for an explanation see *chapter 5.3.6 Statistical Analysis, page 71).*

(a) Adaptable feedback accounted for 4.3 % of the variance of practical knowledge, $F(1, 96) = 4.32$, $p < .05$ and also for 4.3 % of the variance of strategic knowledge, $F(1, 96) = 4.32$, $p < .05$. The other diagnostic competence components were not significantly affected by adaptable feedback (declarative-conceptual knowledge, $F(1, 96) = 2.22$, p = .64.; conditional knowledge, $F(1, 96) = 2.21$, $p = .14$.).

(b) Adaptable feedback did not affect metacognitive competence significantly ($F(1, 96) = .71$, $p = .40$). This indicates no mediation of metacognitive competence can be shown.

5.4.6 Effect of Cognitive Load (RQ5)

Germane cognitive load correlated negatively with diagnostic competence ($r = -.34$, $p < .01$) indicating that the sub-scales proposed by Paas and Kalyuga (2005) could not be replicated with this sample of medical students. Thus in the following cognitive load is treated as aggregated measure.

Cognitive load correlated negatively with practical knowledge ($r = -.21$, $p < .05$), strategic knowledge ($r = -.25$, $p < .05$), and with conditional knowledge ($r = -.28$, $p < .01$). Cognitive load did not significantly correlate with declarative-conceptual knowledge ($r = -.03$, $p = .75$). Learners who experienced a higher cognitive load acquired accordingly less practical knowledge whereas the declarative-conceptual knowledge was unaffected.

A correlation between cognitive load and prior diagnostic competence was not significant ($r = -.15$, $p = .14$) indicating learners experienced cognitive load independently from their prior knowledge.

Descriptive data on cognitive load in the four conditions can be found in Table 10, page 73. To test if self-explanation prompts and adaptable feedback (independent variables) had an influence on cognitive load (dependent variable) an ANOVA was calculated.

The ANOVA did not show a main effect of self-explanation prompts ($F(1, 94) = 3.37, p = .07$) and of adaptable feedback ($F(1, 94) = 1.82, p = .18$) on cognitive load. Also no interaction of self-explanation prompts and adaptable feedback on cognitive load showed ($F(1, 94) = .87, p = .35$).

To answer research question five it can be concluded the scaffolding used in the study (self-explanation prompts and adaptable feedback) did not influence cognitive load significantly.

5.4.7 Mediation of Cognitive Load (RQ6)

To answer research questions 6 again the procedure already used by Roelle and colleagues (in press) was used (see page 77). However, as another analysis on research question one (see page 73) already revealed that the independent variable (self-explanation prompts) did not affect the dependent variable (diagnostic competence) significantly the first of Baron and Kenny's (1986) causal steps was not met. Therefore it can be concluded that a mediation of cognitive load cannot be shown.

5.5 Discussion

In a computer-based learning environment in which erroneous worked examples were implemented it was investigated if two instructional support methods, scaffolding with self-explanation prompts and adaptable feedback, would foster learning of diagnostic competence in future physicians.

The preliminary analyses found no differences concerning prior diagnostic competence and metacognitive competence prior to the study. A high correlation was found between diagnostic competence in the pretest and in the posttest, indicating a gain in diagnostic competence and a low influence of the self-explanation prompts and of adaptable feedback on diagnostic competence. Adaptable feedback had no effect on time-on-task. Learners did spend an equal amount of time receiving feedback. Whereas in other studies (e.g. Corbett & Anderson, 2001) learners did not use feedback provided on demand, in this learning environment, learners did not fade out the feedback, even though that would have been possible. Self-explanation prompts, in contrast more than doubled the learning time. The learning time did not predict the acquisition of diagnostic competence.

First, short summaries of findings on the different research questions are presented. Regarding research question one, contrary to the assumption presented, self-explanation prompts did not have an effect on the acquisition of diagnostic competence (declarative-conceptual, strategic, and conditional knowledge). Adaptable feedback had no effect on the acquisition of declarative-conceptual, and on conditional knowledge, but in contrast had a positive effect on strategic knowledge. The effects mainly indicate that learners who learned with both scaffolds outperformed their fellow students in the condition with self-explanation only (RQ 1). The three self-explanation prompts had differentiated effects on diagnostic competence. The self-explanation prompt that targeted on problem solving was not positively associated with diagnostic competence. The two self-explanation prompts that targeted on error-recognition and on conditional knowledge were positively related with the acquisition of conditional knowledge (RQ 2). Regarding the effect of adaptable feedback it can be said that making feedback adaptable could not increase the motivation of the learners (RQ 3). Metacognitive competence did not mediate the relation of adaptable feedback and diagnostic competence (RQ 4). Regarding cognitive load it can be said that learners who experienced a higher cognitive load acquired less practical knowledge whereas the declarative-conceptual knowledge was unaffected. Learners experienced cognitive load independently from their prior knowledge. Cognitive load was not affected by any of the scaffolds and was thus no mediator of the relation between self-explanation prompts and diagnostic competence (RQ 5 + 6)

One of the dangers to provide self-explanation prompts and on-demand help together is that the combination can decrease the self-explanation activity of the learners as found in other studies (e.g. Schworm & Renkl, 2006). It is possible that also in the present study the availability of feedback decreased the amount of self-explanation activity that learners were willing to invest. A similar findings is known from feedback research: availability of a correct solution reduces the effort to figure out the correct solution by oneself and thus can reduce the learning outcomes (Kulhavy, 1977).

Prompts have the goal to direct a learners' attention and to induce strategies that a learner is capable of but does not show by his or her own (Pressley et al., 1992). In case of learning with erroneous worked examples, that is to guide the learners' attention to self-explaining the errors and their underlying principles. A possible reason why self-explanations prompts failed to increase learning of diagnostic competence may be that there was no need to guide learners' attention to the explanation of the error as the mere inclusion and the provided feedback could already be enough guidance. Another consideration could be that the self-explanation prompts from a theoretical perspective are assumed to help learners realize their lack of understanding (Renkl, 2002). It is possible that this is not true in case of learning from errors. It may be the case that self-explanation prompts cannot help the learner any further with this regard, as through the errors in combination with feedback learners may already have recognized their lack of understanding and further prompting was not necessary. Another benefit that is usually assumed for self-explanation prompts is to prevent from passive processing of worked examples (Renkl, in press). Again through the errors passive processing could have been avoided without prompting. Self-explanation prompts are generally assumed to have a positive effect on learning (see chapter *3.2.1 Self-Explanation Prompts*). However, they pose a high demand on the learner in particular if combined with other demands such as with processing errors. Also in other studies were self-explanation prompts were combined with e.g., gaps in a worked example they could not increase learning (Gerjets et al., 2006; Hilbert et al., 2008). In contrast to these studies in this study none of the scaffolds had an effect on cognitive load. Indicating that the self-explanation prompts did in fact not pose a cognitive load that was detrimental for learning. At a first glance it seems as self-explanation prompts in erroneous worked examples that provide feedback could be dispensable. Keeping in mind expertise research it nonetheless might be important to let students face realistic cases and include reflective elements to the cases in order to prevent a skill from premature automatization (Ericsson, 2006). Maybe the types of prompts were not optimal to reach that.

The hypothesis that, a prompt focusing on problem solving would have an effect on strategic knowledge and a prompt focusing on the understanding of why a procedure was performed has positive effects on practical knowledge was not confirmed. In contrast to a study by Berthold, Röder, Knörzer, Kessler and Renkl (2011), in the present study, the error-detection prompt that was targeting on error-recognition as well as the knowledge-decomposition prompts that targeted on the underlying principles was positively related to practical knowledge and particularly to conditional knowledge. As learners need to be aware of an error and understand it in order to be able to learn from it (Schank, 1999) it is not surprising that prompting these procedures can help to learn from an error at least on a conceptual level. Both prompts had no effect on strategic knowledge and thus on problem solving performance. A prompt that targeted on problem-solving strategies was not related to diagnostic competence at all. This findings support the claim that self-explanation are beneficial if they direct the attention of the leaner to the connection of the case and its underlying principles (Renkl, in press). To increase problem-solving performance prompting with a focus on principles might not be useful. Another type of prompt seems to be necessary if prompting can help in this regard at all.

Some authors assume that also incorrect and fragmented self-explanations can increase learning (Chi, 2000), whereas other authors state that this is only true if a high percentage of self-explanations are correct (Aleven & Koedinger, 2002). It is not unlikely that in a complex field such as in the diagnosis of patient's illnesses the percentage of correct self-explanations was too little to have an impact on learning. However, learners could have used the feedback to close gaps in their knowledge. It is however interesting that the main difference in learning of diagnostic competence was between the group that learned with both scaffolds and the one that learned with only self-explanations.

At a first glance it may be surprising that no effect of the two scaffolds on conditional knowledge was shown. A reason might be that for the explanation why a procedure can reach its goals farer transfer is necessary than for solving problems with a similar structure such as in the key feature tasks (Barnett & Ceci, 2002). Accordingly, the result might reflect a lack of transfer.

Adaptable feedback had no effect on the acquisition of declarative-conceptual and on conditional knowledge, but a positive effect on strategic knowledge. Strategic knowledge in this study was assessed with problem-solving tasks. To let learners decide on the amount of feedback they need, thus seem to have increased their ability to solve problems later but did not lead to better conceptual understanding. Learners in this study in contrast to other studies (Aleven et al., 2003) seemed to be able to seek help when needed. The relation of adaptable feedback and diagnostic competence was not mediated by metacognitive competence indicating that not only learners with high metacognitive competence but also those with less favorable metacognitive competence were able to adapt the feedback to their needs. More learner control is often associated with positive effects on motivation (Scheiter & Gerjets, 2007), but in this study this effect was not found. It might be that in a highly structured learning environment with worked example, to let learners only decide on the content of the feedback was simply not enough learner control to increase motivation.

Self-explaining worked examples can prevent learners from developing procedural knowledge and focus the attention of a learner more on conceptual understanding (Nokes-Malach et al., 2013). The findings from the presented study are in some contrast to that, as learners did not develop more conditional knowledge for which deep conceptual understanding is necessary. They thus not seemed to have concentrated on the development of conceptual understanding but rather on developing problem solving skills as indicated by the gain in strategic knowledge in particular in the group that learned with both scaffolds. Following the stage model of expertise development with more experience with patient cases, in an intermediate stage the physician's knowledge gets encapsulated and illness scripts start to develop (H. Schmidt & Rikers, 2007). The lack of awareness of underlying principles reflected in the conditional knowledge may thus be an indication for an early intermediate stage of expertise development in which illness script make problem solving in form of diagnosing patients easier and less prone for errors and underlying features get less dominant. Learner might already have gained an understanding of underlying principles and concentrated more on the proceduralisation of knowledge. The adaptability of the feedback seemed to have fostered that process. Increased motivation was not the underlying mechanism for that, as adaptable feedback did not affect motivation. This might give support to Chi's (2009) claim that active activities can promote the integration of existing knowledge and new knowledge. Relating this findings to general feedback literature (Hattie & Timperley, 2007), targeting the feedback into recognizing a wrong procedure, in how to proceed and in what the goal of procedure is, might have helped the learner to recognize the relevant knowledge he or she needs. Adaptable feedback could have made it easier for learners to find relevant information without the need to scan through the whole elaborated feedback.

With the diagnostic competence model used for operationalization in this study differential effects of the two scaffolds on the three types of knowledge (declarative-conceptual, strategic and conditional knowledge) could be shown. Whereas declarative-conceptual and conditional knowledge was unaffected, strategic knowledge was fostered by adaptable feedback. Also regarding the different prompts it showed that only the prompt targeting on error-recognition and on conditional knowledge was positively related to conditional knowledge. The two types of practical knowledge were fostered by different instructional support. The only knowledge that was mostly unaffected was declarative-conceptual knowledge. Methodological problems could be the reason for that. Another explanation might be that in a case based reasoning approach knowledge of facts that is not related to cases might not play a major role. A model with the aim of fostering diagnostic competence might benefit from the differentiation in three types of knowledge; however, it is also conceivable to exclude mere factual knowledge that is represented in the declarative-conceptual knowledge.

The presented study has certain limitations which are discussed in *chapter 9.2 Limitations of the Studies on page 153* because they mainly concern all three studies (in medicine, in nursing and in teaching).

6 Study 2: Fostering Diagnostic Competence in Nursing

6.1 Context

Diagnostic competence is important in nursing (Banning, 2008; Lee et al., 2006). A lack of diagnostic competences can result in failure of noticing a critical patient condition and may endanger patients (Aiken et al., 2003). Diagnostic competence is a categorization task in which a patient condition is diagnosed on the basis of patient attributes (Buckingham & Adams, 2000a; Taylor, 1997). Different processes are involved in diagnosis such as collecting cues, and implementing interventions (Levett-Jones et al., 2010). In addition hypotheses are produced and weighted against each other (Simmons, 2010). The process seems to be similar to the process in medicine (Simmons et al., 2003).

In recent approaches on the processing of diagnostic situations, diagnostic competence in medicine is described with an integrated model in which analytical and non-analytical processing are involved (Croskerry, 2009; Eva, 2004). Non-analytical processing is in particular important in an early stage for building hypotheses, whereas at a later stage for testing hypotheses or in complex, unfamiliar cases analytical processing is more important (Eva, 2004). If the same can also be assumed for nursing is so far not well researched.

The development of diagnostic competence in nursing can similar to medicine be described in terms of knowledge encapsulation and building of scripts (Buckingham & Adams, 2000b) (see 2.1.2 Diagnostic Competence in Nursing). Novices in nursing show rule-based behavior (Benner et al., 2009). With more experience advanced beginners can recognize relevant cues easier. Later in the expertise development underlying concepts are becoming unconscious in routine cases. A nurse can respond intuitively through the recognition of patterns (Benner et al., 2009). It can be concluded that in both medical domains, expertise development is described in a similar way in current research. For a more detailed explanation see *chapter 2.1.1 Diagnostic Competence in Medicine, page 3.* The described stage model of expertise in nursing same as the stage model in medicine lacks the perspective how expertise development can be fostered. Other expertise models such as the model of domain learning (Alexander, 1997; Alexander et al., 2009) can give an hints on important affective factors such as interest in expertise development. Not every learner becomes an expert even with enough experience (Ericsson, 2006). Cognitive processes usually become automatized after daily tasks can be solved sufficiently, Deliberate practice can prevent from automatization and hence a skill can be continuously developed (Ericsson, 2006). Important in deliberate practice is to reflect on the appropriateness of a procedure and how procedure can be improved. Accordingly, besides the experience from cases also a reflective element seems to be important for expertise development. Even though a high amount of daily work of nurse are routine cases, in particular in emergency situations that are unfamiliar to the nurse adaptive expertise may be of major importance. Certainly a nurse should also be able to deal with non-routine cases to ensure patient-safety.

In education of prospective nurses diagnostic competence is so far not taught adequately (Kuiper & Pesut, 2004; Levett-Jones et al., 2010; Murphy, 2004) maybe because only little empirical evidence on how to foster the acquisition of diagnostic competence can be found. However, it is likely that nursing students have similar problems applying their knowledge to practical situations than medical students have.

Empirical evidence from medical education on fostering the development of diagnostic competence, suggest that cases seem to be a promising (Charlin et al., 2000; Eva, 2004; Mamede et al., 2012; Norman, 2005; H. G. Schmidt & Rikers, 2007). This claim is also made by author in research in nursing (Dutra, 2013; Profetto-McGrath, 2005; Taylor, 1997). Deliberations on problem solving and how it can be learned are in line with a case-based approach (see chapter *3.1* Learning with Cases). Real life problems are ill-structured and could not be effective for learning particularly for novices without sufficient support (van Merriënboer, 2013). Guidance through adequate scaffolding can increase learning with complex cases (Hmelo-Silver et al., 2007). Worked examples could be a possibility to let also novices profit from learning with cases (van Gog et al., 2010). A promising method to prevent learners from passive processing of the worked examples is to include errors (Booth et al., 2013; Große & Renkl, 2004, 2007; Stark et al., 2011). Including errors themselves could in addition have some advantages for learning (see chapter *3.1.3 Learning with Erroneous Worked Examples)*. Learners with low prior knowledge may need support when learning with errors (Renkl, in press). Through sufficient scaffolding it may be possible, that also these learners can profit from erroneous worked examples. Two particularly promising scaffolds are: letting learners self-explain the error and providing learners with help to identify the underlying principles of an error.

6.2 Aims of this Study and Specific Research Questions

In the last study the effect of scaffolding on diagnostic competence in medicine was tested. To get an insight into the domain specificity of these effects a conceptual replication was conducted in nursing. Therefore the same research questions and the same methods than in medicine were used.

In this study, from general research questions one specific questions and hypotheses are formulated.

(RQ1) To what extent can two scaffolding methods (self-explanation prompts and adaptable feedback) facilitate diagnostic competence in nurse education?

Currently it is not known if self-explanation prompts focusing on diagnostic errors can foster diagnostic competence in prospective nurses. A positive influence is anticipated overall on the basis of the theoretical assumptions outlined in chapter *3.2.1 Self-Explanation Prompts*. The second scaffolding method that is investigated is adaptable feedback. Letting learners decide how much feedback he or she needs has certain advantages but could also hinder learning, as a learner needs adequate help-seeking skills that are not present in all learners. If the combination of self-explanation prompts and adaptable feedback is in particular positive for learning has not been systematically addressed by research so far. The two methods may interact positively because the combination might reduce illusions of understanding, provide learners that cannot find adequate self-explanations with the underlying principles of a problem and might foster active processing of the feedback. But there might also be limitations as the additional instruction could suppress the self-explanation activity of the learners for instance.

(RQ2) What are the effects of self-explanation prompts targeting different kinds of knowledge on diagnostic competence in nurse education?

Differential effects of prompts targeting different kinds of diagnostic knowledge have not been investigated systematically. It was expect that prompts focusing on problem solving and thus on strategic knowledge have a positive relation with the acquisition of strategic knowledge. A prompts that is focused on understanding why a procedure is appropriate may lead to increased conditional knowledge. The prompts might hence primary have an effect on practical knowledge.

(RQ3) Can motivation be increased by the use of adaptable feedback in nurse education?

One of the advantages of adaptable feedback and thus of letting learners decide about the level of detail in feedback can be, that the autonomy of the learner might be fostered and therefore the conditions for motivation are improved (Deci & Ryan, 1993).

(RQ4) Are the effects of adaptable feedback on the acquisition of diagnostic competence mediated by metacognitive competence in nursing education?

Metacognitive competence is necessary for successfully adapting feedback to one's own need. Metacognitive competence might be missing in some learners.

(RQ5) What are the effects of two scaffolding methods (self-explanation prompts and adaptable feedback) on cognitive load in nurse education?
(RQ6) Are the effects of self-explanation prompts on the acquisition of diagnostic competence mediated by cognitive load nurse education?

It is also unclear to what extent additional scaffolding might affect cognitive load. While learning a complex task such as the diagnosis of the resulting limitations of a patient's illness, self-explanation prompts could possibly overload cognitive capacity due to high processing demands (Berthold et al., 2011; Renkl, in press). To analyze this effect, it is investigated if cognitive load mediates the influence of self-explanation prompts on diagnostic competence in research question 6.

6.3 Method

6.3.1 Sample and Design

The study sample consisted of N=152 nursing students from four nursing schools that voluntarily participated in this study. Participants all were in their third and final year of nursing training. On average the participants were 23.5 years old (*SD* = 3.98). Among them 17 % were male and 83 % were female.

A implemented a 2 x 2 factorial design with the factors self-explanation prompts (with vs. without) and adaptable feedback (with vs. without) was implemented (see Table 12: ***Design of the study in nursing***). The subjects were randomly assigned to one of the four experimental conditions.

Table 12: *Design of the study in nursing*

Adaptable feedback	Self-explanation prompts	
	With	Without
With	39	37
Without	38	38

6.3.2 Learning Environment

The case materials were same as in the study in medicine text-based worked examples. The learners worked individually in a computer-based learning environment. They were to immerse themselves with a fictitious nursing student having a deployment in a hospital ward with an experienced nurse. The fictitious nursing student is on duty at a hospital ward and has the task to diagnose the limitation resulting from a patient's illness during that time. While diagnosing the fictitious student commits errors. For an example see Figure 6. The context of the error is: *"Ms. Muric was described as a patient with serious exertional dynpnoea."*

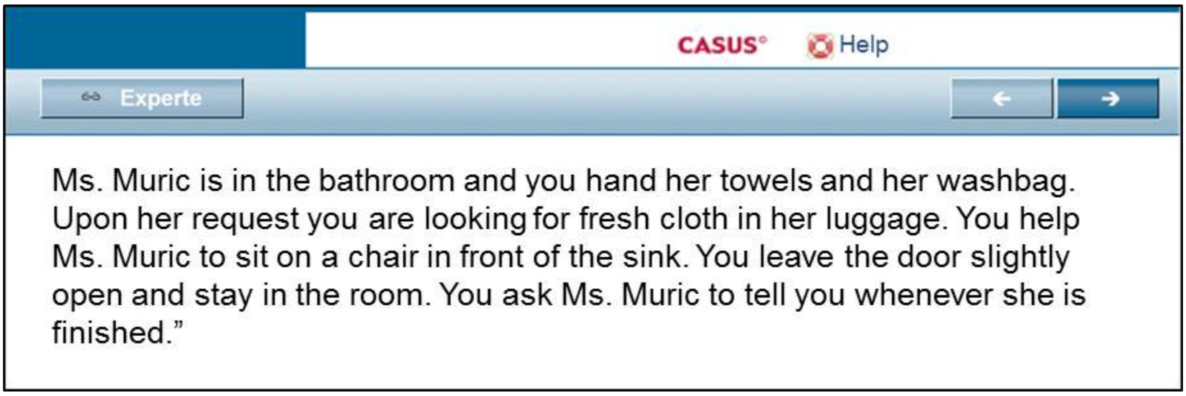

Figure 6: *Screenshot of an error of the fictitious nursing student*

In the condition with self-explanation prompts students were prompted to think about the errors. The experienced nurse in the worked examples gave feedback after each erroneous step of the fictitious nursing student. The worked example cases including the errors were developed and improved by experienced nurses. The erroneous worked examples were implemented into the computer-supported learning environment 'CASUS' (M. Fischer, 2000). For an example case see Appendix A Example Case Medicine.

6.3.3 Procedure

The same procedure than in medicine was used: First, an explanation of the purpose and the procedure of the study took place by the experimenter. Then each prospective nurse watched a short video in which the learning environment was explained. Subsequently participants filled out a questionnaire for demographic and other control variables such as prior knowledge and metacognitive competence. Afterwards the nursing students continued with the prior knowledge test on diagnostic competence on the computer and solved six key feature and six knowledge-decomposition tasks. This was followed by an individual learning phase in which learners studied three of the already described worked examples in the online learning environment. After the individual learning phase students filled out process questionnaires in which cognitive load and motivation was assed. Hereafter, online posttests for strategic and conditional knowledge were administered. Finally the learners completed a paper-based posttest for declarative-conceptual knowledge. For an overview on the procedure and the duration of the steps see Table 2, page 61.

6.3.4 Experimental Conditions

Self-explanation prompts

After the erroneous step of the fictitious nursing student, learners in the condition with self-explanation prompts students were prompted to think about the error. The same self-explanation prompts than in medicine were used (see Table 13 for an example). For a more detailed explanation and a screenshot see *chapter 5.3.4* Experimental Conditions, page 61.

Table 13: *Self-explanation prompts used in the learning environment*

Name of the prompt	Self-explanation prompt in the learning environment
1. Error-recognition prompt	*What can you criticize on this procedure and what would be the correct procedure?*
2. Problem-solving prompt	*Which problem solving strategy could have been applied to prevent the error?*
3. Knowledge-decomposition prompt	*What is the theoretical background for the correct behavior or what are the goals of the correct behavior?*

Adaptable Feedback

After the erroneous step of the fictitious nursing student and depending on the condition after the prompts all learners got feedback from an also fictitious experienced nurse. In the condition with adaptable feedback, additional information was provided on three levels: The first level marked the error and the right procedure to be taken. The recognition of the error and the current progress being made were the focus of this feedback level. Level one feedback can answer the question “what progress is being made toward the goal?” (see Hattie & Timperley, 2007). An example is:

> *“It is correct to not leave Ms. Muric completely alone. However, as the short way to the bath room already triggered an exertional dyspnea you also need to help Ms. Muric with her personal care.”*

Feedback on level two gave hints on problem-solving strategies and heuristics. Feedback on level two answered the question “what activities need to be undertaken to make better progress?” (see Hattie & Timperley, 2007). Similar to the problem-solving prompt level two feedback also targeted on strategic knowledge. An example is:

> *“In general dyspnea is a sign that a patient needs a rest period. You should keep in mind patients with heart problems need rest period during nursing activities. It may be good to wash some body parts e.g. legs already in bed. […].”*

Feedback on level three focused on the theoretical background and the goals of the procedure. Hence it relates the case information to the scientific knowledge available. Level three feedback answers the question “What are the goals?” (see Hattie & Timperley, 2007). Similar to the knowledge-decomposition prompt, level three feedback also targeted on conditional knowledge. An example is:

> *“Dyspnea shows after strain in patients with a heart condition. A dyspnea at rest can be a sign for a decompensated left heart failure, which can lead to life threating situations. […]”*

Feedback on level one was received by all learners in the adaptable feedback condition automatically for the reason that recognizing an error is a central prerequisite for learning from it. Through marking the error also less advanced students can be enabled to identify the error. Feedback on levels two and three was provided to learners only if they clicked on a link to request it. A new window opened in which the level two respectively level three feedback was given. For a screenshot see Figure 3, page 63.

Participants without adaptable feedback also received elaborated feedback (Narciss, 2008). All information on all three levels was provided simultaneously.

6.3.5 Data Sources and Instruments

Pretest

Prior Diagnostic Competence: During the pretest prior diagnostic competence was assessed using the conceptualization of Stark and colleagues (2011). Hence it differentiates into (a) declarative-conceptual knowledge and (b) practical knowledge (consisting of strategic and conditional knowledge) (see *chapter 2.2* Operationalization of Diagnostic Competence*, page 20*).

(a) Prior *declarative-conceptual knowledge* was measured through a 21 item multiple-choice questionnaire on cardiac failure and resulting need for nursing actions (for an example item see Table 14). In the multiple-choice questionnaire zero to four answers were correct in every question. Learners received one point for every correctly marked or correctly not marked answer. Five questions had to be removed to increase the internal consistency during scale formation. Maximum points were 56. Cronbach's α for the remaining 16 items was satisfactory (see Table 19). The test can be found in Appendix F Test for Declarative-Conceptual Knowledge in Nursing.

Table 14: *Example multiple-choice test item to assess declarative-conceptual knowledge in nursing*

Which position for easing leg edema would you recommend to a patient with decompensated cardiac failure NYHA II?	
❍	to position leg low
❍	to sit
❍	to position leg high
❍	to bend the knee in supine position

(b) Prior *practical knowledge* was measured using key feature tasks (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) for conditional knowledge. The tasks were similarly constructed than in medicine.

Strategic knowledge was measured with six key feature tasks (Farmer & Page, 2005). Three key feature tasks each were about one patient. After a short case vignette of a patient, participants had to derive consequences for further actions. An example can be seen in Table 15:

Table 15: *Example key feature tasks to assess strategic knowledge in nursing*

Initial patient vignette 1 *Ms. Huber is 68 years old and on your ward because of a hypertonic crisis (230/120 mmHg) two days ago. In addition she has a left heart failure, a diverticulosis and a hyperthyreosis. This morning her blood pressure war 160/85 mmHg. Now her bed neighbor rings and tells you that Ms. Huber is in the bathroom and not well. Ms. Huber sits in front of the sink and is breathing hard.*
Question 1 *What are your next steps?*
Continued patient vignette 2 *Ms. Huber is in bed now and gets well soon. Her blood pressure now is 145/85 mmHg, her pulse 88/min and her respiration is 25/min and gets more calm by every minute. Upon request she tells you that she thinks she has overburdened herself. She wanted to fresh herself up as she has an examination soon. Even so her breathlessness gets better she is unhappy and angry.*
Question 2 *How do you respond to that situation?*
Continued patient vignette 3: *Ms. Huber describes herself as difficult and impatient patient. She tells you that lately she was a little sloppy with her medication.*
Question 3: *How do you react?*

The answers were rated by two raters. For each key feature task a maximum of three points could be achieved. The more a student was able to relate scientific knowledge to the case of application the more points he or she got. The maximum score of the strategic knowledge test was 18 points. The intra-class correlation coefficient (ICC) was used for calculating the inter-rater agreement for the key feature tasks. The ICCs for the different key feature tasks ranged from satisfactory (ICC = .43) to excellent values (ICC = .76). The ICCs can be seen in Table 19. The strategic knowledge test can be found in Appendix G Test for Strategic Knowledge in Nursing.

Conditional knowledge was measured with six knowledge-decomposition tasks (Holmes et al., in press). Three knowledge-decomposition tasks were about one patient. Therefore two different patients were included. A patient vignette was presented and afterwards it was described how a nurse reacted in a diagnostic situation. Subsequently students were asked why the reaction of the nurse can reach a correct solution based on their scientific knowledge. To correctly answer these knowledge-decomposition tasks a deep and fine grained understanding of content is necessary (Holmes et al., in press). Knowledge-decomposition tasks were successfully used in different studies to assess learning outcomes (Holmes et al., in press; Roll et al., 2011). An example for a knowledge-decomposition task can be seen in Table 16.

Table 16: *Example knowledge-decomposition tasks to asses conditional knowledge in nursing*

Initial patient vignette 1 *Ms. Hansen is on your ward because of a cardiac failure NYHA III. You accompany Ms. Hansen to the toilet. You recognize that the way to the toilette is exhausting for her and triggers an exertional dyspnea. Back in bed you raise the bedhead.*
Question 1 *Why did you do that?*
Continued patient vignette 2 *In addition you control Ms. Hansens blood pressure, the respiration, the pulse and her skin tone.*
Question 2 *Please explain why you check these values.*
Continued patient vignette 3: *Ms. Hansen gets worse. She has a dyspnea at rest. As a consequence you position her into lower limb elevation.*
Question 3: *Why did you choose this positioning?*

Answers were rated by two raters. Up to three points could be achieved. The maximum score was 18. The ICCs for the different knowledge-decomposition tasks for conditional knowledge ranged from good (ICC = .70) to excellent values (ICC = .95). The ICCs can be seen in Table 17. The conditional knowledge test can be found in Appendix H Test for Conditional Knowledge in Nursing.

Table 17: *ICCs in the key feature and knowledge-decomposition task in the pretest in nursing*

Item	ICC
Pre key feature task 1.1	.43**
Pre key feature task 1.2	.67**
Pre key feature task 1.3	.40**
Pre key feature task 2.1	.49**
Pre key feature task 2.2	.76**
Pre key feature task 2.3	.74**
Pre knowledge-decomposition task 1.1	.75**
Pre knowledge-decomposition task 1.2	.70**
Pre knowledge-decomposition task 1.3	.72**
Pre knowledge-decomposition task 2.1	.70**
Pre knowledge-decomposition task 2.2	.95**
Pre knowledge-decomposition task 2.3	.95**

Note ** = p <.01, * = p <.05

The Cronbach's α for the key feature task and for the knowledge-decomposition task were low (key feature tasks Cronbach's α = .32; knowledge-decomposition task tasks Cronbach's α = .36). The aggregated prior diagnostic competence consisting of 15 MC-test items, four key feature tasks and three knowledge-decomposition tasks (12 items needed to be removed in order to increase internal consistency) had satisfactory Cronbach's (see Table 19, page 96). Maximum score of prior diagnostic competence was 81 points.

Metacognitive competence: The same questionnaire to assess metacognitive competence than in medicine was used. For a more detailed description of the questionnaire see page 67. For metacognitive competence the score was computed based on the mean of the responses on all items (Cronbach's α = .85; see Table 19, page 96). The test can be found in Appendix L Test for Metacognitive Competence.

Process data

All process data were the same measures as in the study in medicine. For a more detailed description please see page 68.

Cognitive load: Cognitive load was assessed with an eight item subjective rating scale ranging from 1 (very easy) to 7 (very difficult) (Paas & Kalyuga, 2005). The score for cognitive load was computed based on the mean of the responses on all items. Cronbach's α was satisfactory (see Table 9). The test can be found in Appendix M Test for Cognitive Load.

Motivation: Motivation was assessed with a 11 items questionnaire (Prenzel et al., 1993). The score was computed based on the mean of the responses on all items.

Cronbach's α was satisfactory (see Table 9). The test can be found in Appendix N Test for Motivation.

Processing time: The learning environment logged the time spent on each step (e.g., time spent on the three different prompts) while working with the worked example.

Posttest

Diagnostic Competence: During the posttest diagnostic competence was assessed. Diagnostic competence consisted of (a) declarative-conceptual knowledge and (b) of practical knowledge aspects (see page 90). For more details on the knowledge test see *chapter 5.3.5 Data Sources and Instruments, page 68*.

(a) Declarative-conceptual knowledge in the posttest was assessed through a multiple-choice questionnaire. Five items needed to be removed to increase internal consistency. Some items from the multiple-choice questionnaire from the pretest are contained also in the posttest. Maximum score was 52 points. Cronbach's α for the remaining 16 items was .53 (see Table 19).

(b) Practical knowledge same as in the pretest was again measured through key feature tasks (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) for conditional knowledge.

Strategic knowledge: In addition to the six key feature tasks used in the pretest additional 12 key feature task about four patients were used. Answers were rated by two raters and up to three points per key feature task could be achieved. The ICCs for the different key feature tasks ranged from satisfactory (ICC = .45) to excellent values (ICC = .93). The ICCs can be seen in Table 18. Maximum score was 54 points. Cronbach's α was satisfactory (see Table 19, page 96).

Conditional knowledge: In addition to the six knowledge-decomposition tasks used in the pretest, additional 12 knowledge-decomposition tasks about four patients were used. Answers were rated by two raters. Up to three points per task could be achieved. The ICCs for the different key-feature tasks ranged from satisfactory (ICC = .49) to excellent values (ICC = 1.00). The ICCs can be seen in Table 18. Maximum score was accordingly 54 points. Cronbach's α was .59 (see Table 9).

For the aggregated measure practical knowledge (36 Items) consisting of the key feature and of the knowledge-decomposition tasks the Cronbach's α was good. The maximum score 108.

Table 18: *ICCs in the key feature tasks and in the knowledge-decomposition tasks in the posttest in nursing*

Item	ICC
Post key feature task 1.1	.47**
Post key feature task 1.2	.62**
Post key feature task 1.3	.98**
Post key feature task 2.1	.56**
Post key feature task 2.2	.82**
Post key feature task 2.3	.83**
Post key feature task 3.1	.93**
Post key feature task 3.2	.56**
Post key feature task 3.3	.78**
Post key feature task 4.1	.80**
Post key feature task 4.2	.96**
Post key feature task 4.3	.80**
Post key feature task 5.1	.93**
Post key feature task 5.2	.94**
Post key feature task 5.3	.85**
Post key feature task 5.3	.45**
Post key feature task 5.3	.60**
Post key feature task 5.3	.46**
Post knowledge-decomposition task 1.1	.68**
Post knowledge-decomposition task 1.2	.65**
Post knowledge-decomposition task 1.3	.79**
Post knowledge-decomposition task 2.1	.62**
Post knowledge-decomposition task 2.2	.58**
Post knowledge-decomposition task 2.3	.94**
Post knowledge-decomposition task 3.1	.00**
Post knowledge-decomposition task 3.2	.46**
Post knowledge-decomposition task 3.3	.72**
Post knowledge-decomposition task 4.1	.47**
Post knowledge-decomposition task 4.2	.47**
Post knowledge-decomposition task 4.3	1.00**
Post knowledge-decomposition task 5.1	.91**
Post knowledge-decomposition task 5.2	.87**
Post knowledge-decomposition task 5.3	.49**
Post knowledge-decomposition task 6.1	.98**
Post knowledge-decomposition task 6.2	1.00**
Post knowledge-decomposition task 6.3	1.00**

Note ** = $p < .01$, * = $p < .05$

Bivariate correlations were calculated using Pearson's product-moment correlation. Between strategic and conditional knowledge the correlation was high (r = .54, p < .01). The correlation between declarative-conceptual knowledge and strategic knowledge (r = .23, p < .01) and also conditional knowledge was small (r = .21, p < .01).

Table 19: *Instruments, internal consistency in the study in nursing*

Measures	Cronbach's α
Pretest	
Prior diagnostic competence	.66
Declarative-conceptual knowledge	.61
Strategic knowledge	.32
Conditional knowledge	.33
Metacognitive competence	.85
Process	
Cognitive load	.82
Motivation	.85
Posttest	
Diagnostic competence	
Declarative-conceptual knowledge	.58
Practical knowledge	.72
Strategic knowledge	.63
Conditional knowledge	.59

6.3.6 Statistical Analysis

The alpha level of .05 was used for the statistical analyses. Partial eta^2 was used as a measure of effect size. Values of about .01 are considered as weak effect size, of about .06 as medium, and of about .14 as large (Cohen, 1988). Bivariate correlations were calculated using Pearson's product-moment correlation. Values of .01 are considered small, of about .30 as medium, and of above .50 as large (Cohen, 1988). In addition MANCOVAs, ANCOVAs, ANOVAs, and t-tests were used to compare means between the experimental groups. Post-hoc comparisons were conducted using linear independent, pairwise and Bonferroni-adjusted contrasts. In case of unequal variances a Kruskal-Walis test with follow-up Man-Whitney tests were applied. For the two mediation analysis in research questions four and six, causal steps strategy (Baron & Kenny, 1986) and products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986) was used. According to the causal steps strategy, a variable (e.g., metacognitive competence) is a mediator of the effects of an independent variable (e.g., adaptable feedback) on a dependent variable (e.g., diagnostic competence) if four conditions are met: (a) the independent variable (adaptable feedback) must affect the dependent variable (diagnostic competence). (b) the independent variable (adaptable feedback) must affect the potential mediator (metacognitive competence), (c) the mediating variable (metacognitive competence) must affect the dependent variable (diagnostic competence) when both the independent variable (adaptable feedback) and mediating variable (metacognitive competence) are predictors of the dependent variable (diagnostic competence), and (d) the effect of the independent variable (adaptable feedback) on the dependent variable (diagnostic competence) should be substantially reduced (partial mediation) or zero (complete mediation) when the mediator is included as an additional predictor of the dependent variable (MacKinnon et al., 2007; Preacher & Hayes, 2008).

6.4 Results

6.4.1 Preliminary Analyses

No differences concerning prior diagnostic competence ($F(3, 148) = 1.41$, $p = .24$), and metacognitive competence ($F(3, 148) = .84$, $p = .48$), were found between the four conditions prior to the experiment. For descriptive values please see Table 20.

The correlations of prior knowledge with diagnostic competence were significant and either high or moderate, indicating a pre to posttest gain (for declarative-conceptual knowledge, $r = .61$, $p < .01$; for strategic knowledge, $r = .37$, $p < .01$; for conditional knowledge, $r = .39$, $p < .01$).

Regarding the effect of self-explanation prompts and adaptable feedback on time-on-task, the Levene's test for equality of variances was found to be significant for the present analysis ($F(3, 148) = 6.67$, $p < .01$) indicating unequal variances. In addition Hartley's variance ratio showed a value of $F_{max} = 4.15$ and is thus above the critical value (Pearson & Hartley, 1976), further indicating substantial differences in variance. Therefore a Kruskal–Wallis test, with follow-up Man-Whitney tests were applied. The experimental variation through self-explanation prompts (with and without) and adaptable feedback (with and without) were significantly affecting time-on-task ($H(3) = 107.43$, $p < .01$). Mann–Whitney tests were used to follow-up this finding. A Bonferroni correction was applied and so all effects are reported at a .025 level. Self-explanation prompts did affect time-on task ($U = 99$, $p <.01$). In contrast adaptable feedback had no effect on time-on-task ($U = 2611$, $p = .31$). That is learners with self-explanation prompts learned longer than learners without, however, adaptable feedback had no additional effect on the learning time and also the two measures did not interact with each other regarding the learning time (for descriptive data see Table 20).

Time-on-task was not significantly correlated to declarative-conceptual knowledge ($r = -.09$, $p = .27$) and to strategic knowledge ($r = -.15$, $p = .06$). However, it was negatively correlated to conditional knowledge ($r = -.31$, $p < .01$).

Table 20: *Means and (SD) of prior diagnostic competence, prior declarative-conceptual knowledge, metacognitive competence, cognitive load, motivation, time-on-task, diagnostic competence, declarative-conceptual knowledge, practical knowledge, strategic knowledge, and conditional knowledge in nursing*

	With self-explanation prompts		Without self-explanation prompts	
	With adaptable feedback (n = 39)	Without adaptable feedback (n = 37)	With adaptable feedback (n = 38)	Without adaptable feedback (n = 38)
Prior diagnostic competence	53.56 (6.28)	50.97 (6.28)	52.95 (6.27)	52.29 (6.27)
Metacognitive competence	4.52 (.48)	4.64 (.47)	4.66 (.40)	4.69 (.55)
Cognitive load	3.82 (0.83)	4.11 (0.75)	3.23 (0.81)	3.49 (0.72)
Motivation	2.50 (.49)	2.49 (0.63)	2.69 (0.51)	2.71 (0.58)
Time-on-task	51.75 (14.53)	53.92 (15.01)	19.65 (7.38)	23.99 (9.30)
Diagnostic competence				
Declarative-conceptual knowledge	41.62 (5.07)	41.71 (4.78)	42.86 (3.46)	42.48 (4.83)
Practical knowledge	37.41 (5.83)	35.44 (6.88)	40.62 (7.13)	42.39 (8.52)
Strategic knowledge	19.41 (2.64)	18.11 (4.42)	21.11 (4.85)	21.66 (4.92)
Conditional knowledge	18.00 (3.92)	17.34 (3.59)	19.51 (3.59)	20.74 (4.73)

6.4.2 Effect on Diagnostic Competence (RQ1)

Descriptive data on the diagnostic competence measures in the four conditions can be seen in Table 20. To test if the combination of self-explanation prompts and adaptable feedback can facilitate learning of diagnostic competence, a MANCOVA with self-explanation prompts and adaptable feedback as independent variable, diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) as dependent variable and prior knowledge a covariate was conducted. The MANCOVA showed that the interaction between the self-explanation prompts and the adaptable feedback was not significant Wilks's λ = .99, $F(3, 145) = 7.60$, $p = .52$. Further the MANCOVA showed no multivariate effect of adaptable feedback on diagnostic competence (Wilks's λ = .97, $F(3, 145) = 1.30$, $p = .28$). However, it also showed a multivariate effect of self-explanation prompts on diagnostic competence (Wilks's λ = .85, $F(3, 145) = 8.64, p < .01$).

The next steps in the analytic strategy addressed the different component variables of diagnostic competence. To test the effect of the two independent variables self-explanation prompts and adaptable feedback on the dependent variables declarative-conceptual knowledge, strategic knowledge, and conditional knowledge three ANCOVAs with prior diagnostic competence as a covariate were calculated.

Declarative-conceptual knowledge: The first ANCOVA with self-explanation prompts and adaptable feedback as independent, declarative-conceptual knowledge as dependent variable and prior diagnostic competence as covariate showed no significant interaction effect of self-explanation prompts and adaptable feedback on declarative-conceptual knowledge ($F(1, 147) = .80$, $p = .37$). As this analysis did not reveal an interaction effect, the main effects of self-explanation prompts and adaptable feedback on declarative-conceptual knowledge were tested while prior diagnostic competence was controlled. The ANCOVA showed no effect of self-explanation prompts ($F(1, 147) = 3.11$, $p = .08$) or adaptable feedback ($F(1, 147) = 2.08$, $p = .15$). Planned contrasts revealed no significant group differences between any of the groups.

Practical knowledge: Three more ANCOVAs with self-explanation prompts and adaptable feedback as independent, prior diagnostic competence as covariate and strategic, conditional, or practical knowledge as dependent variable were calculated. The first ANCOVA with self-explanation prompts and adaptable feedback as independent, prior diagnostic competence as covariate and strategic knowledge showed a significant Levene's test ($F(3, 148) = 3.72$, $p < .05$) indicating unequal variances. Hartley's variance ratio in contrary shows a value of $F_{max} = 3.46$ and is thus above the critical value (Pearson & Hartley, 1976) indicating substantial differences in variance. As no nonparametric test exists in which a covariate can be included the ANCOVA with strategic knowledge is still presented but the results can only be interpreted with caution. The three ANCOVAs did not reveal a significant interaction effect of self-explanation prompts and adaptable feedback on strategic ($F(1, 147) = .31$, $p = .31$), conditional knowledge ($F(1, 147) = 1.27$, $p = .26$) and on the aggregated measure practical knowledge showed ($F(1, 147) = 1.63$, $p = .20$). As this analysis did not reveal an interaction effect, the main effects of self-explanation prompts and adaptable feedback were tested while prior diagnostic competence was controlled. To analyze the main effects in more detail three ANCOVAs with self-explanation prompts and adaptable feedback as independent variable, prior knowledge as covariate and strategic or conditional or practical knowledge as dependent variables were conducted. A significant medium effect of self-explanation prompts on strategic knowledge ($F(1, 147) = 15.15$, $p < .01$, *partial* $\eta^2 = .09$; $p < .01$, CI [-3.81,) (see Figure 7), on conditional knowledge ($F(1, 147) = 15.71$, $p < .01$, *partial* $\eta^2 = .10$) (see Figure 8), and on practical ($F(1, 147) = 22.03$, $p < .01$, *partial* $\eta^2 = .13$) (see Figure 9) showed.

A Bonferroni correction was applied and so all effects are reported at a .025 level. Learners in the condition with self-explanation prompts acquired less strategic knowledge (with $M = 18.77$, $SD = 3.66$; without $M = 21.39$, $SD = 4.86$, post-hoc comparison $p <.01$), conditional knowledge (with $M = 17.68$, $SD = 3.75$; without $M = 20.13$, $SD = 4.22$, post-hoc comparison $p <.01$), and practical knowledge (with $M = 36.44$, $SD = 6.41$; without $M =$

41.52, *SD* = 7.86 post-hoc comparison p <.01) than learners in the condition without self-explanation prompts.

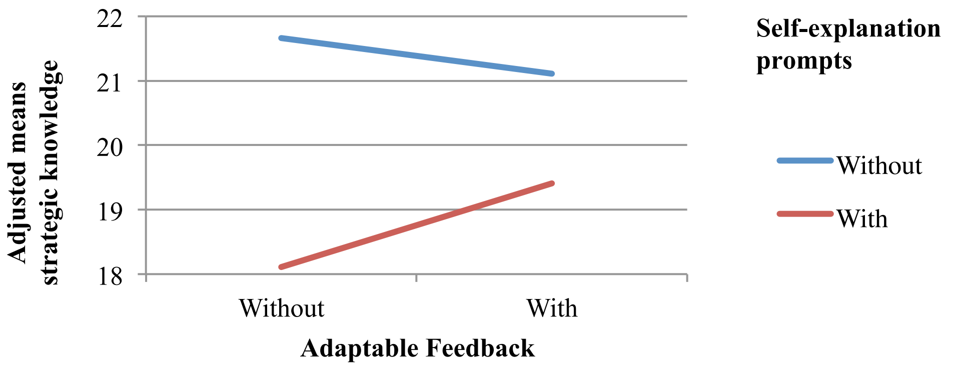

Figure 7: *Adjusted means of strategic knowledge in the four experimental conditions in nursing*

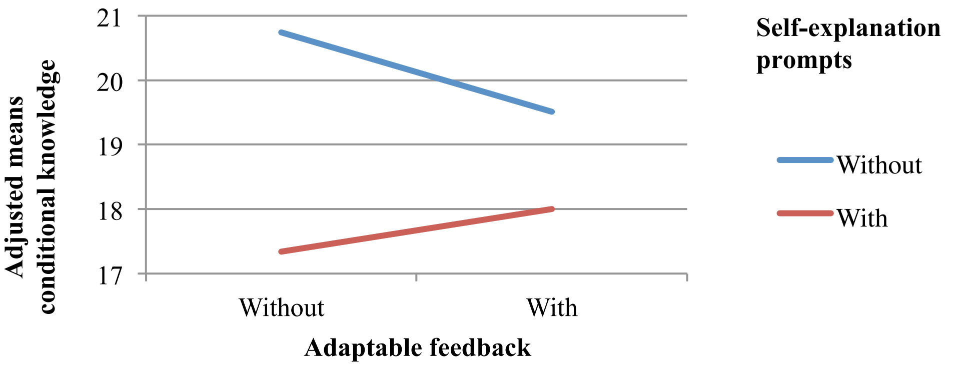

Figure 8: *Adjusted means of conditional knowledge in the four experimental conditions in nursing*

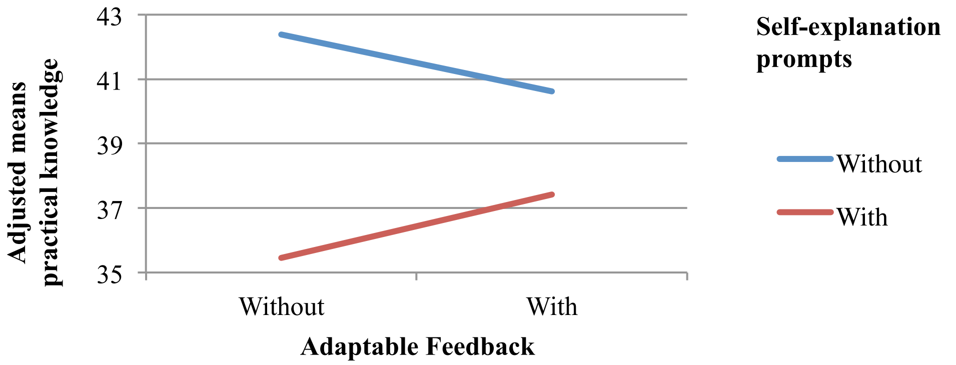

Figure 9: *Adjusted means of practical knowledge in the four experimental conditions in nursing*

To answer research question one it can be said, self-explanation prompts had no significant effect on diagnostic competence. Adaptable feedback had a positive main effect on strategic and practical knowledge but not on conditional knowledge. The combination of self -explanation prompts had no effect on diagnostic competence.

6.4.3 Type of Prompt (RQ2)

To analyze the relation of the three different prompts with the types of knowledge contained in the model of diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge), bivariate correlations were calculated using Pearson's product-moment correlation. The automatically logged time a learner spent answering the three prompts and diagnostic competence were correlated. The time a learner spent on answering the prompts is interpreted as processing time similar as in the study by Sánchez and García-Rodicio (2013). Accordingly, more time used for answering a specific prompt can be regarded as an indicator for more intense processing (Sánchez & García-Rodicio, 2013). There was no significant correlation between time spent on the problem-solving prompt and diagnostic competence (see

Table 21). There were significant, negative correlations between the time spend on the knowledge-decomposition prompts and practical knowledge (r = -.29, p < .01), strategic knowledge (r = -.20, p < .05) and conditional knowledge (r = -.30, p < .01).

Table 21: *Correlations between time on the three prompts with diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) in nursing*

	Pearson's Correlation (two tailed)		
	Time on error-recognition prompt	Time on problem solving prompt	Time on knowledge-decomposition prompt
Declarative-conceptual knowledge	.02	-.11	-.08
Practical knowledge	.04	-.01	-.29**
Strategic knowledge	.18	.10	-.20*
Conditional knowledge	-.10	-.11	-.30**

Note ** = p < .01, * = p < .05

In sum, the three self-explanation prompts had differentiated effects on diagnostic competence. Whereas the time spent on the self-explanation prompts that targeted on error-recognition and on the one targeted on problem solving had no effect on diagnostic competence, the self-explanation prompts that targeted on conditional knowledge was negatively related with the acquisition of practical knowledge.

6.4.4 Effect of Adaptable Feedback on Motivation (RQ3)

To analyze the effect of adaptable feedback on motivation an independent t-test with adaptable feedback as independent and motivation as dependent variable was calculated. It showed no difference between those groups ($t(150) = .06$, $p = .95$). That is the group with adaptable feedback ($M = 2.60$, $SD = .61$) had no higher motivation than the group without adaptable feedback ($M = 2.59$, $SD = .50$). To answer research question three it can be said, that motivation could not be increased by the use of adaptable feedback.

6.4.5 Mediation by Metacognitive Competence (RQ4)

In research question four it was investigated whether the potential effects of adaptable feedback on the acquisition of diagnostic competence were mediated by metacognitive competence. For the analysis the causal steps strategy by Baron and Kenny (1986) was used and the products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986). For a more detailed description *see chapter 5.3.6 Statistical Analysis, page 71*. According to the causal steps strategy, metacognitive competence is a mediator of the effects of adaptable feedback on diagnostic competence if four conditions are met: (a) Adaptable feedback must affect diagnostic competence. (b) Adaptable feedback must affect metacognitive competence, (c) metacognitive competence must affect the diagnostic competence when both the adaptable feedback and metacognitive competence are predictors of diagnostic competence, and (d) the effect of the adaptable feedback on diagnostic competence should be substantially reduced (partial mediation) or zero (complete mediation) when metacognitive competence is included as an additional predictor of diagnostic competence (MacKinnon et al., 2007; Preacher & Hayes, 2008).

(a) As another analysis on research question one (see page 98) already revealed that the adaptable feedback did not affect the dependent variable diagnostic competence significantly the first of Baron and Kenny's (1986) causal steps was not met. This indicates that a possible mediation by metacognitive competence can not be tested

6.4.6 Effect of Cognitive Load (RQ5)

Germane cognitive load correlated negatively with diagnostic competence (r = -.20, p < .05) indicating that the sub-scales proposed by Paas and Kalyuga (2005) could not be replicated with this sample of prospective nurses. Thus in the following cognitive load is treated as aggregated measure.

Cognitive load correlated negatively with the posttest measures declarative-conceptual knowledge (r = -.22, p < .01). The correlations with strategic knowledge (r = .04, p = .67), with conditional knowledge (r = .10, p = .20), and with practical knowledge (r = -.04, p = .66) were not significant. The correlations are indicating that learners that experienced a higher cognitive load gained less declarative-conceptual knowledge whereas practical knowledge was unaffected by cognitive load.

A correlation between cognitive load and prior diagnostic competence was not significant (r = -.13, p = .11) indicating learners experienced cognitive load independently from their prior knowledge.

Descriptive data on cognitive load in the four conditions can be found in Table 20, page 98. To test if self-explanation prompts and adaptable feedback (independent variables) had an influence on cognitive load (dependent variable) an ANOVA was calculated.

The ANOVA did show a main effect of self-explanation prompts (F(1, 148) = 22.85, p < .01 *partial* η^2 = .10) and of adaptable feedback F(1, 148) = 4.73, p < .05, *partial* η^2 = .03) on cognitive load. No interaction of self-explanation prompts and adaptable feedback on cognitive load showed (F(1, 152) = .01, p = .92). Post hoc tests using the Bonferroni correction revealed the average reported cognitive load was significantly higher in the groups that learned with self-explanation prompts and with adaptable feedback (M = 3.82, SD = .83), than in the group that learned without self-explanation prompts and with adaptable feedback (M = 3.23, SD = .81) (p < .01). Also learners with self-explanation prompts and without adaptable feedback (M = 4.11, SD = .75) reported a higher cognitive load than learners without self-explanation prompts and without adaptable feedback (M = 3.49, SD = .42) (p < .01). In addition the learner with self-explanation prompts and without adaptable feedback (M = 4.11, SD = .75) reported a higher cognitive load than the group without self-explanation prompts and without adaptable feedback (M = 3.49, SD = .42) (p < .01). This analysis is indicating that the main effect of adaptable feedback mainly shows because of the difference between learners with self-explanation prompts and with adaptable feedback and learner without self-explanation prompts and with adaptable feedback.

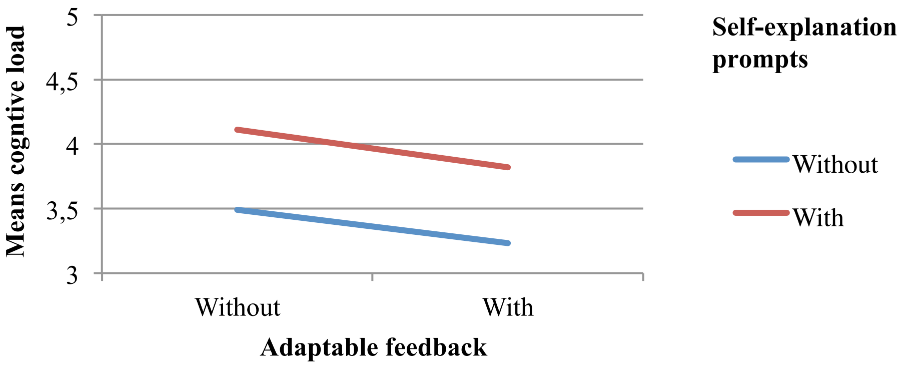

Figure 10: *Means of cognitive load in the four experimental condition in nursing*

To answer research question five it can be concluded the self-explanation prompts increase cognitive load significantly. In contrast adaptable feedback decreased cognitive load significantly.

6.4.7 Mediation of Cognitive Load (RQ6)

For the analysis the causal steps strategy by Baron and Kenny (1986) was used and the products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986). For a more detailed description see *chapter 5.4.5 Mediation by Metacognitive Competence (RQ4)*.

According to the causal steps strategy cognitive load is a mediator of the effects of adaptable feedback on diagnostic competence if four conditions are met: (a) Self-explanation prompts must affect diagnostic competence. (b) Self-explanation prompts must affect cognitive load, (c) cognitive load must affect the diagnostic competence when both the self-explanation prompts and cognitive load are predictors of diagnostic competence, and (d) the effect of the self-explanation prompts on diagnostic competence should be substantially reduced (partial mediation) or zero (complete mediation) when cognitive load is included as an additional predictor of diagnostic competence (MacKinnon et al., 2007; Preacher & Hayes, 2008).

(a) In first regressions with self-explanation prompts as independent and declarative-conceptual or strategic or conditional or practical knowledge as dependent variable showed that self-explanation prompts accounted for 11.3 % of the variance of practical knowledge ($F(1, 150) = 19.10$, $p < .01$), for 8.6 % of the variance of strategic knowledge ($F(1, 150) =$ 14.15, $p < .01$), and for 8.8 % of the variance of conditional knowledge ($F(1, 150) = 14.41$,

$p < .01$). Declarative-conceptual knowledge was not affected by self-explanation prompts ($F(1, 150) = 2.66$, $p = .11$).

(b) In a second regression with self-explanation prompts as independent and cognitive load as dependent variable it showed that self-explanation prompts did account for 12.9 % of the variance of cognitive load ($F(1, 150) = 11.18$, $p < .01$).

(c) In a third regression analysis, practical or strategic or conditional knowledge was regressed on self-explanation prompts and cognitive load in a simultaneous multiple regression model.

Strategic knowledge: This regression equation accounted for 12.9 % of the variance in strategic knowledge ($F(2, 149) = 9.14$, $p < .01$). In this multiple regression model, self-explanation prompts were a significant predictor of strategic knowledge $b = -.35$, $t(149) = -4.25$, $p < .01$. By contrast cognitive load did not significantly predict strategic knowledge, $b = .16$, $t(149) = 1.97$, $p = .051$.

Conditional knowledge: This regression equation accounted for 8.8 % of the variance in conditional knowledge ($F(2, 149) = 7.16$, $p < .01$). In this multiple regression model, self-explanation prompts were a significant predictor of conditional knowledge $b = -.30$, $t(149) = -3.54$, $p < .01$. By contrast cognitive load did not significantly predict conditional knowledge, $b = .00$, $t(149) = .03$, $p = .98$.

Practical knowledge: This regression equation accounted for 12.1 % of the variance in practical knowledge ($F(2, 149) = 10.28$, $p < .01$). In this multiple regression model, self-explanation prompts were a significant predictor of strategic knowledge $b = -.37$, $t(149) = -4.51$, $p < .01$. By contrast cognitive load did not significantly predict conditional knowledge, $b = .10$, $t(149) = 1.18$, $p = .24$.

The previous analysis indicates cognitive load was not mediating the influence of self-explanation prompts on diagnostic competence.

6.5 Discussion

In this study erroneous worked examples were implemented in a computer-based learning environment with the aim of fostering diagnostic competence in prospective nurses. If scaffolding with self-explanation prompts and adaptable feedback can foster learning of diagnostic competence in future nurses was investigated.

No differences concerning prior diagnostic competence and metacognitive competence prior to the study were found. Moderate to high correlations between diagnostic competence in the pretest and in the posttest, are indicating a gain in diagnostic competence and a low influence of the independent variables self-explanation prompts and adaptable feedback. Adaptable feedback had no effect on the time a learner spent processing the learning material. Thus, learners spent an equal amount of time receiving the feedback regardless of its adaptability. In other studies learners did not use feedback provided on demand very often (e.g. Corbett & Anderson, 2001), whereas in this study learners did not fade out the feedback even though they could have. Self-explanation prompts, in contrast more than doubled the learning time. The learning time did not influence the acquisition declarative-conceptual knowledge and strategic knowledge, whereas learning time was negatively related to conditional knowledge. That is, learners gained less conditional knowledge if they spent more time processing the worked examples.

Regarding research question one, contrary to the assumption, self-explanation prompts had a negative effect on the acquisition of strategic, and conditional knowledge. Adaptable feedback had no effect on diagnostic competence (declarative-conceptual, strategic, and conditional knowledge) (RQ 1). Findings on the effects of prompts targeting different kinds of knowledge showed that the three self-explanation prompts had differentiated effects on diagnostic competence. The time spent processing the self-explanation prompt that targeted on error-recognition (the first prompt), and the one targeted on problem solving (second prompt) had no positive relation to diagnostic competence. The self-explanation prompt that targeted on conditional knowledge was negatively related to the acquisition of strategic, and conditional knowledge (RQ 2). Adaptable feedback could not increase the motivation of the learners (RQ 3). Metacognitive competence did not mediate the relation of adaptable feedback and diagnostic competence (RQ 4). Regarding cognitive load it can be said learners who experienced a higher cognitive load acquired less declarative-conceptual knowledge, whereas practical knowledge was unaffected. Learners experienced cognitive load independently from their prior knowledge. Self-explanation prompts increased cognitive load. In contrast adaptable feedback decreased cognitive load (RQ 5). However, cognitive load no mediator for the influence of self-explanation prompts on diagnostic competence (RQ 6).

As prompts have the goal to induce strategies that a learner is capable of, but does not show by his or her own (Pressley et al., 1992) it is necessary to profit from prompts that a leaner is able to perform a certain strategy. A possible reason why self-explanations prompts failed to increase learning of diagnostic competence may be that learners were not able to produce sufficient self-explanations. In some other studies learners could also profit from self-explanations if they were incorrect or fragmented (Chi, 2000). Other authors hold against, this may only be true if a high percentage of self-explanations are correct (Aleven & Koedinger, 2002). In a complex field such as in diagnosing patient states the percentage of correct self-explanations could be to little to have an impact on learning. However, learners could have used the feedback to close gaps in their knowledge. For finding relevant information in the feedback it can be assumed that a certain basic understanding is a prerequisite.

Following an expertise model by Benner and colleagues (2009) novices have problems noticing relevant knowledge. Only advanced beginners are able to recognize relevant cues. This is in line with a recent expertise model, the model of domain learning (Alexander, 1997; Alexander et al., 2009). Also in the first phase the 'acclimation' the learner does not have much relevant knowledge in a domain and gains basic knowledge that is not very well connected and also incomplete which is related to the problem of novices being unable to distinguish between relevant and non-relevant knowledge (Alexander et al., 1994). It might be that learners were in the novices' or acclimation stage and thus not able to identify relevant knowledge in the feedback.

Another explanation for the lack of effects of adaptable feedback to increase learning could be that the increased learner control could not increase motivation. It can be possible that in a highly structured learning environment with worked example the amount of learner control was simply not enough. However, in the study in medicine (see *chapter 5 Study 1: Fostering Diagnostic Competence in Medicine*) adaptable feedback had no effect on motivation but could still increase learning. One other reason could be that learners may not have been able to seek help efficiently as also found by others (e.g. for an overview see the review by Aleven et al., 2003). It is possible that learners who need additional explanations the most, are the least prone to ask for them, in some cases because they do not even know they need it (Gräsel, F. Fischer, & Mandl, 2001; Narciss, Proske, & Koerndle, 2007). What also might point in that direction is that the adaptable feedback did decrease cognitive load. Leaners might not have put much effort in thinking what knowledge they might need and then processing that information.

Self-explanation prompts more than doubled the learning time, but in fact learners who learned with self-explanation prompts were obviously rather hindered than supported with respect to strategic and conditional knowledge. Reconsidering previous findings from research on prompts (Chamberland et al., 2013; Chamberland, St-Onge, et al., 2011; Schworm & Renkl, 2007; Stark, 1999) an important difference to the present study arises. In the presented study prompts were specifically designed to support the learners in analyzing errors. The learners might have been so concentrated on the corrections of the errors that they were distracted from principle-based self-explanations, which are considered to be important for learning from worked examples (Renkl, in press). Instead of relating the underlying principles of the domain to the case, learner may have tried to find the correct procedure, maybe using weak problem-solving strategies (van Merriënboer, 2013).

Self-explanation prompts are generally assumed to have a positive effect on learning (see *chapter 3.2.1 Self-Explanation Prompts)*. However, they pose a high demand on the learner in particular if combined with other demands such as with processing errors. Also in other studies were self-explanation prompts were combined with e.g. gaps in a worked example they could not increase learning (Gerjets et al., 2006; Hilbert et al., 2008). The combination of erroneous worked examples and self-explanation prompts may have increased cognitive load up to a detrimental level (Sweller, 2010). Another possibility may be that the additional demand leads to a cognitive conflict with the elaboration induced by the error. While studying the errors in the worked examples and trying to understand them, the learners were asked to self-explain the errors in a specific order of question and type in the solutions. The two demands may have interfered with each other. The relatively high amount of self-reported cognitive load in the group with self-explanation prompts can be seen as evidence for this explanation.

Providing instruction to self-explain and on-demand help can decrease the self-explanation activity of the learners as found in other studies (e.g. Schworm & Renkl, 2006). The learners might reduce the effort of finding self-explanations if feedback offering a correct solution is available (Kulhavy, 1977). However, with this explanation cognitive load should not have been higher for learner with self-explanation prompts. Therefore, for this study it is not be an adequate explanation.

The differentiated effects of prompts targeting different kinds of knowledge, point in another direction: Whereas the time a learner tried to find the error, and to find problem-solving strategies had no effect on diagnostic competence, the time a learner spent with explaining why a procedure can reach its goal was negatively related with the acquisition of strategic, and conditional knowledge. An interpretation for this finding could be that thinking about other’s errors might, as found in the study by Kapur (2013), not have as much learning potential than one’s own error. Interesting in that regard are the deliberation of Loibl and Rummel, (in press). They state that the mechanism that promotes learning in Kapur and Bielaczyc's (2012) productive failure approach may in fact not be the experience of failure. In Loibl and Rummel's (in press) study, it showed that guidance during problem solving did lead to less failure but not to less learning. Rather then thinking about errors the learning mechanism might be a motivational factor that helps to activate prior knowledge. Using prompts to think about the error might not have had the same motivational effect than committing an error oneself. It could be possible that the learning potential of the errors of other’s might indeed be limited. It could be that the general argument by Kolodner (2006) that learners can also learn from the cases of others is in fact not valid for learning from cases in which an error was committed.

The negative effect of self-explanation prompts on strategic and on conditional knowledge could indicate negative transfer of knowledge (Pennington & Rehder, 1995). This however is surprising as negative transfer can occurs if problem-solving strategies are taught in isolation from cases of application. As this was not the case in this study learners may have concentrated on superficial features during their self-explanation and not on the underlying principles of the case. This could have lead to overgeneralizations. Thus, it could have come to the application of strategies without prior checking of prerequisites, ignoring the contextual features of the specific case in the posttest. But how can thus overgeneralization be prevented? It might be a possibility to include besides constructive activities also interactive activities in the learning material (Chi, 2009). This could have the advantages that one's own positions need to be argued and defended and also the position of another learner needs to be incorporated and included in one's own thinking processes. Therefore, including interactive activities might have the advantage of preventing overgeneralizations. As discussed in *chapter 3.2 Scaffolding in Erroneous Worked Examples, page 38* this was not included to not risk transfer to the real world. However, as already near transfer on similar tasks was negative, the greater risk might be to have learners overgeneralize strategies. In other studies in which complex skills were taught interactive activity had beneficial effects for learning with modeling examples (Rummel et al., 2009).

The diagnostic competence model used for operationalization in this study in nursing (Stark et al., 2011)showed differential effects of the two scaffolds on at least two types of knowledge (strategic and conditional knowledge). Whereas declarative-conceptual was unaffected, strategic and conditional knowledge were negatively affected by self-explanation prompts. Also regarding the different prompts it showed that only the prompt targeting conditional knowledge was negatively related to strategic and conditional knowledge. In this study in nursing education the effect on strategic and on conditional level were in similar directions. Thus, it might also be possible to not differentiate between strategic and conditional knowledge. A model with the aim of fostering diagnostic competence might therefore benefit from the differentiation but maybe a differentiation into declarative-conceptual knowledge and in practical knowledge could be conclusive.

The presented study in nursing has certain limitations which are discussed in *chapter 9.2 Limitations of the Studies, page 153* because they mainly concern all three studies (in medicine, in nursing and in teaching)

7 Study 3: Fostering Diagnostic Competence in Teaching

7.1 Context

For teachers it is an important competence to analyze, if a pedagogical methods is implemented appropriately in a classroom and also if it fits the needs of the learners. Teachers are supposed to analyze complex classroom situations with multiple actors in which they need to take into account many different theoretical concepts. Then, teachers are expected to derive consequences from that analysis, based on their professional knowledge and experience (Schrader & Hartz, 2003). To meet these expectations, teachers need diagnostic competences. Diagnostic competences, however, seem to be difficult to acquire. This study addresses the possibilities of fostering diagnostic competences in a computer-supported learning environment.

Diagnostic competence is one of the core tasks of a teacher (Artelt & Gräsel, 2009; F.-W. Schrader, 2011). In teaching, diagnosing has the goal to use methods to develop competences of a learner or a class and to optimize the used methods regarding the present and the desired state of the competences (Helmke et al., 2012). Diagnosing classroom situations is important for providing instructional support to the learner. The competence to assess the impact of instruction while teaching and to explain it on the basis of scientific knowledge is a central competence for a teacher (Borko, 2004; Darling-Hammond & Youngs, 2002). Systematical quantitative research is still rare (Cochran-Smith & Zeichner, 2005).

One interesting concept that is closely related with analyzing classroom situations is professional vision. Professional vision is similar to informal or implicit diagnoses that happen during teaching (F.-W. Schrader & Helmke, 2001). Processes involved are noticing important features and direct attention accordingly, then knowledge-based reasoning takes places (van Es & Sherin, 2008). Studies on the early development of professional vision in novices are rare and had small sample sizes (Blomberg et al., 2013; Stürmer et al., 2013). The development of professional vision can be related to the integrated processing approach from the medical domain. First, through non-analytical processing, cues in the classroom are noticed, and then unconsciously related to networks of existing knowledge and initial hypotheses are generated. In a second step, analytical processing takes place, in which hypotheses are tested based on professional knowledge about teaching and learning. An integrated processing model is thus also conceivable for teaching.

The development of diagnostic competence in teachers is described in similar ways to that in nursing as it is also based on the work by S. Dreyfus and Dreyfus (1980). Thus also novice teachers are described to show rule-based behavior (Berliner, 1994). Through more experience advanced beginners can then recognize relevant cues. In a later stage of expertise development underlying concepts are becoming unconscious in routine cases. It can be concluded that even though major differences between teaching and the medical domains may exist, expertise development is described in a similar way in current research. For a more detailed explanation see *chapter 2.4 Expertise on page 25*. The stage model of expertise development by Berliner (1994) same as other stage models in nursing and in medicine lack the perspective how expertise development can be fostered. The model of domain learning which is domain comprehensive can give hints on important factors in expertise development such as interest (Alexander, 1997; Alexander et al., 2009). Enough opportunities to gain different experiences are necessary but not sufficient to develop adaptive-expertise (Patel, Arocha, & Leccisi, 2001) as not every learner becomes an expert with enough experience (Ericsson, 2006). Cognitive processes become in general improved until a daily tasks can be solved sufficiently. Through deliberate practice automatization of skills can be prevented and hence a skill can be continuously developed (Ericsson, 2006). Important in deliberate practice is to reflect on the appropriateness of a procedure and how a procedure can be improved further. Besides the experience from cases also a reflective element seems to be important for expertise development. In teaching, adaptive expertise is important as a teacher needs to adapt his or her teaching to the needs of the learners and also to learners' conceptions or misconceptions (Hammerness et al., 2005).

Cases are also recommended from didactics in teacher education (Borko, 2004; Seidel & Prenzel, 2007). Simulated cases present a good opportunity to expose learners to both typical and also to atypical cases (Graber, 2009). Deliberations on problem solving and how it can be learned are in line with a case-based approach (see *chapter 3.1 Learning with Cases*). Real life problems are ill-structured and could particularly for novices without sufficient support be not effective for learning (van Merriënboer, 2013). Guidance through adequate scaffolding can increase learning with complex cases (Hmelo-Silver et al., 2007). Worked examples could be a possibility to let also novices profit from learning with cases (van Gog et al., 2010). A promising method to prevent learners from passively processing worked examples is to include errors (Booth et al., 2013; Große & Renkl, 2004, 2007; Stark et al., 2011). Including errors themselves could in addition have some advantages for learning (see *chapter 3.1.3 Learning with Erroneous Worked Examples*). Learners with low prior knowledge may need support when learning with errors (Renkl, in press). Through sufficient scaffolding it may be possible, that also these learners can profit from erroneous worked. Two particularly promising scaffolds are: letting learners self-explain the error and providing learners with help to identify the underlying principles of an error through adaptable feedback.

7.2 Aims of this Study and Specific Research Questions

The aim of this study is to investigate the effect of scaffolding on diagnostic competence in teaching during learning with erroneous worked examples. More specifically, scaffolding through self-explanation prompts, adaptable feedback, and a combination of both is analyzed. In this study from general research questions one specific questions and hypotheses are formulated.

(RQ1) To what extent can two scaffolding methods (self-explanation prompts and adaptable feedback) facilitate diagnostic competence in teacher education?

If self-explanation prompts focusing on diagnostic errors can foster diagnostic competence is currently not known. A positive influence is anticipated overall on the basis of the theoretical assumptions outlined in *chapter 3.2.1 Self-Explanation Prompts*. The second scaffolding method that is investigated is adaptable feedback. Letting prospective teachers decide how much feedback he or she needs has certain advantages but could also hinder learning, as a learner needs adequate help-seeking skills that are not present in all learners. If the combination of self-explanation prompts and adaptable feedback is in particular positive for learning has not been systematically addressed by research so far. The two methods may interact positively because the combination might reduce illusions of understanding, provide learners that cannot find adequate self-explanations with the underlying principles of a problem and might foster active processing of the feedback. But there might also be limitations as the additional instruction could suppress the self-explanation activity of the learners for instance.

(RQ2) What are the effects of self-explanation prompts targeting different kinds of knowledge on diagnostic competence in teacher education?

Effect of prompts targeting different kinds of diagnostic knowledge on diagnostic competence has not been investigated systematically so far. A prompt focusing on problem solving strategy and thus on strategic knowledge is expected to have a positive relation with the acquisition of strategic knowledge. Prompts that are focused on understanding why a procedure is appropriate may lead to increased conditional knowledge.

(RQ3) Can motivation be increased by the use of adaptable feedback in teacher education?

One of the advantages of adaptable feedback and thus of letting learners decide about the level of detail in feedback can be, that the autonomy of the learner might be fostered and therefore the conditions for motivation are improved (Deci & Ryan, 1993).

(RQ4) Are the effects of adaptable feedback on the acquisition of diagnostic competence mediated by metacognitive competence in teacher education?

Metacognitive competence is necessary for successfully adapting feedback to one's own need. Metacognitive competence might be missing in some learners.

(RQ5) What are the effects of two scaffolding methods (self-explanation prompts and adaptable feedback) on cognitive load over time in teacher education?
(RQ6) Are the effects of self-explanation prompts on the acquisition of diagnostic competence mediated by cognitive load in teacher education?

It is unclear to what extent additional scaffolding might affect cognitive load in particular over time. While learning a complex task such a diagnosing a classroom situation, scaffolding with self-explanation prompts could possibly overload cognitive capacity due to high processing demands (Berthold et al., 2011; Renkl, in press). To analyze this effect, it is investigated if cognitive load mediates the influence of self-explanation prompts on diagnostic competence in research question 6.

7.3 Method

7.3.1 Sample and Design

The study sample consisted of N=108 students from preservice teacher education programs and educational science that voluntarily participated in this study. On average the participants were 25.6 years old (*SD* = 5.20). Among them 27 % were male and 71 % were female.

A 2 x 2 factorial design with the factors self-explanation prompts (with vs. without) and adaptable feedback (with vs. without) was implemented (see Table 22). The subjects were randomly assigned to one of the four experimental conditions.

Table 22: *Design of the study in teaching*

Adaptable feedback	Self-explanation prompts	
	With	Without
With	26	26
Without	29	27

7.3.2 Learning Environment

The case materials were again text-based worked examples on which learners worked individually in a computer-based learning environment. They were to immerse themselves with a fictitious student doing an elective with an experienced teacher in a school. The fictitious student prepared and implemented lessons on the topic civil courage after the instructional approach problem-based learning (Hmelo-Silver, 2004). While diagnosing the fictitious student commits errors. For an example see Figure 11.

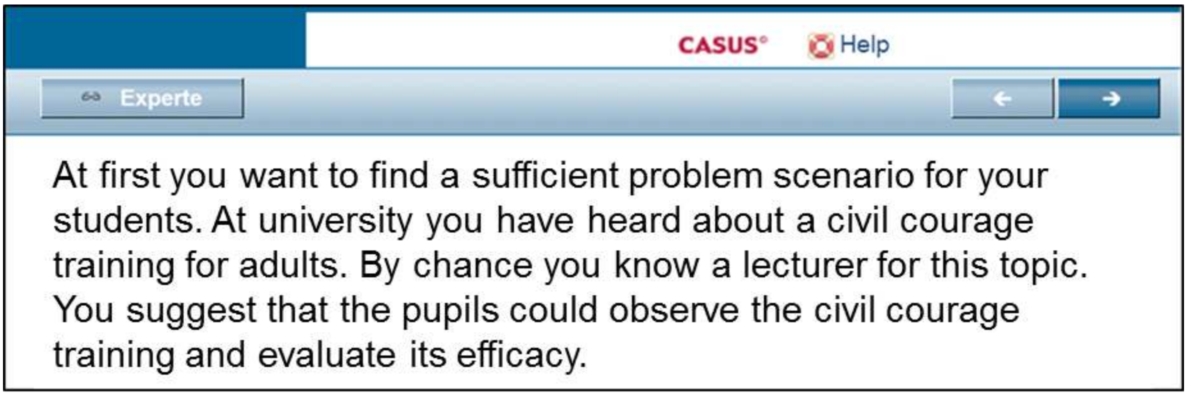

Figure 11: *Screenshot of an error of the fictitious student in teaching*

In the condition with self-explanation prompts students were prompted to think about the errors afterwards. The experienced teacher in the worked examples gave feedback after each erroneous step of the fictitious student. The worked examples including the errors were developed and improved in an expert workshop. In this workshop instructional design experts discussed typical and relevant errors that can happen during the implementation of instructional approach problem-based learning (Hmelo-Silver, 2004). Afterwards the worked examples were developed together with an experienced teacher. The erroneous worked examples were implemented into the computer-supported learning environment 'CASUS' (M. Fischer, 2000).

7.3.3 Procedure

Due to practical reasons during the implementation of the study the procedure somehow differed to the procedure in medicine and in nursing. First, an explanation of the purpose and the procedure of the study took place by the experimenter. This was followed by a brief talk held by the experimenter on instructional design to activate prior knowledge. Then each participant watched a short video in which the learning environment was explained. Subsequently participants filled out a questionnaire for demographic and other control variables such as prior knowledge and metacognitive competence. This was followed by an individual learning phase in which the learner studied two of the already described worked examples in the online learning environment. After the first and after the second worked example participants filled out process questionnaires in which cognitive load and motivation was assed. Hereafter, online posttests for strategic and conditional knowledge were administered. Finally the learners completed a paper-based posttest for declarative-conceptual knowledge. For an overview on the procedure and the duration of the steps see Table 23.

Table 23: *Procedures and durations in teaching*

Procedure	Planned Duration in Minutes (minutes cumulated)	
Introduction by experimenter	15	
Video	5	(20)
Pretest	5	(25)
Individual learning phase 1	30	(55)
Process questionnaire time 1	5	(60)
Individual learning phase 2	30	(90)
Process questionnaire time 2	5	(95)
Posttest	25	(120)

7.3.4 Experimental Conditions

Self-explanation prompts

After the erroneous step of the fictitious teaching student, learners in the condition with self-explanation prompts students were prompted to think about the error. The same self-explanation prompts than in medicine and nursing were used (see Table 13 for an example). For a more detailed explanation and a screenshot see *chapter 5.3.4* Experimental Conditions, page 61.

Table 24: *Self-explanation prompts used in the learning environment*

Name of the prompt	Self-explanation prompt in the learning environment
1. Error-recognition prompt	*What can you criticize on this procedure and what would be the correct procedure?*
2. Problem-solving prompt	*Which problem solving strategy could have been applied to prevent the error?*
3. Knowledge-decomposition prompt	*What is the theoretical background for the correct behavior or what are the goals of the correct behavior?*

Adaptable Feedback

After the erroneous step of the fictitious teaching student and depending on the condition after the prompts all learners got feedback from an also fictitious experienced teacher. For subjects in the condition with adaptable feedback, information was provided on three feedback levels: The first level marked the error as such and included information about the right procedure to be taken. Level one feedback targeted on the recognition of the error and on the current progress being made. Feedback on level one answers the question "what progress is being made toward the goal?" (see Hattie & Timperley, 2007). An example is:

> *"I appreciate that you took a problem from real life. Nonetheless I am not sure the problem is relevant enough for a teenager."*

Feedback on level two additionally gave hints on problem-solving strategies and heuristics. Therefore it answers the question "what activities need to be undertaken to make better progress?" (see Hattie & Timperley, 2007). Similar that the the problem-solving prompt (prompt two) it targeted on strategic knowledge. An example is:

> *"When I am trying to identify a problem scenario I always keep in mind my target group, in this case teenagers. If I cannot figure out a relevant problem scenario on my own I conduct a group discussion with my students."*

Feedback on the third level added the theoretical background and the goals of the procedure. Level three feedback answers the question "What are the goals?" (see Hattie &

Timperley, 2007). Similar to the knowledge-decomposition prompt, level three feedback targeted on conditional knowledge. An example is:

> *"To ensure motivation and initiative one should use a problem that is relevant for students. Therefore the problem scenario should have characteristics from real life problems such as being realistic, ill-structured, and complex. This might be beneficial for transfer into everyday life, under some circumstances. […]"*

Recognizing an error as such is a central prerequisite for learning from it. Accordingly all learners in the adaptable feedback condition received feedback on level one automatically. Also less advanced students were subsequently enabled to identify the error. Feedback on levels two and three was only provided if learners clicked on a link it. It opened in a new window in which the level two respectively level three feedback was given. For an screenshot see Figure 3, page 63.

Subjects without adaptable feedback received elaborated feedback, in which information on all three levels was provided simultaneously (Narciss, 2008).

7.3.5 Data Sources and Instruments

Pretest

Due to time constraints during the study in teaching and in contrast to the other two studies in medicine and in nursing prior knowledge in the pretest was measured only through a 21-item multiple-choice questionnaire on declarative-conceptual knowledge on the topic problem-based learning (for an example item see Table 25). In the multiple-choice questionnaire zero to four answers were correct in every question. Learners received one point for every correctly marked or correctly not marked answer. During scale formation, one question had to be removed to increase the internal consistency. Maximum points that could be achieved were 80. Cronbach's α was good Table 29, page 121.

Table 25: *Example item multiple-choice test to assess declarative-conceptual knowledge in teaching*

It is the goal of problem-based learning to…	
❍	solve problems.
❍	to acquire flexibly adaptable knowledge.
❍	find as much realistic problems as possible.
❍	to increase motivation and interest through authentic problems.

Metacognitive competence: The same questionnaire to assess metacognitive competence than in medicine and in nursing was using. For a more detailed description of the questionnaire see page 67. An example item is "*I can estimate well to which times I can study best.* ". The responses were on a 6-point Likert scale. Answers were ranging from one (fully disagree) to sic (fully agree). The score was computed based on the mean of the responses on all items (Cronbach's α = .85; see Table 29, page 121). The test can be found in Appendix L Test for Metacognitive Competence.

Process data

All process data was the using the same measures as in the study in medicine and nursing. For a more detailed description please see page 68. In contrast to the other two studies cognitive load and motivation were assessed two times: The first time was in the middle of the learning session and the second time at the end of the learning session.

Cognitive load: Cognitive load was assessed with an eight item subjective rating scale. An example item is *''How easy or difficult did you find it to understand the solution of the last worked example?".*The scale was ranging from one (very easy) to seven (very difficult) (Paas & Kalyuga, 2005). With the sample of prospective teachers in this study, the sub-scales proposed by Paas and Kalyuga (2005) could not be replicated. The score was computed based on the mean of the responses on all items. Cronbach's α was satisfactory (see Table 29, page 121). The test can be found in Appendix M Test for Cognitive Load.

Motivation: Motivation was assessed with a questionnaire using 11 items fromt a questionnaire developed by (Prenzel et al., 1993). An example item is "*During the learning session so far I enjoyed studying*.". The items were answered using a rating scale ranging from zero (almost never) to three (very frequently). The score was computed based on the mean of the responses on all items. Cronbach's α was satisfactory (see Table 29, page 121). The test can be found in Appendix N Test for Motivation.

Processing time: The learning environment logged the time spent on the content (e.g., time spent on the three different prompts). The time a learner spent on a specific content can be interpreted as processing time of the content (Sánchez & García-Rodicio, 2013). Thus more time spent on the elaboration of a specific content can be regarded as an indicator for more intense processing (Sánchez & García-Rodicio, 2013).

Posttest

Diagnostic Competence: During the posttest diagnostic competence was assessed using the conceptualization of Stark and colleagues (2011) that differentiates into (a) declarative-conceptual knowledge and (b) practical knowledge (consisting of strategic and conditional knowledge) (see *chapter 2.1 Diagnostic Competence in Medicine, Nursing, and in Teaching*

Diagnostic Competence in Medicine*, page 21*). As professional knowledge is bound to contexts and situations (Borko, 2004; Seidel & Prenzel, 2007) it might be beneficial to assess practical knowledge with cases in which the application of knowledge is necessary because then situational and contextual features can be concluded.

(a) Declarative-conceptual knowledge in the posttest was assessed through the multiple-choice questionnaire already used in the pretest. Thus the maximum score was again 80. Cronbach's α was satisfactory (see Table 29, page 121). The test on declarative-conceptual knowledge can be found in Appendix J Test for Declarative-Conceptual Knowledge in Teaching.

(b) Practical knowledge was measured using key feature tasks (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) for conditional knowledge.

Strategic knowledge was measured with 9 key feature tasks (Farmer & Page, 2005). After a short description of a classroom situation, learners had to derive consequences for further actions. An example can be seen in Table 26. Key Feature tasks make problem solving necessary and can be compared to problem-solving tasks used e.g. by Richey and Nokes-Malach (2013). As in another study, the transfer taxonomy by Barnett and Ceci (2002) (see *chapter 2.4 Expertise, page 25*) is used to classify key feature tasks according to their need of transfer knowledge (Nokes-Malach et al., 2013). Key feature tasks in this study asseed near transfer as the execution of prior problem solving procedures introduced in the worked examples needs to be applied. The key feature tasks were similarly structured then the worked examples and required the application of knowledge to a similar problem with different surface features. The answers were rated by two raters and for each key feature task up to three points could be achieved. The more a student was able to relate scientific knowledge to the case of application the more points he or she got. The maximum score was 27 points. The ICCs for the different key-feature tasks ranged from satisfactory (ICC = .41) to excellent values (ICC = .92). The ICCs can be seen in

Table 28. Cronbach's α was .70 (see Table 29, page 121). The strategic knowledge test can be found in Appendix K Test for Strategic and Conditional Knowledge in Teaching.

Table 26: *Example key feature tasks to assess strategic knowledge in teaching*

Classroom situation *Ms. Hummel is very interested in situated learning approaches. She likes your approach very much. Ms. Hummel is asking you to prepare a plan for the next teaching unit. She will ask specific questions on all eight phases of your planned problem-based learning unit.*
Question 1 *How do you find an adequate problem scenario?*
Question 2 *What is an adequate problem scenario for your unit?*

Conditional knowledge was measured through 9 knowledge-decomposition tasks in which students were asked about the reasons and the theoretical explanation for an action. For an example see Table 27. Following again the transfer taxonomy by Barnett and Ceci (2002) (see *chapter 2.4 Expertise on page 25*) knowledge-decomposition tasks in this study assess intermediate transfer of content as a learner not just performs what he or she learned in a similar situation to the learning situation but needs to reflect on alternatives. Accordingly a learner not only needs to know what he or she does, but also why and under which conditions a strategy can be used. Tasks in which deep conceptual understanding is necessary are considered even considered far transfer by some authors (Nokes-Malach et al., 2013; Richey & Nokes-Malach, 2013). Answers again were rated by two raters. Up to three points could be achieved. The maximum score was 27 points. The ICCs for the different key-feature tasks ranged from satisfactory (ICC = .46) to excellent values (ICC = .74). The ICCs can be seen in

Table 28. Cronbach's α was .75 (see Table 29). The conditional knowledge test can be found in Appendix K Test for Strategic and Conditional Knowledge in Teaching.

For the aggregated measure practical knowledge (18 Items) consisting of the key feature and of the knowledge-decomposition tasks the Cronbach's α was .84, and the maximum score 54.

Table 27: *Example knowledge-decomposition tasks to asses conditional knowledge in teaching*

Question 1 *What theoretical background is your decision for a problem scenario is based on?*
Question 2 *What goals do you have with your problem scenario?*

Table 28: *ICCs in the key feature tasks and in the knowledge-decomposition tasks in the posttest in teaching*

Item	ICC
Post key feature task 1	.92**
Post key feature task 2	.85**
Post key feature task 3	.65**
Post key feature task 4	.69**
Post key feature task 5	.43**
Post key feature task 6	.70**
Post key feature task 7	.41**
Post key feature task 8	.45**
Post key feature task 9	.60**
Post knowledge-decomposition task 1	.74**
Post knowledge-decomposition task 2	.70**
Post knowledge-decomposition task 3	.57**
Post knowledge-decomposition task 4	.46**
Post knowledge-decomposition task 5	.55**
Post knowledge-decomposition task 6	.64**
Post knowledge-decomposition task 7	.59**
Post knowledge-decomposition task 9	.67**

Note ** = $p < .01$, * = $p < .05$

Bivariate correlations were calculated using Pearson's product-moment correlation. There were high correlations between declarative-conceptual knowledge and strategic knowledge ($r = .54$, $p < .01$), as well as between strategic and conditional knowledge ($r = .72$, $p < .01$). The correlation between declarative-conceptual knowledge and conditional knowledge was moderate ($r = .54$, $p < .01$).

Table 29: *Instruments, internal consistency in the study in teaching*

Measures	**Cronbach's α**
Pretest	
Prior declarative-conceptual knowledge	.71
Metacognitive competence	.85
Process	
Cognitive load time 1	.83
Cognitive load time 2	.88
Motivation time 1	.86
Motivation time 2	.88
Posttest	
Diagnostic competence	
Declarative-conceptual knowledge	.78
Practical knowledge	.84
Strategic knowledge	.70
Conditional knowledge	.75

7.3.6 Statistical Analysis

The alpha level of .05 was used for the statistical analyses. Partial eta^2 was used as a measure of effect size; values of about .01 are considered as weak effect size, of about .06 as medium, and of about .14 or higher as large (Cohen, 1988). Bivariate correlations were calculated using Pearson's product-moment correlation: values of .01 are considered small, of about .30 as medium, and of above .50 as large (Cohen, 1988). In addition MANCOVAs, ANCOVAs, ANOVAs, and t-tests were used. Post-hoc comparisons were conducted using linear independent, pairwise and Bonferroni-adjusted contrasts. In case of unequal variances a Kruskal-Walis test with follow-up Man-Whitney tests were applied. For the two mediation analysis in research questions four and six the causal steps strategy by (Baron & Kenny, 1986) and the products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986) was used. According to the causal steps strategy, a variable (e.g., metacognitive competence) is a mediator of the effects of an independent variable (e.g., adaptable feedback) on a dependent variable (e.g., diagnostic competence) if four conditions are met: (a) the independent variable (adaptable feedback) must affect the dependent variable (diagnostic competence). (b) the independent variable (adaptable feedback) must affect the potential mediator (metacognitive competence), (c) the mediating variable (metacognitive competence) must affect the dependent variable (diagnostic competence) when both the independent variable (adaptable feedback) and mediating variable (metacognitive competence) are predictors of the dependent variable (diagnostic competence), and (d) the effect of the independent variable (adaptable feedback) on the dependent variable (diagnostic competence) should be substantially reduced (partial mediation) or zero (complete mediation) when the mediator is included as an additional predictor of the dependent variable (MacKinnon et al., 2007; Preacher & Hayes, 2008).

7.4 Results

7.4.1 Preliminary analyses

No differences concerning prior knowledge ($F(3, 104) = .72$, $p = .54$), and metacognitive competence ($F(3, 104) = .60$, $p = .62$) were found between the four conditions prior to the experiment. For descriptive values please see Table 30).

The correlations of prior knowledge with diagnostic competence were significant and either high or moderate (for declarative-conceptual knowledge, r = .65, p < .01; for strategic knowledge, r = .46, p < .01; for conditional knowledge, r = .33, p < .01) indicating a pre to posttest gain. A dependent t-test comparing the value of the declarative-conceptual knowledge test in the pre and in the posttest showed an increased value in in the posttest (M = 60.39, SD = 7.56) compared to the pretest (M = 55.13, SD = 7.12), t(107) = -8.67, p < .01, r = .65.

Regarding the effect of self-explanation prompts and adaptable feedback on time-on-task, the Levene's test for equality of variances was found to be significant for the present analysis (F(3, 104) = 6.69, p < .001) indicating unequal variances. In addition Hartley's variance ratio shows a value of F_{max} = 7.27 and is thus above the critical value (Pearson & Hartley, 1976), further indicating substantial differences in variance. Therefore a Kruskal–Wallis test, with follow-up Man-Whitney tests were applied. The experimental variation through self-explanation prompts (with and without) and adaptable feedback (with and without) were significantly affecting time-on-task (H(3) = 77.48, p < .01). Mann–Whitney tests were used to follow-up this finding. A Bonferroni correction was applied and so all effects are reported at a .025 level. Self-explanation prompts did affect time-on task (U = 27, p <.01). In contrast adaptable feedback had no effect on time-on-task (U = 1373, p = .61). That is learners with self-explanation prompts learned longer than learners without, however, adaptable feedback had no additional effect on the learning time and also the two measures did not interact with each other regarding the learning time. That is learners with self-explanation prompts learned longer than learners without, however, adaptable feedback had no additional effect on the learning time and also the two measures did not interact with each other regarding the learning time (for descriptive data see Table 30).

Time-on-task was not significantly correlated to declarative-conceptual knowledge (r = .04, p = .68) and to conditional knowledge (r = -.18, p = .06). However, it was negatively correlated to strategic knowledge (r = -.27, p < .01).

Table 30: *Means and (SD) of prior diagnostic competence, prior declarative-conceptual knowledge, metacognitive competence, cognitive load, motivation, time-on-task, diagnostic competence, declarative-conceptual knowledge, practical knowledge, strategic knowledge, and conditional knowledge in teaching*

	With self-explanation prompts		Without self-explanation prompts	
	With adaptable feedback (n = 26)	Without adaptable feedback (n = 29)	With adaptable feedback (n = 26)	Without adaptable feedback (n = 27)
Prior knowledge	54.57 (6.98)	53.86 (7.64)	56.46 (6.56)	55.74 (7.33)
Metacognitive competence	4.55 (0.55)	4.69 (0.41)	4.60 (4.75)	4.54 (0.56)
Cognitive load time 1	4.06 (1.12)	4.11 (0.76)	3.24 (0.62)	3.62 (0.71)
Cognitive load time 1	3.62 (1.07)	3.62 (0.76)	2.97 (0.66)	3.25 (0.90)
Motivation time 1	2.57 (0.60)	2.66 (0.69)	2.76 (0.38)	2.58 (0.48)
Motivation time 2	2.60 (0.65)	2.63 (0.69)	2.87 (0.46)	2.56 (0.49)
Time-on-task	49.98 (10.35)	49.46 (10.18)	19.20 (7.04)	20.16 (3.84)
Diagnostic competence				
Declarative-conceptual knowledge	61.96 (5.70)	59.07 (8.69)	59.19 (8.33)	61.44 (6.99)
Practical knowledge	19.88 (7.24)	19.51 (8.97)	27.88 (8.13)	24.52 (10.38)
Strategic knowledge	10.19 (3.25)	10.59 (4.95)	14.58 (4.15)	13.33 (5.58)
Conditional knowledge	9.69 (4.79)	8.93 (4.86)	13.31 (4.90)	11.19 (5.26)

7.4.2 Effect on Diagnostic Competence (RQ1)

Descriptive data on the diagnostic competence measures in the four conditions can be seen in Table 30. To test if self-explanation prompts and adaptable feedback or the combination of them can foster learning of diagnostic competence, a MANCOVA with self-explanation prompts and adaptable feedback as independent variable, diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) as dependent variable and prior knowledge a covariate was conducted. The MANCOVA showed that the interaction between the self-explanation prompts and the adaptable feedback was significant Wilks's $\lambda = .90, F(3, 101) = 3.79, p < .05$.

The next steps in the analytic strategy addressed the different component variables of diagnostic competence. To test the effect of the two independent variables self-explanation prompts and adaptable feedback on the dependent variables declarative-conceptual knowledge, strategic knowledge and conditional knowledge three ANCOVAs with prior knowledge as covariate were calculated.

Declarative-conceptual knowledge: The first ANCOVA revealed a significant interaction effect of self-explanation prompts and adaptable feedback on declarative-conceptual knowledge $F(1, 103) = 5.57$, $p < .05$, *partial* $\eta^2 = .05$. The students who learned with self-explanation prompts and with adaptable feedback ($M = 61.96$; $SD = 5.70$) outperformed their fellow students in the condition without self-explanation prompts and with adaptable feedback ($M = 59.19$; $SD = 8.32$, post-hoc comparison $p < .05$). None of the other conditions differed significantly from each other. Indicating that the interaction effect mainly showed because of the difference between the learner with both scaffolding methods and learners with adaptable feedback only. In Figure 12, this interaction effect can be observed.

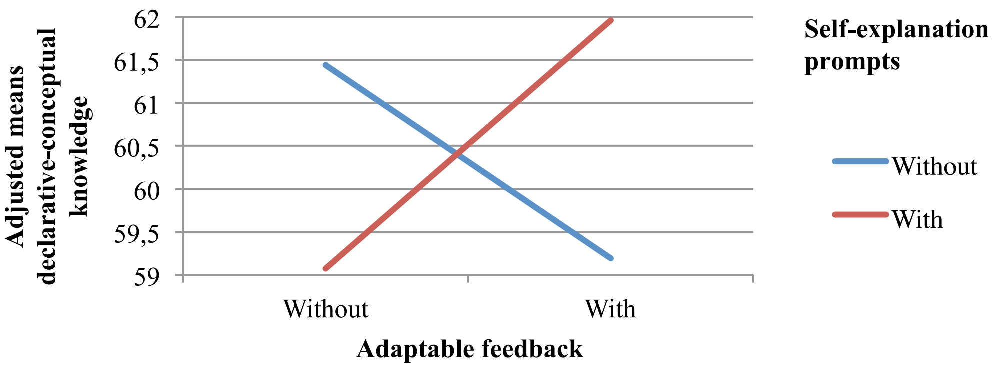

Figure 12: *Adjusted means of declarative-conceptual in the four experimental conditions in teaching*

Practical knowledge: However, a second, third, and fourth ANCOVA with of self-explanation prompts and adaptable feedback as independent, prior knowledge as covariate and strategic knowledge or conditional knowledge or practical knowledge did not reveal a significant interaction effect of self-explanation prompts and adaptable feedback on strategic knowledge ($F(1,103) = 1.05$, $p = .31$), conditional knowledge ($F(1,103) = .55$, $p = .46$) or practical knowledge ($F(1,103) = .93$, $p = .34$). Hence there was only an interaction effect of self-explanation prompts and adaptable feedback on practical knowledge.

As these analysis did not reveal an interaction effect of self-explanation prompts and adaptable feedback, the main effects of self-explanation prompts and adaptable feedback on strategic and on conditional knowledge were tested while prior knowledge was controlled.

To analyze the main effects in more detail three ANCOVAs with self-explanation prompts and adaptable feedback as independent variable, prior knowledge as covariate and strategic or conditional or practical knowledge as dependent variables were conducted. No significant effect of adaptable feedback on strategic knowledge ($F(1,103) = .77$, $p = .78$) (see Figure 13), conditional knowledge ($F(1, 103) = 1.99$, $p = .16$) (see Figure 14), or on practical knowledge ($F(1, 103) = .93$, $p = .37$) (Figure 15) could be shown. There was a medium-sized negative effects of self-explanation prompts on strategic knowledge ($F(1,103) = 14.22$, $p < .001$, *partial* $\eta^2 = .12$), on conditional knowledge ($F(1, 103) = 7.57$, $p < .01$, *partial* $\eta^2=0.07$) as well as on practical knowledge ($F(1, 103) = 12.60$, $p < .01$, *partial* $\eta^2=0.11$).

Learners in the condition with self-explanation prompts acquired *less* strategic knowledge ($M = 10.40$; $SD = 4.20$), conditional knowledge ($M = 9.29$; $SD = 4.80$), and practical knowledge ($M = 19.69$; $SD = 8.12$) than learners without self-explanation prompt (strategic knowledge: $M = 13.94$, $SD = 4.92$, post-hoc comparison $p < .01$; conditional knowledge: $M = 12.22$; $SD = 5.15$, post-hoc comparison $p < .01$, practical knowledge: $M = 26.17$; $SD = 9.41$, post-hoc comparison $p < .01$). Learners with both scaffolds (self-explanation prompts, adaptable feedback) acquired *less* strategic knowledge than learners without any scaffolds (with: $M = 10.19$, $SD = 3.24$; without: $M = 13.33$; $SD = 5.58$, post-hoc comparison $p < .01$).

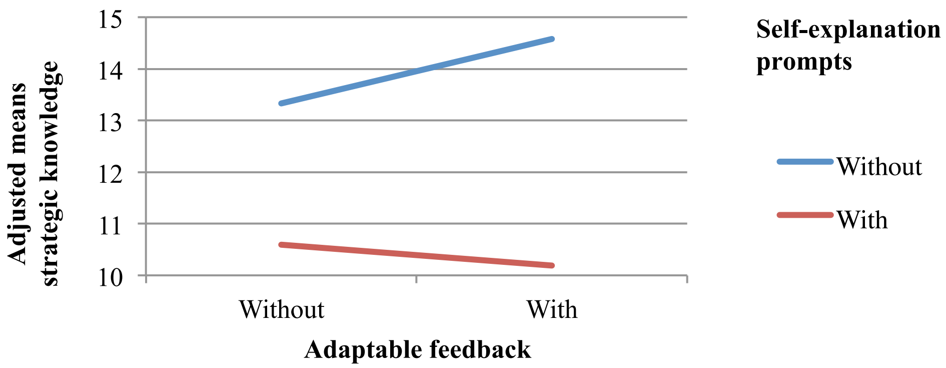

Figure 13: *Adjusted means of strategic knowledge in the four experimental conditions in teaching*

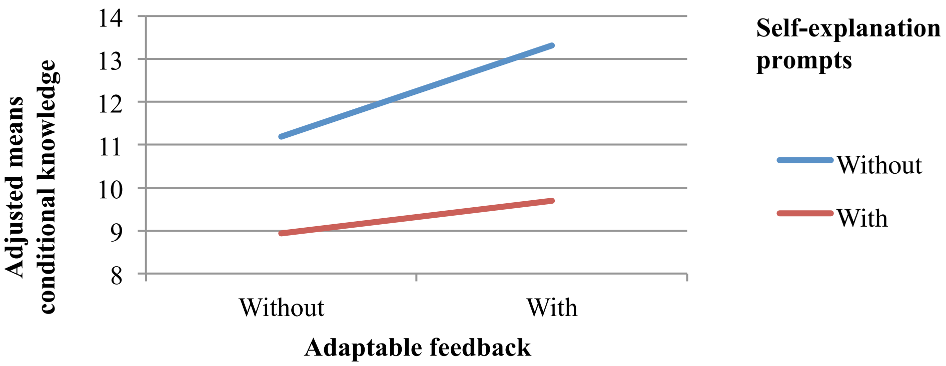

Figure 14: *Adjusted means of conditional knowledge in the four experimental conditions in teaching*

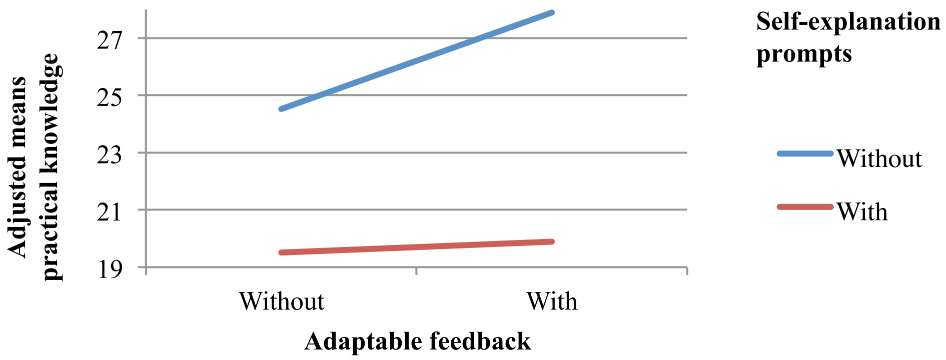

Figure 15: *Adjusted means of practical knowledge in the four experimental conditions in teaching*

To answer research question two it can be said, adaptable feedback had no main effect on diagnostic competence. Self-explanation prompts had a main effect on strategic, conditional and practical knowledge. This effect was negative. The combination of self-explanation prompts and of adaptable feedback had a positive effect on declarative-conceptual knowledge.

7.4.3 Type of Prompt (RQ2)

The relation of the three different prompts (error-recognition prompt, problem-solving prompts, knowledge-decomposition prompt) with the types of knowledge contained in the model of diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) was analyzed with Person's Bivariate correlations between the time spend on the three prompts and diagnostic competence. There was no significant correlation between the time on task spend on the declarative and on the strategic self-explanation prompts,

To analyze the relation of the three different prompts with the types of knowledge contained in the model of diagnostic competence, bivariate correlations were calculated using Pearson's product-moment correlation. The two variables used for that calculation were (1) the automatically logged time a learner spent answering the three prompts and (2) diagnostic competence. The time the learner spent on answering the prompts is interpreted as processing time similar as in the study by Sánchez and García-Rodicio (2013). More time used for answering a specific prompt can be regarded as an indicator for more intense processing (Sánchez & García-Rodicio, 2013). There was no significant correlation between the time-on-task spent on the error recognition prompt and diagnostic competence (see Table 31). There were significant positive correlations between the time spend on the knowledge-decomposition prompt and strategic knowledge (r = .35, p < .01) as well as conditional knowledge (r = .35, p < .01).

Table 31: *Correlations between time on the three prompts with diagnostic competence (declarative-conceptual knowledge, strategic knowledge, conditional knowledge) in teaching*

	Pearson's Correlation (two tailed)		
	Time on error-recognition prompt	Time on problem -solving prompt	Time on knowledge-decomposition prompt
Declarative-conceptual knowledge	-.17	.07	.16
Practical knowledge	.03	.29*	.41**
Strategic knowledge	-.04	.26	.35**
Conditional knowledge	.09	.26	.38**

Note ** = p <0.01, * = p <0.05

In sum, the three self-explanation prompt types had differentiated effects on diagnostic competence. Whereas the self-explanation prompts that targeted on error-recognition was not positively associated with diagnostic competence, the self-explanation prompts that targeted on problem solving and in particular the knowledge-decomposition prompt was positively related with the practical knowledge in teacher students.

7.4.4 Effect of Adaptable Feedback on Motivation (RQ3)

To analyze the effect of adaptable feedback on motivation two independent t-tests with adaptable feedback as independent and motivation at time one or time two as dependent variable was calculated. It showed no difference between those groups (t(106) = -.37, p = .72) at the first assessment point after one worked example and at assessment time two at the end of the learning session (t(106) = -.37, p = -1.28). A dependent t-test showed that motivation did also not differ between the two points of measurement (t(107) = -.69, p = 4.89). To answer research question three it can be said, that motivation could not be increased by adaptable feedback.

7.4.5 Mediation by Metacognitive Competence (RQ4)

To answer research questions four whether the relation of adaptable feedback on the acquisition of diagnostic competence were mediated by metacognitive competence the causal steps strategy by Baron & Kenny, 1986) and the products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986) was used. For a more detailed description see chapter *5.4.5* Mediation by Metacognitive Competence (RQ4) on page 77. According to the causal steps strategy, metacognitive competence is a mediator of the effects of adaptable feedback on diagnostic competence if four conditions are met: (a) Adaptable feedback must affect diagnostic competence. (b) Adaptable feedback must affect metacognitive competence, (c) metacognitive competence must affect the diagnostic competence when both the adaptable feedback and metacognitive competence are predictors of diagnostic competence, and (d) the effect of the adaptable feedback on diagnostic competence should be substantially reduced (partial mediation) or zero (complete mediation) when metacognitive competence is included as an additional predictor of diagnostic competence (MacKinnon et al., 2007; Preacher & Hayes, 2008).

(a) As another analysis on research question one (see page 98) already revealed that the adaptable feedback did not affect the dependent variable diagnostic competence significantly the first of Baron and Kenny's (1986) causal steps was not met. This indicates that a mediation of metacognitive competence affecting the influence of adaptable feedback and diagnostic competence could not be shown.

7.4.6 Effect of Cognitive Load (RQ5)

Cognitive load was measured in the middle of the learning phase (CL 1) and at the end of the learning phase (CL2).

Germane cognitive load correlated negatively with diagnostic competence at both points of measurement (CL1: declarative-conceptual knowledge: $r = -.46, p < .01$, practical knowledge: $r = -.40, p < .01$; CL2: declarative-conceptual knowledge: $r = -.36, p < .01$, practical knowledge: $r = -.37, p < .01$) indicating that the sub-scales proposed by Paas and Kalyuga (2005) could not be replicated with this sample of prospective teachers. Thus in the following cognitive load is treated as aggregated measure.

Cognitive load correlated negatively with the posttest measures declarative-conceptual knowledge (CL1: $r =-.37, p < .01$; CL2: $r =-.33, p < .01$), strategic knowledge (CL1: $r =-.36, p < .01$; CL2: $r =-.36, p < .01$), practical knowledge (CL1: $r =-.40, p < .01$;

CL2: r =-.36, $p < .01$), and with conditional knowledge (CL1: r =-.36, $p < .01$; CL2: r =-.32, $p < .01$). Learners who experienced a higher cognitive load acquired less diagnostic competence.

Correlations between cognitive load at time 1 and time 2 on one side and prior knowledge on the other side were significantly negative (CL1: r =-.41, $p < .01$; CL2: r =-.27, $p < .01$) indicating learners with low prior knowledge experienced higher cognitive load when learning with the worked-out examples.

Descriptive data on cognitive load in the four conditions can be found in Table 30, page 124. To test if self-explanation prompts and adaptable feedback (independent variable) had an influence on cognitive load measured at time one and two (dependent variables as repeated measure) a mixed design ANOVA was calculated.

There was a significant main effect of the time point in which cognitive load was measured on the amount of cognitive load ($F(1, 104) = 31.90$, $p < .01$, $r = .48$). That is cognitive load decreased over time (CL1: $M = 3.77$, $SD = .99$; CL2: $M = 3.37$, $SD = .89$). There also showed a main effect self-explanation prompts on cognitive load ($F(1, 104) = 15.67$, $p < .01$, $r = .99$). However, no significant interaction effects of adaptable feedback could be shown. Also no interaction between the experimental conditions and the time in which cognitive load was measured.

To analyze the differential effects of self-explanation prompts and adaptable feedback on cognitive load time one and time two, ANOVAs with self-explanation prompts and adaptable feedback as independent variable, and cognitive load time one and time two as dependent variables were conducted.

Cognitive load time *1:* An ANOVA with self-explanation prompts and adaptable feedback as independent variable and cognitive load in the middle of the learning phase as dependent variable was conducted. There was no significant effect of adaptable feedback on cognitive load ($F(1, 104) = 1.83$, $p = .18$). There was a significant main effect, however, of self-explanation prompts on cognitive load ($F(1, 104)$ =16.85, $p < .01$, *partial* $\eta^2 = .14$). Learner with self-explanation prompts ($M = 4.08$; $SD = .94$) experienced more cognitive load than students without self-explanation prompts ($M = 3.43$; $SD = .69$, post-hoc comparison $p < .01$). The two factors, adaptable feedback and self-explanation prompts, did not interact with respect to cognitive load at time 1 ($F(1, 104) = 1.08$, $p = .30$).

Cognitive load time *2*. There again was no significant effect of adaptable feedback on cognitive load ($F(1, 104) = .69$, $p = .41$). A significant main effect of self-explanation prompts on cognitive load was identified ($F(1, 104) = 9.40$, $p < .01$, *partial* $\eta^2 = .08$). Learner with self-explanation prompts ($M = 3.62$; $SD = .91$) experienced higher cognitive load than student without self-explanation prompts ($M = 3.11$; $SD = .80$, post-hoc comparison $p < .01$). The two factors, adaptable feedback and self-explanation prompts, did not interact with respect to cognitive load at the second point of measurement ($F(1,104) = .68, p = .41$).

To answer research question one it can be concluded that self-explanation prompts increased cognitive load independently of the adaptable feedback. Cognitive load decreased over time.

7.4.7 Mediation of Cognitive Load (RQ6)

The causal steps strategy by Baron & Kenny, 1986) and the products of coefficients approach (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986) was used for the analysis if cognitive load mediated the relationship between self-explanation prompts and diagnostic competence. For a more detailed description see *chapter 5.4.5 Mediation by Metacognitive Competence (RQ4), page 77.*

According to the causal steps strategy cognitive load is a mediator of the effects of adaptable feedback on diagnostic competence if four conditions are met: (a) Self-explanation prompts must affect diagnostic competence. (b) Self-explanation prompts must affect cognitive load, (c) cognitive load must affect the diagnostic competence when both the self-explanation prompts and cognitive load are predictors of diagnostic competence, and (d) the effect of the self-explanation prompts on diagnostic competence should be substantially reduced (partial mediation) or zero (complete mediation) when cognitive load is included as an additional predictor of diagnostic competence (MacKinnon et al., 2007; Preacher & Hayes, 2008).

(a) In first regressions with self-explanation prompts as independent and declarative-conceptual or strategic or conditional or practical knowledge as dependent variable showed that self-explanation prompts accounted for 12.2 % of practical knowledge ($F(1, 106) = 14.70, p < .01$), for 13.3 % of the variance of strategic knowledge ($F(1, 106) = 16.23, p < .01$), and for 8.1 % of the variance of conditional knowledge ($F(1, 106) = 9.40, p < .01$). Declarative-conceptual knowledge was not affected by self-explanation prompts ($F(1, 106) = .004, p = .95$).

(b) In a further regressions with self-explanation prompts as independent and cognitive load at the two different assessment points as dependent variable it showed that self-explanation prompts did account for 13.6 % of the variance of cognitive load at time 1 ($F(1, 106) = 16.63, p < .01$) and for 8.1 % of the variance of cognitive load at time 2 ($F(1, 106) = 9.37, p < .01$).

(c) In a third regression analysis, practical or strategic or conditional knowledge was regressed on self-explanation prompts and cognitive load at the first or at the second point of measurement are entered in a simultaneous multiple regression model.

Strategic knowledge: A regression equation with cognitive load at time one and self-explanation prompts as independent variables and strategic knowledge as dependent variable the model accounted for 19.2 % of the variance in strategic knowledge ($F(2, 105) = 12.47$, $p < .01$). In this multiple regression model, self-explanation prompts were a significant predictor of strategic knowledge $b = -.27$, $t(105) = -2.84$, $p < .01$ as well as cognitive load, $b = -.26$, $t(105) = -2.77$, $p < .01$. For a regression with cognitive load at time two and self-explanation prompts as independent variables and strategic knowledge as dependent variable the model accounted for 20.1 % of the variance in strategic knowledge ($F(2, 105) = 13.24$, $p < .01$). In this multiple regression model, self-explanation prompts were a significant predictor of strategic knowledge $b = -.29$, $t(105) = -3.15$, $p < .01$ as well as cognitive load, $b = -.27$, $t(105) = -3.01$, $p < .01$.

Conditional knowledge: A regression with cognitive load at time one and self-explanation prompts as independent variables and conditional knowledge as dependent variable accounted for 15.6 % of the variance in conditional knowledge ($F(2, 105) = 9.72$, $p < .01$). In this multiple regression model, cognitive load at time one was a significant predictor of conditional knowledge $b = -.29$, $t(105) = -3.05$ $p < .01$. By contrast self-explanation prompts did not significantly predict conditional knowledge, $b = -.18$, $t(105) = 1.84$, $p = .07$. For a regression with cognitive load at time two and self-explanation prompts as independent variables and conditional knowledge as dependent variable the model accounted for 14.5 % of the variance in conditional knowledge ($F(2, 105) = 8.91$, $p < .01$). In this multiple regression model, self-explanation prompts were a significant predictor of conditional knowledge $b = -.21$, $t(105) = -2.24$, $p < .05$ as well as cognitive load, $b = -.26$, $t(105) = -2.80$, $p < .01$.

Practical knowledge: The regression equation with cognitive load at time one and self-explanation prompts as independent variables and practical knowledge as dependent variable accounted for 20 % of the variance in practical knowledge ($F(2, 105) = 13.09$ $p < .01$). Self-explanation prompts were a significant predictor of practical knowledge $b = -.24$, $t(105) = -2.54$, $p < .05$ as well as cognitive load, $b = -.30$, $t(105) = -3.19$, $p < .01$. For a regression with cognitive load at time two and self-explanation prompts as independent variables and practical knowledge as dependent variable the model accounted for 20 % of the variance in practical knowledge ($F(2, 105) = 13.01$, $p < .01$). Again in this multiple regression model, self-explanation prompts were a significant predictor of conditional knowledge $b = -.27$, $t(105) = -2.93$, $p < .01$ as well as cognitive load, $b = -.29$, $t(105) = -2.90$, $p < .01$.

d) In order to test for partial mediation the products of coefficients approach is used (MacKinnon et al., 2007; Preacher & Hayes, 2008; Sobel, 1986). With this approach it can be tested if the effect of an independent variable (self-explanation prompts) on a dependent variable (strategic, conditional or practical knowledge) is significantly reduced when the mediator (cognitive load time one or time two) is included as additional predictor.

Strategic knowledge: The products of coefficients approach with strategic knowledge as dependent variable, cognitive load at time one and self-explanation prompts as dependent variables yielded a z score of 2.33 that was significant on the 1 % level. For cognitive load at assessment point two the z score was 2.46 and hence also significant on the 1 % level.

Conditional knowledge: For conditional knowledge and cognitive load at time one all conditions for a full mediation are met. For cognitive load at assessment point two the z score was 2.46 and thus significant on the 5 % level.

Practical knowledge: The products of coefficients approach with practical knowledge as dependent variable, cognitive load at time one and self-explanation prompts as dependent variables yielded a z score of 2.51 (significant on the 1 % level). For cognitive load at assessment point two the z score was 2.38 (significant on the 1 % level).

This finding supports the hypothesis that cognitive load mediated the influence of self-explanation prompts on strategic, conditional and practical knowledge.

7.5 Discussion

Erroneous worked examples in a computer-based learning environment with the goal to foster diagnostic competence in preservice teachers were implemented. Two scaffolding methods, self-explanation prompts, and adaptable feedback were varied systematically.

Prior knowledge and metacognitive competence prior to the study did not differ between the experimental groups. Moderate to high correlations were found between diagnostic competence in the pretest and in the posttest, indicating a gain in diagnostic competence. A pretest to posttest gain also showed regarding declarative-conceptual knowledge. No effect of adaptable feedback on time-on-task could be found. Learners spent an equal amount of time processing also the adaptable feedback regardless of its adaptability. In contrast to other studies in which learners did not use feedback provided on demand very often (e.g. Corbett & Anderson, 2001), in this study learners did not fade out the feedback even though they could. In contrast self-explanation prompts, more than doubled the learning time. Learning time did not influence the acquisition of declarative-conceptual knowledge and conditional knowledge, whereas learning time negatively influenced strategic knowledge.

Whereas adaptable feedback did not have an effect on diagnostic competence, self-explanation prompts had a negative effect on at least some aspects of diagnostic competence, namely strategic and conditional knowledge. However, self-explanation prompts and adaptable feedback had a positive interaction effect on declarative-conceptual knowledge. The interaction mainly showed because of the difference between learners with both scaffolding methods and learners with adaptable feedback only (RQ 1). Findings on prompts targeting different kinds of knowledge showed, the three self-explanation prompt types had differentiated effects on diagnostic competence. The self-explanation prompts that targeted on error-recognition was not positively associated with diagnostic competence, the self-explanation prompts that targeted on problem solving and in particular the knowledge-decomposition prompt that targeted on conditional knowledge was positively related with practical knowledge (RQ 2). Adaptable feedback could not increase the motivation of the learners (RQ 3). Metacognitive competence did not mediate the relation of adaptable feedback and diagnostic competence (RQ 4). Self-explanation prompts increased cognitive load independently of the adaptable feedback (RQ 5). Cognitive load mediated the influence of self-explanation prompts on strategic, conditional and practical knowledge, indicating that negative effects of self-explanation prompt occurred because of the high cognitive load (RQ 6). Cognitive load decreased over time.

As prompts have the goal to induce strategies that a learner is capable of, but does not show by his or her own (Pressley et al., 1992) it is necessary to profit from prompts that a leaner is principally able to perform a certain strategy. A possible reason why self-explanations prompts failed to increase learning of diagnostic competence may be that learners were not able to produce sufficient self-explanations. Chi (2000) claims that learning may also be possible from incorrect and fragmented self-explanations (Chi, 2000). Other authors state against, this may only be true if a high percentage of self-explanations are correct (Aleven & Koedinger, 2002). In a complex field such as in diagnosing a classroom situation the amount of correct self-explanations could be to little to have an impact on learning. However, learners could have used the feedback to close gaps in their knowledge. For finding relevant information in the feedback it can be assumed that a certain basic understanding is a prerequisite.

Keeping in mind cognitive skill acquisition (Anderson, Fincham, & Douglass, 1997; VanLehn, 1996), learners in an early stage focus on understanding of domain principles. Only in an intermediate stage learners start to reflect on how abstract strategies are used to solve problems. Self-explanation prompts and adaptable feedback only in combination increased declarative-conceptual knowledge. This might be a result of the focus of the learners. With the prompts it is possible that learners realized a lack of basic concepts and then focused their attention on the declarative-conceptual knowledge in the given feedback. If feedback was not adaptable the learners might not have been able to sort out the relevant information. Relating this findings to general feedback literature (Hattie & Timperley, 2007), structuring the feedback into recognizing a wrong procedure, in how to proceed and in what the goal of procedure is, seems to have helped the learner only if prompted before. The adaptability might have helped to recognize the relevant knowledge and therefore also learners with less favorable learning prerequisites could identify the relevant knowledge.

Self-explanation prompts included into worked examples are generally assumed to have a positive effect on learning (see *chapter 3.2.1 Self-Explanation Prompts*). Additional prompts can pose a high demand on the learner particularly in combination with other demands such as with processing errors. In other studies where self-explanation prompts were combined with e.g. gaps in a worked example they could not increase learning (Gerjets et al., 2006; Hilbert et al., 2008). It might be that the combination of errors in worked examples and self-explanation prompts increased cognitive load up to a detrimental level (Sweller, 2010).

Only the time spent on the conditional prompt was positively correlated to the learning of practical knowledge. Interpreting this correlation might give valuable insights into learning from errors. As learners need to be aware of an error and understand it in order to be able to learn from that error (Schank, 1999). This statement can get complemented: To foster learning from errors with additional instruction it is only valuable to prompt a learner to justify the correct practice with scientific knowledge. If also asked about the correct solution and strategies on how to prevent an error this might instead hinder learning of diagnostic competence. A reason for this might be that elaborations on the connection of scientific knowledge to cases of application in particular foster knowledge encapsulation.

Cognitive load decreased during the relatively short learning session substantially. The lower cognitive load later in the learning session might indicates that students developed enough relations between the declarative-conceptual knowledge and the cases of application that the interactivity of these elements decreased. That is learners could relate their declarative-conceptual knowledge on e.g. how they can find a problem scenario in problem-based learning to the case of finding a problem scenario on civil courage that is suitable for young adults and they can also explain why that scenario is appropriate or what the goals of such a problem scenarios are. Through building that kind of strategic and conditional knowledge the learners do not need to relate the declarative-conceptual knowledge to the case of application spontaneously. The encapsulated knowledge decreased the demand to the working memory. This is in line with the elaborations of Kalyuga (2011).

In order to interpret the use of the diagnostic competence model from medicine for teacher education the differential effects of the instruction on the three kinds of knowledge (declarative-conceptual, strategic and conditional knowledge) need to be considered. Whereas declarative-conceptual knowledge was fostered by a combination of adaptable feedback and self-explanation prompts, strategic and conditional knowledge was not fostered by the instruction. Only the time spend on the conditional prompt was positively related to strategic and conditional knowledge. All three kinds of knowledge of diagnostic competence can be facilitated by different instructional support. A model with the aim of fostering diagnostic competence might therefore benefit from the differentiation in these three kinds of knowledge. However, as the findings on strategic and conditional knowledge both followed similar patterns, also a model with only declarative and practical knowledge is conceivable.

The presented study has certain limitations e.g. prior knowledge was only assessed with a test on declarative-conceptual knowledge, thus it cannot be controlled for prior practical knowledge. A limitation is that learners had limited experience with real teaching situation, as they were all preservice teachers. It would be worthwhile to have a look at more advanced learners such as teachers who already have experience in teaching in schools. More conclusive thoughts on the limitations concerning can be found in *chapter 9.2 Limitations of the Studies, page 153*.

8 Study 4: Fostering Diagnostic Competence in Different Domains

8.1 Context

Diagnostic competence is important in various domains. It involves the analysis of complex situations such as classroom situations or the diagnosis of a patient. The units of diagnoses and the goals differ between domains. In medicine, the unit of analysis is a patient and his/her health limitations; the goal is to identify a health limitation (North American Nursing Diagnosis Association, 1990). In nursing, the goal is to identify the impact of health limitations (North American Nursing Diagnosis Association, 1990). In education, a diagnosis can be concerned with how well a specific pedagogy works in the classroom (Vogt & Rogalla, 2009). Diagnostic competences, however, are difficult to learn. This study addresses the possibilities of fostering diagnostic competences in a computer-supported learning environment using cases in which errors are integrated. Three studies, in the domains of medicine, nursing and teaching, will be reported and the effectiveness of the two scaffolding methods self-explanation prompts and adaptable feedback is compared. For this analysis the data of the already described studies is used and results are compared to each other. General research questions two is thus the focus of this study.

8.2 Aims of this Study and Specific Research Questions

(RQ 1) What are the differences of the effects of scaffolding by self-explanation prompts and adaptable feedback on diagnostic competence in a case-based learning environment that uses erroneous worked examples in teaching and in the medical domains medicine and nursing?

In the learning environment in these three studies, authentic narrative cases in which errors were integrated were used. As the effectiveness of the instructional support is specific to the domain was also of major interest, the studies were conducted in different domains, two medical domains (medicine, nursing) and in teaching. The expectations were:

If prompts focusing on diagnostic errors can foster diagnostic competence is currently not known. A positive influence is anticipated overall as the prompts could support students engagement in the explanation of errors made by others. The influence of the domain is unclear. In medicine, justifying one's own action with scientific knowledge is much more common than in nursing or teaching. Students in nursing and teaching could be overwhelmed by this additional demand. However, prompts could also induce the use of scientific knowledge in those domains and thus lead to elaboration that would not have occurred otherwise.

To what extent learners can benefit from adaptability of feedback is also not clear so far. A positive influence is anticipated overall. No influence by the domain is expected.

How can prospective physicians, nurses and teachers be supported in learning to diagnose patient cases or classroom events? The two methods, scaffolding by self-explanation prompts and adaptable feedback may interact positively because the prompts may draw the attention to misconceptions or to the lack of knowledge. The adaptability of the feedback could make it easier for learners to focus their attention on the areas in which they need to build knowledge, without getting also feedback on aspects they already know.

8.3 Method

8.3.1 Sample and Design

Data from the studies already described in the *chapter 5 Study 1: Fostering Diagnostic Competence in Medicine, chapter 6 Study 2: Fostering Diagnostic Competence in Nursing, and chapter 7 Study 3: Fostering Diagnostic Competence in Teaching* is reused for some further analysis. In study one a total of N=103 medical students in the clinical part of their studies. The data of 5 participants needed to be removed prior to the following analysis, as they did not follow the instructions e.g., they did not give answers to the self-explanation prompts. The resulting sample thus consisted of N=98 participants. In study two a total of N=152 nursing students in the final year of their education and in study three N=108 prospective teachers took part in this in this laboratory study. None of the participants had extensive practical experience. A 2 x 2 factorial design with the factors self-explanation prompts (with vs. without) and adaptable feedback (with vs. without) (see Table 32) was implemented. The subjects were randomly assigned to one of the four experimental conditions.

Table 32: *Design of the studies in medicine, nursing, and in teaching*

Adaptable feedback	Self-explanation prompts	
	With	Without
With	25 (medicine) 39 (nursing) 26 (teaching)	25 (medicine) 37 (nursing) 26 (teaching)
Without	25 (medicine) 38 (nursing) 29 (teaching)	23 (medicine) 38 (nursing) 27 (teaching)

8.3.2 Learning Environment

Learners worked individually and were asked to immerse themselves in situations of a fictitious student doing a medical clerkship (medical student participants), or an internship in a hospital (nursing student participants) or in a school (teaching student participants). While diagnosing, the fictitious student commits errors. For examples please see table 1. The cases were implemented into the computer-supported learning environment 'CASUS' (M. Fischer, 2000).

Table 33: *Examples of integrated errors from the three studies*

Study 1: Medicine Context: Mr. Drexel collapsed earlier that night. *"As Mr. Drexel is awake and cooperative again you register him for further cardiac diagnostic with an echocardiography for the next day."*
Study 2: Nursing Context: Ms. Muric was described as a patient with serious exertional dyspnea. *"Ms. Muric is in the bathroom and you hand her towels and her wash bag. Upon her request you are looking for fresh clothes in her luggage. You help Ms. Muric to sit on a chair in front of the sink. You leave the door slightly open and stay in the room. You ask Ms. Muric to tell you whenever she is finished."*
Study 3: Teaching Context: The fictitious student prepared and implemented lessons using the instructional approach "problem-based learning". *"At first you want to find a sufficient problem scenario for your students. At university you*

have heard about civil courage training for adults. By chance you know a lecturer for this topic. You suggest that the students observe the civil courage training and evaluate its efficacy."

8.3.3 Procedure

The procedures were similar in all of the studies. However, in the study in teaching the procedure differed to the procedure in medicine and in nursing, mainly due to practical reasons during the implementation of the study. First, an explanation of the purpose and the procedure of the study took place by the experimenter. Then each participant watched a video in which the learning environment was explained. Subsequently participants filled out a questionnaire for demographic and other control variables such as prior knowledge and metacognitive competence. Afterwards in the study in nursing and in medicine students continued with the prior knowledge test on diagnostic competence on the computer and solved six key feature and six knowledge-decomposition tasks. This was followed by an individual learning phase in which learners studied in medicine and in nursing three of the already described worked examples in the online learning environment. Due to the higher length of the worked examples in teaching only two examples were studied. In the teaching study learners filled out process questionnaires in which cognitive load and motivation was assed one time in the middle of the learning session and one time at the end of the learning sessions. In the study in medicine and in nursing the process questionnaire was only administered one time at the end of the learning session. Hereafter, online posttests for strategic and conditional knowledge were administered. Finally the learners completed a paper-based posttest for declarative-conceptual knowledge. For an overview on the procedure and the duration of the steps see in medicine Table 2, page 61 and in teaching Table 23, page 115.

8.3.4 Experimental Conditions

Self-explanation prompts

After the erroneous step of the fictitious student, learners in the condition with self-explanation prompts students were prompted to think about the error. The same self-explanation prompts were used in all three studies (see Table 34 for an example).

Table 34: *Self-explanation prompts used in the learning environment*

Name of the prompt	Self-explanation prompt in the learning environment
1. Error-recognition prompt	*What can you criticize on this procedure and what would be the correct procedure?*
2. Problem-solving prompt	*Which problem solving strategy could have been applied to prevent the error?*
3. Knowledge-decomposition prompt	*What is the theoretical background for the correct behavior or what are the goals of the correct behavior?*

The first of the presented self-explanation prompt targeted on the recognition of the error. The other two self-explanation prompt focused on practical knowledge and targeted on the relation of scientific knowledge to the cases. In the second prompt learners were asked about problem solving. The second prompts and was hence related to strategic knowledge. In the third prompts learner were asked to justify the correct procedure using scientific knowledge. The knowledge-decomposition prompt focused on conditional knowledge. Learners had to type their analysis after each prompt. For a screenshot see Figure 2, page 62.

Adaptable Feedback

After the erroneous step of the fictitious students, and depending on the condition, after the prompts all learners got feedback from an experienced medical practitioner / nurse / teacher. For participants in the condition with adaptable feedback, additional information on three levels was provided. The first level included information about the erroneous procedure or the more appropriated procedure to be taken. Level 1 feedback targeted recognition of the error and the current progress being made. It answers the question, “What progress is being made toward the goal?” Feedback on level 2 additionally gave hints on problem solving strategies and heuristics. Therefore, it is the answer to the question, “What activities need to be undertaken to make better progress?” Level 3 feedback contained the theoretical background and the goals of the procedure. Level 3 feedback is the answer to the question, “What are the goals?” All learners in the adaptable feedback condition received feedback on level 1 automatically to ensure that even less advanced students could identify the error. Feedback on levels 2 and 3 was only provided if learners clicked on a link to request it. Only then would a new window open in which the level two and level three feedback was given. For an example in medicine see page 62, for nursing see page 89, and for teaching see page 116.

8.3.5 Data Sources and Instruments

Diagnostic competence was operationalized using Stark and colleagues' (2011) model by in which diagnostic competence is comprised of (a) declarative-conceptual knowledge as well as (b) practically-oriented kinds of knowledge (strategic and conditional knowledge).

Pretest

During the pretest prior knowledge was assessed. In the studies in medicine and in nursing prior knowledge consisted of declarative-conceptual knowledge and of practical knowledge aspects. In the study in teaching, however, it consisted only of declarative-conceptual knowledge due to time constraints during the implementation of the study.

(a) Prior declarative-conceptual knowledge was measured through a 21-item multiple-choice questionnaire (for an example item from medicine see Table 35). In the multiple-choice questionnaire zero to four answers were correct in every question. Learners received one point for every correctly marked or correctly not marked answer.

Table 35: *Example item multiple-choice test to assess declarative-conceptual knowledge from medicine*

Which of the following description(s) is/are compatible with level III of the New York Heart Association (NYHA) classification?
❍ no complaints at rest
❍ shortness of breath while rising or sitting
❍ anginose symptoms during daily gardening
❍ breathing pause after two staircases

(b) Practical knowledge was measured using key feature tasks (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) for conditional knowledge. Strategic knowledge was measured with 6 key feature tasks in which, after a short case description of a patient, learners had to derive consequences for further actions. Conditional knowledge was measured through 6 knowledge-decomposition tasks in which a short patient case description was present. Afterwards it was described how a person reacted to this case description. Participants then were asked about the reasons and the theoretical explanation for that reaction. To correctly answer these knowledge-decomposition tasks a deep and fine grained understanding of content is necessary (Holmes et al., in press). Knowledge-decomposition tasks were successfully used in different studies to assess learning outcomes (Holmes et al., in press; Roll et al., 2011). An example for a knowledge-decomposition task can be seen in Table

16. Two raters rated the answers and for each key feature and knowledge-decomposition task up to three points could be achieved. The maximum score was 18 points. The intra-class correlation coefficient (ICC) was used for calculating the inter-rater agreement for the key feature tasks. The ICCs for the different key feature and knowledge-decomposition tasks ranged from satisfactory (ICC = .41) to excellent values (ICC = 1.00). During building of the variable prior knowledge some items were removed in order to increase internal consistency. Cronbach's α can be found in Table 36.

Table 36: *Instruments, Internal Consistency of the studies*

Instrument		Cronbach's α
Study 1 Medicine	Prior knowledge (26 Items)	.69
Study 2 Nursing	Prior knowledge (21 Items)	.71
Study 3 Teaching	Prior knowledge (20 Items)	.61
Study 1 Medicine	Declarative-conceptual knowledge (12 Items)	.56
	Practical knowledge (36 Items)	.76
Study 2 Nursing	Declarative-conceptual knowledge (16 Items)	.58
	Practical knowledge (36 Items)	.72
Study 3 Teaching	Declarative-conceptual knowledge (20 Items)	.78
	Practical knowledge (18 Items)	.84

Posttest

During the posttest diagnostic competence was assessed using the conceptualization of Stark and colleagues (2011) that differentiates into (a) declarative-conceptual knowledge and (b) practical knowledge (consisting of strategic and conditional knowledge) (see *chapter 2.2 Operationalization of Diagnostic Competence, page 20*).

(a) Declarative-conceptual knowledge in the posttest was assessed through the similar multiple-choice questionnaire used in the pretest.

(b) Practical knowledge was again measured using key feature tasks (Farmer & Page, 2005) for strategic knowledge and knowledge-decomposition tasks (Holmes et al., in press) for conditional knowledge. In studies 1 and 2, in addition to the 6 key feature and 6 knowledge-decomposition tasks used in the pretest, an additional 12 key feature tasks and 12 knowledge-decomposition tasks were used. In study 3, 9 key feature and 9 knowledge-decomposition tasks were used. Key Feature tasks make problem solving necessary and can be compared to problem-solving tasks used e.g. by Richey and Nokes-Malach (2013). The transfer taxonomy by Barnett and Ceci (2002) (see *chapter 2.4 Expertise, page 25*) can be used to classify learning task according to their need of transfer knowledge (Nokes-Malach et al., 2013). Key feature tasks here assess near transfer of content as the execution of prior problem solving procedures introduced in the worked examples need to be applied. The key feature tasks were similarly structured then the worked examples and required the

application of knowledge to a similar problem with different surface features. Following again the transfer taxonomy by Barnett and Ceci (2002) (see *chapter 2.4 Expertise, page 25*) the used knowledge-decomposition tasks can assess intermediate transfer of content as an individual not just performs what he or she learned in a similar situation to the learning situation but also needs to reflect on different alternatives. Hence a learner not only needs to know what he or she does, but also why. A learner has to know under which conditions a strategy can be used. Tasks in which deep conceptual understanding is necessary are considered even far transfer by some authors (Nokes-Malach et al., 2013; Richey & Nokes-Malach, 2013). Answers were rated by two raters and up to three points could be achieved in every task. The ICCs for the different key feature and knowledge-decomposition tasks ranged from satisfactory (ICC = .43) to excellent values (ICC = 1.00). Cronbach's α for practical knowledge were good (see Table 36).

8.3.6 Statistical Analysis

The alpha level of .05 was used for the statistical analyses. All knowledge test in all three studies were transformed to Z-scores (i.e., with mean score of 0, standard deviation set to 1). Partial eta^2 was used as a measure of effect size; values of about .01 are considered as weak effect size, of about .06 as medium, and of about .14 or higher as large (Cohen, 1988). Bivariate correlations were calculated using Pearson's product-moment correlation: values of .01 are considered small, of about .30 as medium, and of above .50 as large (Cohen, 1988). In addition MANCOVAs, ANCOVAs, and ANOVAs were used. Post-hoc comparisons were conducted using linear independent, pairwise and Bonferroni-adjusted contrasts. In case of unequal variances a Kruskal-Walis test with follow-up Man-Whitney tests were applied.

8.4 Results

8.4.1 Preliminary Analyses

No differences concerning prior knowledge ($F(3, 354) = 2.45$, $p = .63$) and metacognitive competence ($F(3, 354) = 1.35$, $p = .26$) were found between the four conditions in any of the studies prior to the experiment. For descriptive values see Table 37.

The correlations of prior knowledge with diagnostic competence were significant and high indicating a pre to posttest gain (declarative-conceptual knowledge, $r = .56$, $p < .01$; practical knowledge, $r = .42$, $p < .01$).

Regarding time on task Levene's test for equality of variances was found to be significant for the present analysis of the effect of self-explanation prompts on time on task ($F(3, 354) = 11.14$, $p < .01$) indicating unequal variances. Therefore a Kruskal–Wallis test, with follow-up Man-Whitney tests were applied. The experimental variation through self-explanation prompts (with and without) and adaptable feedback (with and without) were significantly affecting time-on-task ($H(3) = 245.529$, $p < .01$). Mann–Whitney tests were used to follow-up this finding. A Bonferroni correction was applied and so all effects are reported at a .025 level. Self-explanation prompts did affect time-on task (U = 727.50, $p < .01$). In contrast adaptable feedback had no effect on time-on-task (U = 14784.50, $p = .21$;). That is learners with self-explanation prompts learned longer than learners without, however, adaptable feedback had no additional effect on the learning time and also the two measures did not interact with each other regarding the learning time (for descriptive data see Table 37).

Table 37: *Means and (SD) of prior knowledge, metacognitive competence, time-on-task, diagnostic competence, declarative-conceptual knowledge, practical knowledge, strategic knowledge, and conditional knowledge in teaching*

	With self-explanation prompts		Without self-explanation prompts	
	With adaptable feedback	Without adaptable feedback	With adaptable feedback	Without adaptable feedback
Prior diagnostic competence	-.08 (1.18) (medicine)	-.26 (.96) (medicine)	.18 (.99) (medicine)	.18 (.81) (medicine)
	.19 (1.08) (nursing)	.25 (1.08) (nursing)	.86 (.66) (nursing)	-.03 (1.08) (nursing)
	-.08 (.98) (teaching)	.18 (1.07) (teaching)	.19 (.92) (teaching)	.09 (1.03) (teaching)
Metacognitive competence	4.43 (.50) (medicine)	4.63 (.48) (medicine)	4.52 (.64) (medicine)	4.50 (.68) (medicine)
	4.52 (.48) (nursing)	4.64 (.47) (nursing)	4.66 (.40) (nursing)	4.69 (.55) (nursing)
	4.55 (.55) (teaching)	4.69 (.41) (teaching)	4.60 (4.75) (teaching)	4.54 (.56) (teaching)
Time-on-task	59.92 (22.08) (medicine)	63.88 (21.44) (medicine)	26.68 (10.08) (medicine)	27.92 (7.83) (medicine)
	51.75 (14.53) (nursing)	53.92 (15.01) (nursing)	19.65 (7.38) (nursing)	23.99 (9.30) (nursing)
	49.98 (10.35) (teaching)	49.46 (10.18) (teaching)	19.20 (7.04) (teaching)	20.16 (3.84) (teaching)
Diagnostic competence				
Declarative-conceptual knowledge	-.17 (.90) (medicine)	-.02 (.95) (medicine)	.26 (3.34) (medicine)	-.08 (1.30) (medicine)
	-.14 (1.11) (nursing)	-.12 (1.04) (nursing)	.13 (3.46) (nursing)	.13 (1.05) (nursing)
	.21 (.75) (teaching)	-.17 (1.15) (teaching)	-.16 (8.33) (teaching)	.14 (.92) (teaching)
Practical knowledge	.36 (1.04) (medicine)	-.37 (.94) (medicine)	.48 (.97) (medicine)	-.04 (0.97) (medicine)
	-.20 (.77) (nursing)	-.46 (.91) (nursing)	.22 (.94) (nursing)	.45 (1.12) (nursing)
	-.20 (.93) (teaching)	-.35 (.94) (teaching)	.50 (.95) (teaching)	.09 (1.02) (teaching)

8.4.2 Effect on Diagnostic Competence (RQ1)

To test if self-explanation prompts and adaptable feedback or the combination of both can foster learning of diagnostic competence, a MANCOVA was conducted. Self-explanation prompts, adaptable feedback, and the domain (medicine, nursing, or teaching) were the independent variables, diagnostic competence, including declarative-conceptual knowledge and practical knowledge were the dependent variables. It was also controlled for prior diagnostic knowledge. Descriptive results can be found in Table 37.

The results showed that the multivariate effect of self-explanation prompts on diagnostic competence was significant (Wilks's λ = .97, $F(2, 344) = 5.99$ $p < .01$). The interaction effect of domain and self-explanation prompts was also significant (Wilks's λ = .96, $F(4, 688) = 3.86$ $p < .01$). Also significant became the interaction of promprs, adaptable feedback and the domain (Wilks's λ = .96, $F(4, 688) = 3.28$ $p < .05$).The effects of adaptable feedback (Wilks's λ = .99, $F(2, 344) = 1.90$ $p = .15$), interaction of prompts and adaptable feedback (Wilks's λ = 1.00, $F(2, 344) = .79$ $p = .46$), and adaptable feedback and domain (Wilks's λ = .94, $F(4, 688) = 1.34$ $p = .24$) on diagnostic competence was not significant.

The next steps in the analytic strategy addressed the different component variables of diagnostic competence. To test the effect of the two independent variables self-explanation prompts and adaptable feedback on the dependent variables declarative-conceptual knowledge and practical knowledge ANCOVAs with prior knowledge as a covariate were calculated.

Declarative-conceptual knowledge: Results showed a small effect of self-explanation prompts, adaptable feedback, and the domain on declarative-conceptual knowledge ($F(2, 345) = 4.20$, $p < .05$, *partial* $\eta^2 = .02$). The effect can be observed in *Figure 16*. All other effects on declarative-conceptual knowledge were not significant.

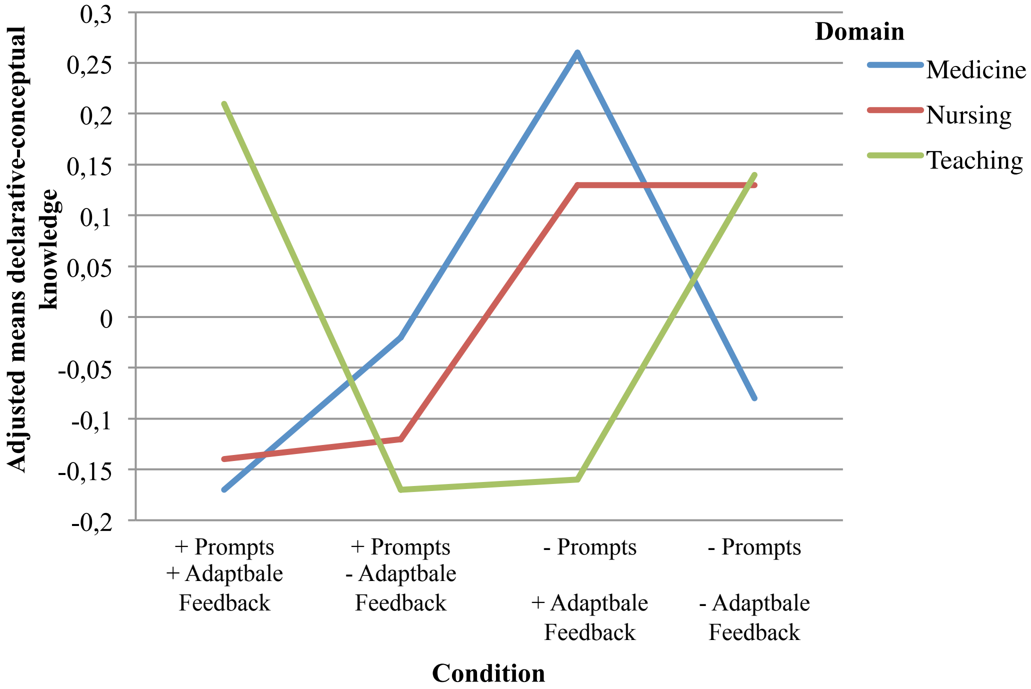

Figure 16: *Adjusted means of declarative-conceptual in the four experimental conditions in medicine, nursing, and teaching*

Practical knowledge. Results showed a significant negative effect of self-explanation prompts on practical knowledge ($F(1, 345) = 11.92$, $p < .01$, *partial* $\eta^2 = .03$). Also the interaction effect of self-explanation prompts and the domain on diagnostic competence became significant ($F(2, 345) = 6.07$, $p < .01$, *partial* $\eta^2 = .03$). Learners in the condition with self-explanation prompts ($M = -.22$; $SD = .93$) acquired *less* practical knowledge than learners in the condition without ($M = .23$; $SD = 1.01$, post-hoc comparison $p < .01$).

Within regard to declarative conceptual knowledge learners profited from the combination of self-explanation prompts and adaptable feedback depended on the domains. Self-explanation prompts had a negative effect on practical diagnostic competence that was depending on the domain.

8.5 Discussion

In a computer-based learning environment in which worked examples with integrated errors were implemented it was investigated if two additional instructional support methods, scaffolding with self-explanation prompts and adaptable feedback, would foster learning of diagnostic competence in two domains in medical education and in teacher education.

The discussion of the domain specificity of the two instructional measures see *chapter 9 General Discussion*.

9 General Discussion

In this chapter first the four conducted studies are summarized. Then limitations of the studies are presented. This is followed by an explanation of these findings and a deduction of theoretical and practical implications. Finally the conclusion of this thesis is explained.

9.1 Summaries of the Studies

The aim of this thesis is to enhance the understanding of how to foster diagnostic competence in the domains medicine, nursing, and in teaching. An open question so far was how to best scaffold learning from errors in worked examples with the goal of fostering diagnostic competence. Two scaffolding methods (self-explanation prompts and adaptable feedback) that seemed particularly promising were investigated systematically in the domains medicine, nursing and in teaching.

Self-explanation prompts are well established to enhance learning from worked examples. However, research on self-explanation prompts in erroneous worked examples so far is inconclusive. What self-explanation prompts should focus on is unclear, particularly in case of erroneous examples. Adaptable feedback has certain advantage, but could also hinder learning, as a learner needs adequate help-seeking skills that not every learner has. One question this thesis strives to answer is to what extend two scaffolds (self-explanation prompts and adaptable feedback) can enhance the acquisition of diagnostic competence while learning with erroneous worked examples?

Diagnostic competence has been investigated in different domains such as in medicine, in nursing and in teaching. Findings show similarities as well as differences between diagnostic competences between the domains. A major difference in the domains that might be relevant in fostering diagnostic competence is the kind of evidence that is available and how it is used in practice. In medicine for example research has a larger impact on practice than in education (Riehl, 2006) or nursing. Regarding the use of evidence, nursing and teaching have more similarities to each other than medicine and nursing. These differences may yield differences in the instructional support that is beneficial to foster the development of diagnostic competences. Research so far could not compare scaffolding across domains systematically. Therefore, the second question of this thesis is: "To what extent is the effect of self-explanation prompts, adaptable feedback, and their combination for the acquisition of diagnostic competence while learning with erroneous worked examples different in medicine, nursing, and teaching?"

To answer the presented questions, conceptual replication studies, using material and designs as similar as possible in the domains medicine, nursing, and in teaching were conducted. All three studies used the same operationalization of diagnostic competence by Stark and colleagues (2011) that is comprised of declarative-conceptual knowledge on basic concepts and objects in a domain as well as practically-oriented types of knowledge: strategic and conditional knowledge (van Gog et al., 2004). Strategic knowledge is knowledge on procedures, problem-solving strategies and heuristics. Conditional knowledge is knowledge on the rationale of a procedure and of its goals.

In all three studies prospective physicians, nurses, or teachers worked individually with a computer-based learning environment in which erroneous worked examples were implemented. Participants were asked to immerse themselves in situations of a fictitious student doing a medical clerkship (medical student participants), or an internship in a hospital (nursing student participants) or in a school, respectively (teaching student participants). The worked examples were realistic cases in which a peer diagnosed either a patient's disease or state or a classroom situation. While diagnosing, the fictitious student apprentice commits errors.

In the studies, a design was implemented in which self-explanation prompts (with or without) and adaptable feedback (with and without) were varied systematically. Participants were randomly assigned to one of the four experimental conditions.

A different pattern of results in the domains was found. Adaptable feedback did not have an effect on diagnostic competence in nursing and teaching, however, it had a significant positive effect on strategic and practical knowledge in medicine. Across studies adaptable feedback did not have an effect on diagnostic competence. Contrary to the prediction scaffolding with self-explanation prompts had a negative effect on the learning of strategic, conditional, and practical knowledge in nursing and teaching, but had no effect in medicine. The effect of self-explanation prompts on diagnostic competence was dependant on the domain. In teaching, self-explanation prompts and adaptable feedback had a positive interaction effect on declarative-conceptual knowledge, which could mean the prompts helped learners to realize their lack of knowledge on basic concepts and learners could then concentrate better on these aspects if the feedback was adaptable. In the other two domains (medicine and nursing), no interaction effects and no effect on declarative-conceptual knowledge were found. The interaction effect of self-explanation prompts and adaptable feedback was dependant on the domain. However, in the studies in medicine and nursing, the test on declarative-conceptual knowledge had problematic internal consistencies.

None of the provided prompts was positively or negatively related to declarative-conceptual knowledge. The three different prompts (error-recognition prompt, problem-solving prompts, knowledge-decomposition prompts) had differentiated effects on the acquisition of diagnostic competence in the different domains. The error-recognition prompts only had an effect in medicine, as it was positive related to conditional, and practical knowledge. The problem-solving prompt had a positive relation to practical knowledge in teaching. The effect of the knowledge-decomposition prompt was positive for conditional and practical knowledge in medicine and in teaching in addition in teaching it was also positive for strategic knowledge. In contrast the relation of the knowledge-decomposition prompt with strategic, conditional, and practical knowledge in nursing was negative.

Adaptable feedback increased motivation in none of the studies, indicating that the increased learner control might not have been enough for a gain in motivation. Metacognitive competence was not a mediator between adaptable feedback an diagnostic competence in any of the studies, indicating that adaptable feedback influences diagnostic competence independently from metacognitive competence.

Regarding cognitive load the result patterns are even more dependent on the domain: Learners who experienced a higher cognitive load acquired less practical knowledge in medicine and in teaching and less declarative-conceptual knowledge in nursing and in teaching. In medicine and in nursing learners experienced cognitive load independently from prior knowledge, whereas in teaching learners with low prior knowledge experienced higher cognitive load. Also the scaffolds had different effects on cognitive load dependent on the domain. In medicine none of the scaffolds had an effect on cognitive load. However, in nursing and in teaching cognitive load was increased through the self-explanation prompts. In nursing adaptable feedback decreased cognitive load. In teaching cognitive load mediated the effect of self-explanation prompts on diagnostic competence. In the next section limitations of the conducted studies are presented. Then, theoretical and practical implications are discussed.

9.2 Limitations of the Studies

The main limitation of studies that compare domains is that the material cannot be completely the same. In particular in research that uses cases these might cause differences that cannot be controled for, as not all domain differences are understood completely. Therefore, conceptual replications can only try to replicate the underlying mechanism and not use the same tasks in different domains. Case material was constructed in a similar way with similar underlying structure.

There might be a confounding variable with respect to the domains. In Germany as in many other countries, admission to medical school is highly selective and only the students with the best prior academic performance are admitted to study medicine. It could be that differences in academic skills or more general ability-related aspects can explain parts of the differences in the pattern of effects between the study with medical student on the one side, and nursing and teacher education students on the other side e.g. that the adaptable feedback only had a positive effect in the study conducted with medical students.

The presented studies also have other limitations e.g. some of the tests used for declarative-conceptual knowledge in medicine and in nursing in the posttest failed to reach sufficient internal consistency. A possible explanation for low internal consistency of knowledge tests is provided in a study by Wecker and collegues (2013): the items may not be linked by relations that can enable a learner to conclude the items from one another. Therefore possible effects might remain undetected with regards to declarative-conceptual knowledge in the studies in nursing and in medicine.

Possible limitations might also be the assessment methods for metacognitive competence, motivation and cognitive load that all were administered with subjective rating scale. Metacognitive competence did not mediate the relation of adaptable feedback and diagnostic competence. This could imply other underlying mechanism as well as a lack of correspondents to actual behavior that was also found in other studies (Veenman, Hout-Wolters, & Afflerbach, 2006). Also motivation was not influenced by adaptable feedback which again could be a problem of the assessment via self-reported questionnaires. The subscales of cognitive load proposed by Paas and Kalyuga (2005) could not be replicated and thus were treated as one aggregated measure. Learners in this study seemed to be unable to differentiate between different types of loads in their ratings. However, with this method central assumptions of the cognitive load theory cannot be used e.g., that extraneous load should be reduced. With only one cognitive load measure it cannot be told if the load was in fact beneficial for learning.

In this study the major research interest was in scaffolding via self-explanation prompts and adaptable feedback. No control condition was administered. Hence, it cannot be told if the presented approach using erroneous worked examples and different scaffolds was beneficial compared to another approach such as guided problem solving.

Another limitation is that no delayed posttest was included in this study. In another study that used erroneous worked examples, a positive effect only showed in a delayed posttest (McLaren et al., 2012). Similar results were found in a study in which correct and incorrect examples were compared (Durkin & Rittle-Johnson, 2012). This effect can be attributed to deep generative learning processes, that are more challenging and have shown to lead to delayed learning gains earlier (R. Schmidt & Bjork, 1992). It might be that learning including errors is in particular challenging and effects become more evident in delayed posttest due to this high demand.

With the data in this study it cannot be excluded that learners still self-explain without self-explanation prompts. The errors included into the worked examples in combination with the instructional explanations could have induced self-explanation that cannot be controlled for. Think-aloud studies would be an interesting method to gain understanding the mechanism that promotes learning in this setting.

The prompts in these studies were not varied systematically, and thus it cannot be excluded that the order in which they were presented played a role. In further studies it might be of major importance to vary prompts more systematically as the central mechanisms that promote learning from errors and what to prompt is unclear so far. Maybe a think-aloud study could enrich the understanding of these mechanisms.

Errors in the learning environment were implemented into worked examples. All worked example steps contained an error. The fact that learners knew that an error was implemented into the worked out steps could have an influence on how learners processed the errors. Another limitation is the short learning time. Future studies may investigate longer or repeated trainings to examine positive effects that were found in this study.

9.3 Scaffolding with Self-Explanation Prompts and Adaptable Feedback in Medicine, Nursing, and in Teaching

Our finding regarding the influence or self-explanation prompts on diagnostic competence were contrary to the assumption as they either had no or a negative effect on practical types of diagnostic competence. Adaptable feedback only had a positive effect in medicine. In teaching adaptable feedback only was beneficial if it was combined with self-explanation prompts. In the following possible explanations of the findings are discussed and theoretical implications are explained. However, it needs to be considered that a strong control conditions was implemented, as even learners without self-explanation prompts and without adaptable feedback were guided still with erroneous worked examples and still got static non-adaptable elaborated feedback.

Prompts have the goal to direct a learners' attention and to induce strategies that a learner is capable of but does not show by his or her own (Pressley et al., 1992). In case of learning with erroneous worked examples, that is to guide the learners' attention to self-explaining the errors and their underlying principles. However, what if a learner does not need additional prompting? A possible reason why self-explanations prompts failed to increase learning of diagnostic competence in medicine may be that there was no need to guide learners' attention to the explanation of the error as the mere inclusion and the provided feedback could already be enough guidance. Same might be true for another advantage that is assumed from a theoretical perspective; Prompts can help learners realize their lack of understanding (Renkl, 2002). It could be that this is not true in case of learning from errors. It may be the case that self-explanation prompts cannot help the learner any further with this regard, as through the errors in combination with feedback learners might already have recognized their lack of understanding and further prompting was not necessary. Another benefit that is usually assumed for self-explanation prompts is to prevent from passive processing of worked examples (Renkl, in press). It might be that again through the errors passive processing was avoided even without prompting. These explanations might be relevant to why the prompts had no effect on diagnostic competence but they cannot explain why prompts might have had a negative effect in nursing and in teaching.

Self-explanation prompts are generally assumed to have a positive effect on learning. However, they pose a high demand on the learner in particular if combined with other demands such as with processing errors. Also in other studies where self-explanation prompts were combined with e.g., gaps in a worked example they could not increase learning (Gerjets et al., 2006; Hilbert et al., 2008). It might be that the combination of erroneous worked examples and self-explanation prompts increased cognitive load up to a detrimental level (Sweller, 2010). What also points in this direction is that in the study in medicine in which self-explanation prompts did not increase cognitive load, the self-explanation prompts did not have a negative but had no effect on learning of diagnostic competence.

In other studies including erroneous worked examples only advanced learners could profit from erroneous worked examples (Tsovaltzi et al., 2012). The effect that only learners with favorable learning prerequisite could profit was also found for learning with self-explanation prompts (Berthold et al., 2011). The demand to self-explain errors obviously overwhelmed learners. A possibility to reduce the demand could be to create a menu with a limited number of alternatives to choose from. A similar approach was successfully used in other studies (McLaren et al., 2012; Tsovaltzi et al., 2012)

Prompts are generally assumed to have a positive influence on learning, but more differentiated and systematic studies, particularly in the context of learning with errors, are lacking. Self-explanation prompts more than doubled the learning time, however, in the studies presented in this thesis prospective nurses and teachers who learned with self-explanation prompts were obviously rather hindered than supported with respect to strategic and conditional knowledge. Reconsidering previous findings from research on prompts (Chamberland et al., 2013; Chamberland, St Onge, et al., 2011; Schworm & Renkl, 2007; Stark, 1999) an important difference to other studies arises. In the presented study prompts were specifically designed to support the learners in analyzing errors. The learners might have been so concentrated on the errors that they were distracted from principle-based self-explanations, which are considered to be important for learning from worked examples (Renkl, in press). That self-explanation during studying erroneous worked examples without specific prompting, can be at the costs of principle-based self explanation was also found in another study (Große & Renkl, 2007). Instead of relating the underlying principles of the domain to the case, learners may have tried to find the correct procedure, maybe through using weak problem-solving strategies (van Merriënboer, 2013).

Another reason for the negative effect of self-explanation prompts may be that this additional demand lead to a cognitive conflict with the elaboration induced by the error. While studying the errors in the worked examples and trying to understand them, the learners were asked to self-explain the errors in a specific order of question and type in the solutions. The two demands may have interfered with each other. The mediation of cognitive load between self-explanation and practical knowledge is indicating that the negative effect is in fact caused by cognitive load. This can be interpreted as evidence for this explanation.

Prompts might not have lead to more involvement in analyzing the errors committed by others. The fact that these errors need to be made by oneself to be productive could also be further support for the findings from Kapur (2013) in which a group that learned from their own mistakes outperformed their fellow students in a vicarious learning conditions. In that regard the deliberation of Loibl and Rummel (in press) is interesting. They state that the mechanism that promotes learning in Kapur and Bielaczyc's (2012) productive failure approach, may not be the experience of failure. In Loibl and Rummel's (in press) study, it guidance during problem solving did lead to less failure but not to less learning. Rather then thinking about errors the learning mechanism might be a motivational factor that helps to activate prior knowledge. Using prompts to think about the error might not have had the same motivational effect than committing an error. It could be possible that the learning potential of the errors of other's might indeed be limited. It could be that the general argument by Kolodner (2006) that learners can also learn from the cases of others is in fact not valid for learning from cases in which an error was committed.

The three different prompts (error-recognition prompt, problem-solving prompts, knowledge-decomposition prompts) had differentiated effects on the acquisition of diagnostic competence. The error-recognition prompts only had an effect in medicine, as it was positively related to practical knowledge. Superficially speaking it may be surprising that this prompt was not related in the other two domains as being aware of an error and understanding it is necessary in order to learn from an error ((Schank, 1999). An explanation could be that if a learner cannot realize what an error is, it may not help to think about it for a long time. The problem-solving prompt had a positive relation to practical knowledge in teaching. The effect of the knowledge-decomposition prompt was positive in medicine and in teaching but negative in nursing. The findings show huge differences between the domains. For the two academic domains teaching and medicine, findings can support the claim that self-explanation should direct the attention of the leaner to the connection of the case and its underlying principles (Renkl, in press). It also suggests that increasing problem-solving performance prompting with a focus on principles might not be of major use. Another type of prompt seems to be necessary if prompting can help in this regard at all. In the context of error learning: in order to understand the mechanism of different prompts further theoretical as well as empirical advancement seem to be necessary before general implications for practice can be formulated. Maybe a practical implication that is restricted to teacher education could be that in case of learning from errors, it might not be of advantage to advice learners to extensively think what the error was and how it could have been prevented but rather what the underlying principles are that promote a correct solution. Maybe because that is something that teachers otherwise do not think of very often.

Another explanation why self-explanation failed to increase learning might be that learners were not able to create sufficient self-explanations. In some earlier work learners could also profit from worked examples if they were incorrect or fragmented (Chi, 2000). Other authors state against, this may only be true if a high percentage of self-explanations are correct (Aleven & Koedinger, 2002). In a complex field such as in diagnosing patients or classroom situation it is not unlikely that the percentage of correct self-explanations could be too little to have an impact on learning. However, learners could have used the feedback to close gaps in their knowledge. For finding relevant information in the feedback it can be assumed that a certain basic understanding is a prerequisite.

At a first glance it seems as self-explanation prompts in erroneous worked examples that provide feedback could be dispensable. Keeping in mind expertise research nonetheless it might be important to let students face realistic cases and include reflective elements to the cases in order to prevent a skill from automatization (Ericsson, 2006). Maybe the types of prompts were not optimal to reach that.

It is interesting that cognitive load decreased during the relatively short learning session in teaching substantially. The lower cognitive load later in the learning session may be indicating that students developed enough relations between the declarative-conceptual knowledge and the cases of application that the interactivity of these elements decreased. That is, learners could relate their declarative-conceptual knowledge on e.g. how they can find a problem scenario in problem-based learning to the case of finding a problem scenario on civil courage that is suitable for young adults and they can also explain why that scenario is appropriate or what the goals of such a problem scenario are. Through building that kind of strategic and conditional knowledge the learners do not need to relate the declarative-conceptual knowledge to the case of application spontaneously. The encapsulated knowledge decreased the demand to the working memory. This is in line with the elaborations of Kalyuga (2011).

Adaptable feedback had a positive effect on strategic knowledge in medicine. Strategic knowledge in this study was assessed with problem-solving tasks. To let learners decide on the amount of feedback they need, thus seemed to have increased their ability to solve problems later but did not lead to better conceptual understanding. Learners in contrast to other studies (Aleven et al., 2003) seemed to be able to seek help when needed. The relation of adaptable feedback and diagnostic competence was not mediated by metacognitive competence indicating that not only learners with high metacognitive competence but also those with less favorable metacognitive competences were able to adapt the feedback to their needs.

An explanation for the lack of effects of adaptable feedback to increase diagnostic competence in the study in nursing, and practical knowledge in teaching might be that the increased learner control could not increase motivation. More learner control is often associated with positive effects on motivation (Scheiter & Gerjets, 2007), but in this study this effect was not found. It might be that in a highly structured learning environment with worked example, letting learners only decide on the content of the feedback was simply not enough learner control. However, in the study in medicine adaptable feedback, had no effect on motivation but could still increase learning. One other reason could be that learners may not have been able to seek help efficiently as also found by others (e.g. for an overview see the review by Aleven et al., 2003). It is possible that learners who need additional explanations the most, are the least prone to ask for them, in some cases because they do not even know they need it (Gräsel, F. Fischer, & Mandl, 2001; Narciss, Proske, & Koerndle, 2007). What also might point in that direction is that the adaptable feedback did decrease cognitive load in nursing. Leaners might not have put much effort in thinking what knowledge they might need and then processing that information.

Providing instruction to self-explain and on-demand help can decrease the self-explanation activity of the learners as found in other studies (e.g. Schworm & Renkl, 2006). The learners might reduce the effort of finding self-explanations if feedback offering a correct solution is available as it could be shown in feedback research (Kulhavy, 1977). However, with this explanation cognitive load should not have been higher for learners with self-explanation prompts. Therefore, for this the study in nursing and in teaching might not be an adequate explanation.

The negative effect of self-explanation prompts on strategic and on conditional knowledge in nursing and in teaching could indicate negative transfer of knowledge (Pennington & Rehder, 1995). This however is surprising as negative transfer generally occurs if problem-solving strategies are taught in isolation from cases of application. As this was not the case in this study it may have been that learners concentrated on superficial features during their self-explanation and not on the underlying principles of the case. This might have lead to overgeneralizations. Thus, it could have come to the application of strategies without prior checking of prerequisites, ignoring the contextual features of the specific case in the posttest. But how can this overgeneralization be prevented? It might be a possibility to include besides constructive activities in the learning material also interactive activities (Chi, 2009). This might have the advantages that separate positions need to be argued and defended and also the position of another learner needs to be incorporated and included in thinking processes. Therefore, it has the possibility to decrease the occurred overgeneralizations. As discussed in *chapter 3.2 Scaffolding in Erroneous Worked Examples, page 39* this was not included in order to not risk transfer to the real world. However, as already near transfer on similar tasks was negative, the greater risk might be to have learners overgeneralize strategies. In other studies in which complex skills were taught interactive activity had beneficial effects for learning with modeling examples (Rummel et al., 2009).

Self-explaining worked examples can prevent learners from developing procedural knowledge and focus the attention of a learner more on conceptual understanding (Nokes-Malach et al., 2013). The findings from the studies of this thesis are in contrast to that statement, as learners did not develop more conditional knowledge for which deep conceptual understanding is necessary. Thus they seemed to not have concentrated on the development of conceptual understanding. In medicine they seemed to have rather concentrated on developing their problem solving skills as indicated by the gain in strategic knowledge in particular in the group that learned with both scaffolds. In teaching learners concentrated more on declarative-conceptual knowledge gain again in particular in the group that learned with both scaffolds. Nursing students could not profit in any of the diagnostic knowledge types from the additional scaffolding.

Following the stage models of expertise development they all state that in the beginning knowledge is organized in more causal networks, whereas with more expertise, declarative-conceptual knowledge is related closer to cases of application.

The fact that students in the study in medicine gained more strategic knowledge may also reflect their stage of expertise. The lack of awareness of underlying principles reflected in the conditional knowledge, could be an indication for an early intermediate stage of expertise development in which illness script make problem solving in form of diagnosing patients easier and less prone for errors but underlying features get less important. Learners might already have gained an understanding of underlying principles and concentrated more on the proceduralisation of knowledge. Maybe even an integrated diagnostic approach using partly also non-analytical processing might have developed. The adaptability of the feedback seemed to have fostered that process. As increased motivation was not the underlying mechanism, this finding might give support to Chi's (2009) claim that active activities can promote the integration of existing knowledge and new knowledge. Relating this findings to general feedback literature (Hattie & Timperley, 2007), structuring the feedback into recognizing a wrong procedure, in how to proceed and in what the goal of procedure is, might have helped the learner to recognize the relevant knowledge he or she needs. Adaptable feedback could have made it easier for learners to find relevant information without the need to scan through the whole elaborated feedback. Elaborated feedback without the possibility to fade unnecessary information could have impaired learning in particular for learners with high prior knowledge (Kalyuga & Renkl, 2010).

Nurses may be in a very early stage of expertise development in which they even have difficulties to recognize relevant knowledge. The fact that an early stage of skill acquisition is related to not recognizing relevant knowledge is in line with a recent expertise model of domain learning (Alexander, 1997; Alexander et al., 2009). Also here in the first phase the acclimation the learner does not have much relevant knowledge in a domain and gains basic knowledge that is not very well connected and also incomplete which is related to the problem of novices being unable to distinguish between relevant and non-relevant knowledge (Alexander et al., 1994). It might be that learners were in the novice or acclimation stage and thus were not able to identify relevant knowledge in the feedback.

Also teachers might have been in an early stage of skill acquisition in which they need to concentrate on understanding domain principles. Only in an intermediate stage learners start to reflect on how abstract strategies are used to solve problems. Self-explanation prompts and adaptable feedback only in combination increased declarative-conceptual knowledge. This might be a result of the focus of the learners. With the prompts learners might have realized a lack of basic concepts and then focused their attention on the declarative-conceptual knowledge in the feedback that was given. If feedback was not adaptable the learners might not have been able to sort out the relevant information.

Another possible explanation of the different result patterns can be found in how education in medical, nursing, and in teacher education is organized. In medical education in Germany medical students practice with patient-cases from a relatively early stage on. They might be more used to relating scientific knowledge to cases of application. For the nurses it might have been particularly difficult to relate scientific knowledge to cases as their whole education is less theory but more practice based. Including prompts that made the application of scientific knowledge to the cases of application necessary could have confused them due to the usual demand. Teacher education in contrast is a very theory based education in Germany. Students can gain experience from teaching a class only later in their studies. Case-based learning is not very common. Thus students might have done what they are used to and concentrated on declarative-conceptual knowledge.

These differences in medical, nurse, and in teacher education could possibly be also a result of different availability of evidence that can be used to justify practices and how that evidence is used in social practices. In medicine more evidence for actions is available and used in the social practice to discuss patients with collegues. In nursing and teaching evidence is often not available and even if available it is often ignored in practice. As nursing and teaching have more similarities regarding these dimensions it might be an explanation why the results in teacher education and nursing education were more comparable.

The diagnostic competence model developed in medical education (Stark et al., 2011) used for operationalization in all studies, made it possible to show differential effects of the two scaffolds on the three types of knowledge (declarative-conceptual, strategic and conditional knowledge) in the three different domains. Whereas declarative-conceptual knowledge was affected by both scaffolds in teaching, none of the scaffolds had an effect in the other two domains. Strategic knowledge was fostered by adaptable feedback in medicine and negatively affected by self-explanation prompts in teaching and in nursing. Conditional knowledge was not affected in medicine but negatively affected by self-explanation prompts in teaching and in nursing. A model with the aim of fostering diagnostic competence might benefit from differentiation in three types of knowledge, as scaffolding methods foster or hinder different kinds of knowledge.

9.4 Conclusions

After consideration of previous findings their explanations and limitations of the studies, the question is still open to what extent the main questions of this thesis can be answered: How can diagnostic competence be fostered with scaffolding in different domains?

An open question that is often neglected in educational research is to what extent findings from one domain can be transferred to another. Even though there is a large body of research on diagnostic competence in medicine, nursing, and in teaching, this research is not related to each other. Even though there are large differences between the domains such as the availability of evidence there are also similarities e.g., in the diagnostic situations. Possibly there is a wasted potential in not transferring findings from one domain to another. With this thesis a contribution to that discussion was made.

Therefore three studies that all tested the same instructional approach in different domains were conducted. Erroneous worked examples were implemented in a computer-based learning environment and two scaffolding methods were varied systematically.

The findings of this studies showed that self-explanation prompts in context of erroneous worked examples are less favorable than assumed from a theoretical perspective. They seemed to have hindered the acquisition of practical diagnostic knowledge in the domains were the use of scientific evidence is less common and had no effect in a domain were evidence is used to justify practice. Even though there are domain differences it can be concluded that the use of self-explanation prompts combined with erroneous worked examples cannot be recommended at the present state. Future studies should try to get an insight into the mechanism of prompting before they are used in combination with errors.

Adaptable feedback can be recommended in domains in which learners are used to the application of scientific knowledge to cases. This easy to implement scaffold can increase learning of strategic knowledge even compared to a condition in which the same information is presented in a non-adaptive way. For domains in which the application of scientific knowledge to cases is not common it may not be ideal. Learners in those domains seem to need more comprehensive explanations on how to use scientific knowledge to solve cases.

In conclusion, the presented studies suggest that scaffolding for self-explanation may not be advantageous under all circumstances and may in fact even hinder learning in the context of learning from errors, at least in the context of vicarious failure and in domains where less scientific knowledge is available and the use of evidence to explain phenomena or support decision-making is less common.

References

Abs, H. J. (2007). Überlegungen zur Modellierung Diagnostischer kompetenz bei Lehrerinnen und Lehrern. In M. Lüders & J. Wissinger (Eds.), *Forschung zur Lehrerbildung: Kompetenzentwicklung und Programmevaluation* (pp. 63–84). Waxmann Verlag.

Adams, D. M., McLaren, B. M., Mayer, R. E., Goguadze, G., & Isotani, S. (2013). Erroneous Examples as Desirable Difficulty. In H. C. Lane, K. Yacef, J. Mostow, & P. Pavlik (Eds.), *Artificial Intelligence in Education* (pp. 803–806). Springer: Berlin Heidelberg.

Aiken, L. H., Clarke, S. P., Cheung, R. B., Sloane, D. M., & Silber, J. H. (2003). Educational Levels of Hospital Nurses and Surgical Patient Mortality. *JAMA : The Journal of the American Medical Association*, *290*(12), 1617–1623.

Aleven, V., & Koedinger, K. R. (2002). An effective metacognitive strategy: learning by doing and explaining with a computer-based Cognitive Tutor. *Cognitive Science*, *26*(2), 147–179.

Aleven, V., Stahl, E., Schworm, S., Fischer, F., & Wallace, R. (2003). Help seeking and help design in interactive learning environments. *Review of Educational Research*, *73*(3), 277–320.

Alexander, P. A. (1997). College Instruction and Concomitant Changes in Students' Knowledge, Interest, and Strategy Use: A Study of Domain Learning. *Contemporary Educational Psychology*, *22*, 125–146.

Alexander, P. A., Jetton, T., Kulikowitch, J., & Woehler, C. (1994). Contrasting instructional and structural importance: The seductive effect of teacher questions. *Journal of Reading Behavior*, *26*(1), 19–45.

Alexander, P. A., Murphy, K., & Kulikowich, J. (2009). Expertise and the Adult Learner: A historical, psychological, and methodological exploration. In M. C. Smith & N. DeFrates-Densch (Eds.), *Handbook of research on adult learning and development* (pp. 484–523). Taylor & Francis.

Alexander, P. A., & Murphy, P. K. (1999). Nurturing the seeds of transfer: a domain-specific perspective. *International Journal of Educational Research*, *31*(7), 561–576.

Alexander, P. A., Murphy, P. K., & Woods, B. S. (1996). Research news and Comment: Of Squalls and Fathoms: Navigating the Seas of Educational Innovation. *Educational Researcher*, *25*(3), 31 –39.

Altrichter, P. D. H. (2010). Schul- und Unterrichtsentwicklung durch Datenrückmeldung. In P. D. H. Altrichter & P. D. K. M. Merki (Eds.), *Handbuch Neue Steuerung im Schulsystem* (pp. 219–254). VS Verlag für Sozialwissenschaften.

Anders, Y., Kunter, M., Brunner, M., Krauss, S., & Baumert, J. (2010). Diagnostische Fähigkeiten von Mathematiklehrkräften und ihre Auswirkungen auf die Leistungen ihrer Schülerinnen und Schüler. *Psychologie in Erziehung und Unterricht*, *57*(3), 175–193.

Anderson, J. R. (1993). *Rules of the Mind*. Hillsdale, NJ: Erlbaum Associates.

Anderson, J. R., Fincham, J. M., & Douglass, S. (1997). The role of examples and rules in the acquisition of a cognitive skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(4), 932–945.

Artelt, C., & Gräsel, C. (2009). Diagnostische Kompetenz von Lehrkräften. *Zeitschrift Für Pädagogische Psychologie*, *23*(3), 157–160.

Atkins, S., & Murphy, K. (1993). Reflection: a review of the literature. *Journal of Advanced Nursing*, *18*(8), 1188–1192.

Atkinson, R. K., Renkl, A., & Merrill, M. (2003). Transitioning from studying examples to solving problems: Effects of self-explanation prompts and fading worked-out steps. *Journal of Educational Psychology*, *95*(4), 774–783.

Azevedo, R., Cromley, J. G., Winters, F. I., Moos, D. C., & Greene, J. A. (2005). Adaptive Human Scaffolding Facilitates Adolescents' Self-regulated Learning with Hypermedia. *Instructional Science*, *33*(5-6), 381–412.

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.

Banning, M. (2008). Clinical reasoning and its application to nursing: concepts and research studies. *Nurse Education In Practice*, *8*(3), 177–183.

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn?: A taxonomy for far transfer. *Psychological Bulletin*, *128*(4), 612–637.

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*(6), 1173–1182.

Benner, P. (1982). From novice to expert. *The American Journal of Nursing*, *82*(3), 402–407.

Benner, P., Tanner, C. A., & Chesla, C. (2009). *Expertise in Nursing Practice: Caring, Clinical Judgment, and Ethics*. New York: Springer Verlag.

Berliner, D. C. (1994). Teacher Expertise. In T. Husén & T. N. Postlethwaite (Eds.), *The International encyclopedia of education* (2nd ed., Vol. 10, pp. 6020–6026). London: Pergamon.

Berliner, D. C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research*, *35*(5), 463–482.

Berner, E. S., & Graber, M. L. (2008). Overconfidence as a cause of diagnostic error in medicine. *The American Journal of Medicine*, *121*, S2–23.

Berthold, K., Eysink, T. H. S., & Renkl, A. (2009). Assisting Self-Explanation Prompts Are More Effective than Open Prompts when Learning with Multiple Representations. *Instructional Science: An International Journal of the Learning Sciences*, *37*(4), 345–363.

Berthold, K., & Renkl, A. (2009). Instructional aids to support a conceptual understanding of multiple representations. *Journal of Educational Psychology*, *101*(1), 70–87.

Berthold, K., & Renkl, A. (2010). How to Foster Active Processing of Explanations in Instructional Communication. *Educational Psychology Review*, *22*(1), 25–40.

Berthold, K., Röder, H., Knörzer, D., Kessler, W., & Renkl, A. (2011). The double-edged effects of explanation prompts. *Computers in Human Behavior*, *27*(1), 69–75.

Blomberg, G., Sherin, M. G., Renkl, A., Glogger, I., & Seidel, T. (2013). Understanding video as a tool for teacher education: Investigating instructional strategies to promote reflection. *Instructional Science*.

Booth, J. L., Lange, K. E., Koedinger, K. R., & Newton, K. J. (2013). Using example problems to improve student learning in algebra: Differentiating between correct and incorrect examples. *Learning and Instruction*, *25*, 24–34.

Borko, H. (2004). Professional Development and Teacher Learning: Mapping the Terrain. *Educational Researcher*, *33*(8), 3–15.

Boshuizen, H. P. A., & Schmidt, H. (1992). On the role of biomedical knowledge in clinical reasoning by experts, intermediates and novices. *Cognitive Science*, *16*(2), 153–184.

Boshuizen, H. P. A., Schmidt, H., Custers, E., & Van de Wiel, M. (1995). Knowledge development and restructuring in the domain of medicine: The role of theory and practice. *Learning and Instruction*, *5*(4), 269–289.

Buckingham, C. D., & Adams, A. (2000a). Classifying clinical decision making: a unifying approach. *Journal of Advanced Nursing*, *32*(4), 981–989.

Buckingham, C. D., & Adams, A. (2000b). Classifying clinical decision making: interpreting nursing intuition, heuristics and medical diagnosis. *Journal of Advanced Nursing*, *32*(4), 990–998.

Chamberland, M., Mamede, S., St-Onge, C., Rivard, M.-A., Setrakian, J., Lévesque, A., Rikers, R. M. J. P. (2013). Students' self-explanations while solving unfamiliar cases: the role of biomedical knowledge. *Medical Education*, *47*(11), 1109–1116.

Chamberland, M., St-Onge, C., Setrakian, J., Lanthier, L., Bergeron, L., Bourget, A., Rikers, R. (2011). The influence of medical students' self-explanations on diagnostic performance. *Medical Education*, *45*(7), 688–695.

Chamberland, M., St-Onge, C., Setrakian, J., Lanthier, L., Bergeron, L., Bourget, A., … Rikers, R. M. J. P. (2011). The influence of medical students' self-explanations on diagnostic performance. *Medical Education*, *45*(7), 688–695. doi:10.1111/j.1365-2923.2011.03933.x

Charlin, B., Boshuizen, H. P. A., Custers, E. J., & Feltovich, P. J. (2007). Scripts and clinical reasoning. *Medical Education*, *41*(12), 1178–1184.

Charlin, B., Lubarsky, S., Millette, B., Crevier, F., Audétat, M.-C., Charbonneau, A., … Bourdy, C. (2012). Clinical reasoning processes: unravelling complexity through graphical representation. *Medical Education*, *46*(5), 454–463.

Charlin, B., Tardif, J., & Boshuizen, H. P. A. (2000). Scripts and medical diagnostic knowledge: theory and applications for clinical reasoning instruction and research. *Academic Medicine: Journal of the Association of American Medical Colleges*, *75*(2), 182–190.

Chi, M. T. H. (2000). Self-explaining: The dual processes of generating inference and repairing mental models. In R. Glaser (Ed.), *Advances in instructional psychology: Educational design and cognitive science, Vol. 5.* (pp. 161–238). Mahwah, NJ US: Lawrence Erlbaum Associates Publishers.

Chi, M. T. H. (2009). Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science*, *1*(1), 73–105.

Chi, M. T. H., & Bassok, M. (1989). Learning from examples via self-explanations. *Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser*, 251–282.

Chi, M. T. H., Bassok, M., Lewis, M. W., & Reimann, P. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science: A Multidisciplinary Journal*, *13*(2), 145–182.

Chi, M. T. H., De Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, *18*(3), 439–477.

Chi, M. T. H., Roy, M., & Hausmann, R. G. M. (2008). Observing Tutorial Dialogues Collaboratively: Insights About Human Tutoring Effectiveness From Vicarious Learning. *Cognitive Science*, *32*(2), 301–341.

Chi, M. T. H., Siler, S. A., & Jeong, H. (2004). Can tutors monitor students´ understanding accurately? *Cognition and Instruction*, *22*(3), 363–387.

Chi, M. T. H., Siler, S. A., Jeong, H., Yamauchi, T., & Hausmann, R. G. (2001). Learning from human tutoring. *Cognitive Science*, *25*(4), 471–533.

Cholowski, K. M., & Chan, L. K. S. (1992). Diagnostic reasoning among second-year nursing students. *Journal of Advanced Nursing*, *17*(10), 1171–1181.

Cioffi, J. (2000). Recognition of patients who require emergency assistance: a descriptive study. *Heart & Lung: The Journal of Critical Care*, *29*(4), 262–268.

Cochran-Smith, M., & Zeichner, K. M. (2005). *Studying teacher education: The report of the AERA Panel on Research and Teacher Education*. (M. Cochran-Smith & K. M. Zeichner, Eds.). Mahwah, NJ Washington, DC USUS: Lawrence Erlbaum Associates Publishers.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. L. Erlbaum Associates.

Conati, C., & VanLehn, K. (2000). Toward Computer-Based Support of Meta-Cognitive Skills: a Computational Framework to Coach Self-Explanation. *International Journal of Artificial Intelligence in Education*, *11*, 398–415.

Corbett, A. T., & Anderson, J. R. (2001). Locus of feedback control in computer-based tutoring: Impact on learning rate, achievement and attitudes. In J. S. Jacko, A. Sears, M. Beaudouin-Lafon, & R. Jacob (Eds.), *roceedings of ACM CHI'2001 Conference on Human Factors in Computing Systems* (pp. 245–252). New York: ACM Press.

Corbett, A. T., & Trask, H. (2000). Instructional Interventions in Computer-Based Tutoring: Differential Impact on Learning Time and Accuracy. In T. Turner, G. Szwillus, & F. Paterno (Eds.), *Proceedings of ACM CHI'2000 Conference on Human Factors in Computing Systems* (pp. 97–104). New York: ACM Press.

Craig, S. D., Chi, M. T. H., & VanLehn, K. (2009). Improving classroom learning by collaboratively observing human tutoring videos while problem solving. *Journal of Educational Psychology*, *101*(4), 779–789.

Croskerry, P. (2009). A universal model of diagnostic reasoning. *Academic Medicine*, *84*(8), 1022–1028.

Croskerry, P., & Nimmo, G. R. (2011). Better clinical decision making and reducing diagnostic error. *The Journal of the Royal College of Physicians of Edinburgh*, *41*(2), 155–162.

Crow, R. A., Chase, J., & Lamond, D. (1995). The cognitive component of nursing assessment: an analysis. *Journal of Advanced Nursing*, *22*(2), 206–212.

Curry, L. (2004). The effects of self-explanations of correct and incorrect solutions on algebra problem-solving performance. In K. Forbus, D. Gent, & T. Regier (Eds.), *Proceedings of the Twenty-sixth annual conference of the Cognitive Science Society* (p. 1548). Mahwah, NJ: Eröbaum.

Darling-Hammond, L., & Youngs, P. (2002). Defining “Highly Qualified Teachers”: What Does “Scientifically-Based Research” Actually Tell Us? *Educational Researcher*, *31*(9), 13–25.

De Bruin, A. B. H., Rikers, R. M. J. P., & Schmidt, H. G. (2007). The effect of self-explanation and prediction on the development of principled understanding of chess in novices. *Contemporary Educational Psychology*, *32*, 188–205.

De Jong, T. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. *Instructional Science*, *38*(2), 105–134.

Deci, E. L., & Ryan, R. M. (1993). Die Selbstbestimmungstheorie der Motivation und ihre Bedeutung für die Pädagogik. *Zeitschrift Für Pädagogik*, *39*(2), 223–238.

DiCenso, A. (2003). Research: Evidence-based Nursing Practice: How to Get There from Here. *Nursing Leadership*, *16*(4), 20–26. doi:10.12927/cjnl.2003.16257

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: a meta-analysis. *Learning and Instruction*, *13*(5), 533–568.

Doyle, W. (2006). Ecological Approaches to Classroom Management. *Handbook of Classroom Management: Research, Practice, and Contemporary Issues*, 97–125.

Dreyfus, S., & Dreyfus, H. (1980). *A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition*. Berkley: Operations Research Centre, University of California Berkely.

Dunlosky, J., & Lipko, A. R. (2007). Metacomprehension A Brief History and How to Improve Its Accuracy. *Current Directions in Psychological Science*, *16*(4), 228–232.

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students’ learning and retention. *Learning and Instruction*, *22*(4), 271–280.

Durkin, K., & Rittle-Johnson, B. (2012). The effectiveness of using incorrect examples to support learning about decimal magnitude. *Learning and Instruction*, *22*(3), 206–214.

Dutra, D. K. (2013). Implementation of case studies in undergraduate didactic nursing courses: a qualitative study. *BMC Nursing*, *12*(1), 15.

Ebright, P. R., Patterson, E. S., Chalko, B. A., & Render, M. L. (2003). Understanding the Complexity of Registered Nurse Work in Acute Care Settings: *JONA: The Journal of Nursing Administration*, *33*(12), 630–638.

Eckert, T. L., Dunn, E. K., Codding, R. S., Begeny, J. C., & Kleinmann, A. E. (2006). Assessment of mathematics and reading performance: An examination of the correspondence between direct assessment of student performance and teacher report. *Psychology in the Schools*, *43*(3), 247–265.

Elstein, A. S. (1978). *Medical problem solving: an analysis of clinical reasoning*. Cambridge: Harvard Univ. Press.

Elstein, A. S., & Bordage, G. (1988). Psychology of clinical reasoning. In J. Dowie & A. S. Elstein (Eds.), *Professional judgment: A reader in clinical decision making.* (pp. 109–129). New York, NY US: Cambridge University Press.

Ericsson, K. A. (2006). 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). New York, NY US: Cambridge University Press.

Eva, K. W. (2004). What every teacher needs to know about clinical reasoning. *Medical Education*, *39*(1), 98–106.

Eva, K. W., Hatala, R. M., Leblanc, V. R., & Brooks, L. R. (2007). Teaching from the clinical reasoning literature: combined reasoning strategies help novice diagnosticians overcome misleading information. *Medical Education*, *41*, 1152–8.

Evers, G. C. M. (1997). *Theorien und Prinzipien der Pflegekunde*. Berlin, Wiesbaden: Ullstein Medical.

Eysink, T. H. S., & de Jong, T. (2012). Does Instructional Approach Matter? How Elaboration Plays a Crucial Role in Multimedia Learning. *Journal of the Learning Sciences*, *21*(4), 583–625.

Eysink, T. H. S., Jong, T. de, Berthold, K., Kolloffel, B., Opfermann, M., & Wouters, P. (2009). Learner Performance in Multimedia Learning Arrangements: An Analysis Across Instructional Approaches. *American Educational Research Journal*, *46*(4), 1107–1149.

Farmer, E. A., & Page, G. (2005). A practical guide to assessing clinical decision-making skills using the key features approach. *Medical Education*, *39*(12), 1188–1194.

Feinberg, A. B., & Shapiro, E. S. (2009). Teacher accuracy: An examination of teacher-based judgments of students' reading with differing achievement levels. *The Journal of Educational Research*, *102*(6), 453–462.

Fischer, M. R. (2000). CASUS - An Authoring and Learning Tool Supporting Diagnostic Reasoning. In *Use of Computers in Medical Education (Part II)* (Vol. 1, pp. 87–98). Ch. Daetwyler.

Fischer, M. R., Hege, I., Hörnlein, A., Puppe, F., Tönshoff, B., & Huwendiek, S. (2008). Virtuelle Patienten in der medizinischen Ausbildung: Vergleich verschiedener Strategien zur curricularen Integration. *Zeitschrift Für Evidenz, Fortbildung Und Qualität Im Gesundheitswesen*, *102*(10), 648–653.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist*, *34*(10), 906–911.

Forsberg, E., Georg, C., Ziegert, K., & Fors, U. (2011). Virtual patients for assessment of clinical reasoning in nursing — A pilot study. *Nurse Education Today*, *31*(8), 757–762.

French, P. (2002). What is the evidence on evidence-based nursing? An epistemological concern. *Journal of Advanced Nursing*, *37*(3), 250–257.

Gennaro, S., Hodnett, E., & Kearney, M. (2001). Making evidence-based practice a reality in your institution. *MCN. The American Journal of Maternal Child Nursing*, *26*(5), 236–244.

Gerjets, P., Scheiter, K., & Catrambone, R. (2006). Can learning from molar and modular worked examples be enhanced by providing instructional explanations and prompting self-explanations? *Learning and Instruction*, *16*(2), 104–121.

Gerjets, P., Scheiter, K., & Schuh, J. (2005). Instruktionale Unterstützung beim Fertigkeitserwerb aus Beispielen in hypertextbasierten Lernumgebungen. *Zeitschrift Für Pädagogische Psychologie*, *19*(1-2), 23–38.

Gholson, B., & Craig, S. D. (2006). Promoting Constructive Activities that Support Vicarious Learning During Computer-Based Instruction. *Educational Psychology Review*, *18*(2), 119–139.

Gick, M. L. (1986). Problem-solving strategies. *Educational Psychologist*, *21*(1-2), 99–120.

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic Decision Making. *Annual Review of Psychology*, *62*(1), 451–482. doi:10.1146/annurev-psych-120709-145346

Glaze, J. E. (2001). Reflection as a transforming process: student advanced nurse practitioners' experiences of developing reflective skills as part of an MSc programme. *Journal of Advanced Nursing*, *34*(5), 639–647.

Graber, M. L. (2009). Educational strategies to reduce diagnostic error: can you teach this stuff? *Advances in Health Sciences Education: Theory and Practice*, *14 Suppl 1*, 63–9.

Graber, M. L., Franklin, N., & Gordon, R. (2005). Diagnostic error in internal medicine. *Archives of Internal Medicine*, *165*(13), 1493–1499.

Gräsel, C., Fischer, F., & Mandl, H. (2001). The Use of Additional Information in Problem-Oriented Learning Environments. *Learning Environments Research*, *3*(3), 287–305.

Gräsel, C., & Mandl, H. (1993). Förderung des Erwerbs diagnostischer Strategien in fallbasierten Lernumgebungen. *Unterrichtswissenschaft*, *21*(4), 355–369.

Greeno, J. G., Moore, J. L., & Smith, D. R. (1993). Transfer of situated learning. In D. K. Detterman & R. J. Sternberg (Eds.), *Transfer on trial: Intelligence, cognition, and instruction.* (pp. 99–167). Westport, CT US: Ablex Publishing.

Greenwood, J. (2000). Critical thinking and nursing scripts: the case for the development of both. *Journal of Advanced Nursing*, *31*(2), 428–436.

Groccia, J. E., & Buskist, W. (2011). Need for evidence-based teaching. *New Directions for Teaching and Learning*, *2011*(128), 5–11.

Große, C. S., & Renkl, A. (2004). Learning from worked examples: What happens if errors are included? In P. Gerjet, J. Elen,, R. Joiner, & P. A. Kirschner (Eds.), *Instructional design for effective and enjoyable computer-supported learning* (pp. 356–364). Tübingen: Knowledge Media Research Center.

Große, C. S., & Renkl, A. (2006). Effects of multiple solution methods in mathematics learning. *Learning and Instruction*, *16*(2), 122–138.

Große, C. S., & Renkl, A. (2007). Finding and fixing errors in worked examples: Can this foster learning outcomes? *Learning and Instruction*, *17*(6), 612–634.

Hammerness, K., Darling-Hammond, L., Bransford, J., Berliner, D., Cochran-Smith, M., McDonald, M., & Zeichner, K. (2005). How Teachers Learn and Develop. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do.* (pp. 358–389). San Francisco, CA US: Jossey-Bass.

Hammersley, M. (Ed.). (2007). *Educational Research and Evidence-based Practice*. Sage Publications Ltd.

Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, *77*(1), 81–112.

Hausmann, R. G. M., & Chi, M. T. H. (2002). Can a computer interface support self-explaining? *Cognitive Technology*, *7*(1), 4–14.

Hausmann, R. G. M., & VanLehn, K. (2007). Explaining self-explaining: A contrast between content and generation. In R. Luckin, K. R. Koedinger, & J. E. Greer (Eds.), *Artificial Intelligence in Education: Building Technology Rich Learning Contexts that Work* (IOS Press., Vol. 158, pp. 417–424). Amsterdam: IOS Press.

Heimbeck, D., Frese, M., Sonnentag, S., & Keith, N. (2003). Integrating errors into the training process: The function of error management instructions and the role of goal orientation. *Personnel Psychology*, *56*(2), 333–361.

Helmke, A. (2010). *Unterrichtsqualität und Lehrerprofessionalität Diagnose, Evaluation und Verbesserung des Unterrichts ; Franz Emanuel Weinert gewidmet*. Seelze-Velber: Klett/Kallmeyer.

Helmke, A., Helmke, T., Lenske, G., Pham, G., Praetorius, A.-K., Schrader, F.-W., & Ade-Thurow, M. (2012). Unterrichtsdiagnostik – Voraussetzung für die Verbesserung der Unterrichtsqualität. In Stephan G. Huber (Ed.), *Jahrbuch Schulleitung 2012. Befunde und Impulse zu den Handlungsfeldern des Schulmanagements* (pp. 133–144). Köln: Carl Link.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141–158.

Higgs, J., Burn, A., & Jones, M. (2001). Integrating clinical reasoning and evidence-based practice. *AACN Clinical Issues*, *12*(4), 482–490.

Higgs, J., & Jones, M. A. (2008). Clinical descision making and multiple problem spaces. In J. Higgs, M. A. Jones, S. Loftus, & N. Christensen (Eds.), *Clinical Reasoning in the Health Professions* (3rd ed., pp. 3–17). Amsterdam: Elsevier (Butterworth Heinemann).

Hilbert, T. S., Renkl, A., Kessler, S., & Reiss, K. (2008). Learning to prove in geometry: Learning from heuristic examples and how it can be supported. *Learning and Instruction*, *18*(1), 54–65.

Hilbert, T. S., Schworm, S., & Renkl, A. (2004). Learning from worked-out examples: The transition from instructional explanations to self-explanation prompts. In P. Kirschner & P. Gerjets (Eds.), *Instructional design for effective and enjoyable computer-supported learning* (pp. 184–192). Tübingen, Germany: Knowledge Media Research Center.

Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review*, *16*(3), 235–266.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99–107.

Hofer, B. K. (2004). Epistemological Understanding as a Metacognitive Process: Thinking Aloud During Online Searching. *Educational Psychologist*, *39*(1), 43–55.

Holmes, N. G., Day, J., Park, A. H. K., Bonn, D. A., & Roll, I. (in press). Making the failure more productive: scaffolding the invention process to improve inquiry behaviors and outcomes in invention activities. *Instructional Science*, 1–16.

Hosenfeld, I., Helmke, A., & Schrader, F.-W. (2002). Diagnostische Kompetenz: Unterrichts- und lernrelevante Schülermerkmale und deren Einschätzung durch Lehrkräfte in der Unterrichtsstudie SALVE. *Zeitschrift für Pädagogik - Beiheft*, *45*, 65–82.

Huang, T.-H., Liu, Y.-C., & Shiu, C.-Y. (2008). Construction of an online learning system for decimal numbers through the use of cognitive conflict strategy. *Computers & Education*, *50*(1), 61–76.

Hutchinson, A. M., & Johnston, L. (2004). Bridging the divide: a survey of nurses' opinions regarding barriers to, and facilitators of, research utilization in the practice setting. *Journal of Clinical Nursing*, *13*(3), 304–315.

Ingenkamp, K.-H. (2008). *Lehrbuch der Pädagogischen Diagnostik*. Weinheim: Beltz.

Ioannidis, J. P. A. (2005). Contradicted and initially stronger effects in highly cited clinical research. *JAMA: The Journal of the American Medical Association*, *294*(2), 218–228.

Isotani, S., Adams, D., Mayer, R. E., Durkin, K., Rittle-Johnson, B., & McLaren, B. M. (2011). Can Erroneous Examples Help Middle-School Students Learn Decimals? In C. D. Kloos, D. Gillet, R. M. C. García, F. Wild, & M. Wolpers (Eds.), *Towards Ubiquitous Learning* (pp. 181–195). Springer Berlin Heidelberg.

Jonassen, D., & Hung, W. (2008). All Problems are Not Equal: Implications for Problem-Based Learning. *Interdisciplinary Journal of Problem-Based Learning*, *2*(2).

Kahneman, D. (2011). *Thinking, Fast and Slow*. Macmillan.

Kalyuga, S. (2011). Cognitive Load Theory: How Many Types of Load Does It Really Need? *Educational Psychology Review*, *23*(1), 1–19.

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist*, *38*(1), 23–31.

Kalyuga, S., & Renkl, A. (2010). Expertise reversal effect and its instructional implications: introduction to the special issue. *Instructional Science*, *38*(3), 209–215.

Kapur, M. (2013). Comparing Learning From Productive Failure and Vicarious Failure. *Journal of the Learning Sciences*, *0*(0), 1–27.

Kapur, M., & Bielaczyc, K. (2012). Designing for Productive Failure. *Journal of the Learning Sciences*, *21*(1), 45–83.

Kassirer, J. P. (2010). Teaching clinical reasoning: case-based and coached. *Academic Medicine: Journal Of The Association Of American Medical Colleges*, *85*(7), 1118–1124.

Kaufman, D., Yoskowitz, A., & Patel, V. L. (2008). Clinical reasoning and biomedical knowledge: implications for teaching. In *Clinical Reasoning in the Health Professions* (pp. 137–150). Amsterdam: Elsevier Health Sciences.

Kersting, N. B., Givvin, K. B., Thompson, B. J., Santagata, R., & Stigler, J. W. (2012). Measuring usable knowledge: Teachers' analyses of mathematics classroom videos predict teaching quality and student learning. *American Educational Research Journal*, *49*(3), 568–589.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance during Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, *41*(2), 75–86.

Klopp, E., Stark, R., Kopp, V., & Fischer, M. R. (2013). Psychological Factors Affecting Medical Students' Learning with Erroneous Worked Examples. *Journal of Education and Learning*, *2*(1), 158–170.

Klug, J., Bruder, S., Kelava, A., Spiel, C., & Schmitz, B. (2013). Diagnostic Competence of Teachers: A Process Model That Accounts for Diagnosing Learning Behavior Tested by Means of a Case Scenario. *Teaching and Teacher Education: An International Journal of Research and Studies*, *30*, 38–46.

Koedinger, K. R., & Aleven, V. (2007). Exploring the Assistance Dilemma in Experiments with Cognitive Tutors, *Educational Psychology Review*, *19*(3), 239-264.

Kolodner, J. L. (1983). Towards an understanding of the role of experience in the evolution from novice to expert. *International Journal of Man-Machine Studies*, *19*(5), 497–518.

Kolodner, J. L. (1992). An introduction to case-based reasoning. *Artificial Intelligence Review*, *6*(1), 3–34.

Kolodner, J. L. (2006). Case-Based Reasoning. In R. K. Sawyer (Ed.), *The Cambridge handbook of: The learning sciences.* (pp. 225–242). New York, NY US: Cambridge University Press.

Kopp, V., Stark, R., Heitzmann, N., & Fischer, M. R. (2009). Self-regulated learning with case-based worked examples: effects of errors. *Evaluation & Research in Education*, *22*(2), 107–119.

Korthagen, F. A. J. (2007). The gap between research and practice revisited. *Educational Research and Evaluation*, *13*(3), 303–310.

Kramer, M., Brewer, B. B., Halfer, D., Maguire, P., Beausoleil, S., Claman, K., … Duchscher, J. B. (2013). Changing our lens: seeing the chaos of professional practice as complexity. *Journal of Nursing Management*, *21*(4), 690–704.

Krause, U.-M. (2007). *Feedback und kooperatives Lernen* (1., Aufl.). Waxmann.

Krolak-Schwerdt, S., Böhmer, M., & Gräsel, C. (2009). Verarbeitung von schülerbezogener Information als zielgeleiteter Prozess. *Zeitschrift Für Pädagogische Psychologie*, *23*(3), 175–186.

Kuiper, R. A., & Pesut, D. J. (2004). Promoting cognitive and metacognitive reflective reasoning skills in nursing practice: self-regulated learning theory. *Journal of Advanced Nursing*, *45*(4), 381–391.

Kulhavy, R. W. (1977). Feedback in Written Instruction. *Review of Educational Research*, *47*(2), 211–232.

Lee, J., Chan, A. C. M., & Phillips, D. R. (2006). Diagnostic practise in nursing: A critical review of the literature. *Nursing and Health Sciences*, *8*(1), 57–65.

Lehmann, R. H., Peek, R., Gänsefuß, R., Lutkat, S., Mücke, S., & Barth, I. (2000). *Qualitätsuntersuchung an Schulen zum Unterricht in Mathematik (QuaSUM)*. Potsdam: Ministrium für Bildung, Jugend, und Sport des Landes Brandenburg.

Leutner, D. (2002). Adaptivität und Adaptierbarkeit multimedialer Lehr- und Informationssysteme. In *Information und Lernen mit Multimedia* (pp. 115–125). Weinheim: Beltz.

Levett-Jones, T., Hoffman, K., Dempsey, J., Jeong, S. Y.-S., Noble, D., Norton, C. A., … Hickey, N. (2010). The “five rights” of clinical reasoning: an educational model to enhance nursing students’ ability to identify and manage clinically “at risk” patients. *Nurse Education Today*, *30*(6), 515–520.

Loibl, K., & Rummel, N. (in press). The impact of guidance during problem-solving prior to instruction on students’ inventions and learning outcomes. *Instructional Science*, 1–22.

MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation Analysis. *Annual Review of Psychology*, *58*(1), 593–614.

Mähler, C., & Stern, E. (2010). Transfer. In D. H. Rost (Ed.), *Handwörterbuch Pädagogische Psychologie* (4., überarbeitete und erweiterte Auflage., pp. 859–869). Weinheim: Beltz Psychologie Verlags Union.

Mamede, S., Schmidt, H. G., & Penaforte, J. C. (2008). Effects of reflective practice on the accuracy of medical diagnoses. *Medical Education*, *42*(5), 468–475.

Mamede, S., Schmidt, H. G., Rikers, R. M. J. P., Custers, E. J. F. M., Splinter, T. A. W., & van Saase, J. L. C. M. (2010). Conscious thought beats deliberation without attention in diagnostic decision-making: at least when you are an expert. *Psychological Research*, *74*(6), 586–592.

Mamede, S., van Gog, T., Moura, A. S., de Faria, R. M. D., Peixoto, J. M., Rikers, R. M. J. P., & Schmidt, H. G. (2012). Reflection as a strategy to foster medical students' acquisition of diagnostic competence. *Medical Education*, *46*(5), 464–472.

Mandinach, E. B. (2012). A Perfect Time for Data Use: Using Data-Driven Decision Making to Inform Practice. *Educational Psychologist*, *47*(2), 71–85.

Mathan, S. A., & Koedinger, K. R. (2005). Fostering the intelligent novice: Learning from errors with metacognitive tutoring. *Educational Psychologist*, *40*(4), 257–265.

McEldoon, K. L., Durkin, K. L., & Rittle-Johnson, B. (2012). Is self-explanation worth the time? A comparison to additional practice. *British Journal of Educational Psychology*, *83*(4), 615–635.

McElvany, N., Schroeder, S., Hachfeld, A., Baumert, J., Richter, T., Schnotz, W., Ullrich, M. (2009). Diagnostische Fähigkeiten von Lehrkräften. *Zeitschrift Für Pädagogische Psychologie*, *23*(3), 223–235.

McKendree, J., Stenning, K., Mayes, T., Lee, J., & Cox, R. (1998). Why observing a dialogue may benefit learning. *Journal of Computer Assisted Learning*, *14*(2), 110–119.

McLaren, B. M., Adams, D., Durkin, K., Goguadze, G., Mayer, R. E., Rittle-Johnson, B., Velsen, M. van. (2012). To Err Is Human, to Explain and Correct Is Divine: A Study of Interactive Erroneous Examples with Middle School Math Students. In A. Ravenscroft, S. Lindstaedt, C. D. Kloos, & D. Hernández-Leo (Eds.), *21st Century Learning for 21st Century Skills* (pp. 222–235). Springer Berlin Heidelberg.

McSherry, D. (1997). Avoiding premature closure in sequential diagnosis. *Artificial Intelligence in Medicine*, *10*(3), 269–283.

Merrill, M. D. (2013). First Principles of Instruction. *Educational Technology Research and Development*, *50*, 43–59.

Murphy, J. I. (2004). Using focused reflection and articulation to promote clinical reasoning: an evidence-based teaching strategy. *Nursing Education Perspectives*, *25*(5), 226–231.

Mwangi, W., & Sweller, J. (1998). Learning to Solve Compare Word Problems: The Effect of Example Format and Generating Self-Explanations. *Cognition and Instruction*, *16*(2), 173–199.

Narciss, S. (2008). Feedback Strategies for Interactive Learning Tasks. In J. M. Spector, M. D. Merrill, J. J. G. Van Merriënboer, & M. P. Driscoll (Eds.), *Handbook of Research on Educational Communications and Technology, Edition* (pp. 125–144). Mahaw, NJ: Erlbaum Associates,.

Narciss, S. (2013). Designing and Evaluating Tutoring Feedback Strategies for digital learning environments on the basis of the Interactive Tutoring Feedback Model. *Digital Education Review*, *0*(23), 7–26.

Narciss, S., Proske, A., & Koerndle, H. (2007). Promoting self-regulated learning in web-based learning environments. *Computers in Human Behavior*, *23*(3), 1126–1144.

Narciss, S., Sosnovsky, S., Schnaubert, L., Andrès, E., Eichelmann, A., Goguadze, G., & Melis, E. (2014). Exploring feedback and student characteristics relevant for personalizing feedback strategies. *Computers & Education*, *71*, 56–76.

Nievelstein, F., van Gog, T., van Dijck, G., & Boshuizen, H. P. A. (2013). The worked example and expertise reversal effect in less structured tasks: Learning to reason about legal cases. *Contemporary Educational Psychology*, *38*(2), 118–125.

Nokes, T., Hausmann, R. G. M., VanLehn, K., & Gershman, S. (2011). Testing the instructional fit hypothesis: the case of self-explanation prompts. *Instructional Science*, *39*(5), 645–666.

Nokes-Malach, T. J., VanLehn, K., Belenky, D. M., Lichtenstein, M., & Cox, G. (2013). Coordinating principles and examples through analogy and self-explanation. *European Journal of Psychology of Education*, *28*(4), 1237–1263.

Norman, G. R. (2005). Research in clinical reasoning: past history and current trends. *Medical Education*, *39*(4), 418–427.

Norman, G. R., Brooks, L. R., Colle, C. L., & Hatala, R. M. (1999). The benefit of diagnostic hypotheses in clinical reasoning: Experimental study of an instructional intervention for forward and backward reasoning. *Cognition and Instruction*, *17*(4), 433–448.

Norman, G. R., & Eva, K. W. (2010). Diagnostic error and clinical reasoning. *Medical Education*, *44*(1), 94–100.

North American Nursing Diagnosis Association. (1990). *Taxonomy I with official Nursing Diagnoses*. St.Louis: NANDA.

O'Neill, E. S., Dluhy, N. M., & Chin, E. (2005). Modelling novice clinical reasoning for a computerized decision support system. *Journal of Advanced Nursing*, *49*(1), 68–77.

Offredy, M., & Meerabeau, E. (2005). The use of "think aloud" technique, information processing theory and schema theory to explain decision-making processes of general practitioners and nurse practitioners using patient scenarios. *Primary Health Care Research and Development*, *6*(1), 46–59.

Ohlsson, S. (1996). Learning from error and the design of task environments. *International Journal of Educational Research*, *25*(5), 419–448.

Oksa, A., Kalyuga, S., & Chandler, P. (2010). Expertise reversal effect in using explanatory notes for readers of Shakespearean text. *Instructional Science*, *38*(3), 217–236.

Ophuysen,, S. (2010). Professionelle pädagogisch diagnostische Kompetenz – eine theoretische und empirische Annäherung. In N. Berkemeyer, N. B., Wilfried Bos, Heinz Günter Holtappels, Nele McElvany, Renate Schulz-Zander, W. Bos, H. G. Holtappels, & N. McElvany (Eds.), *Jahrbuch der Schulentwicklung, Band 16* (pp. 203–234). Weinheim und München: Beltz Juventa.

Ousey, K., & Gallagher, P. (2007). The theory-practice relationship in nursing: a debate. *Nurse Education in Practice*, *7*(4), 199–205.

Paas, F., & Kalyuga, S. (2005). Cognitive Measurements to Design Effective Learning Environments. Presented at the International Workshop and Mini-conference on Extending Cognitive Load Theory and In-structional Design to the Development of Expert Performance,, Heerlen, Netherlands.

Paris, S. G., Lipson, M. Y., & Wixson, K. K. (1983). Becoming a Strategic Reader. *Contemporary Educational Psychology*, *8*(3), 293–316.

Patel, V. L., Arocha, J., & Leccisi, M. (2001). Impact of undergraduate medical training on housestaff problem-solving performance: implications for problem-based curricula. *Journal of Dental Education*, *65*(11), 1199 –1218.

Patel, V. L., Evans, D. A., & Groen, G. J. (1989). Reconciling basic science and clinical reasoning. *Teaching and Learning in Medicine*, *1*(3), 116–121.

Pearson, E. S., & Hartley, H. O. (1976). *Biometrika tables for statisticians: Volume I.* London: Biometrika Trust.

Pennington, N., & Rehder, B. (1995). Looking for Transfer and Interference. In Douglas L. Medin (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. Volume 33, pp. 223–289). San Diego, CA, US: Academic Press.

Pereira, T. V., & Ioannidis, J. P. A. (2011). Statistically significant meta-analyses of clinical trials have modest credibility and inflated effects. *Journal of Clinical Epidemiology*, *64*(10), 1060–1069.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & Mckeachie, W. J. (1993). Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (Mslq). *Educational and Psychological Measurement*, *53*(3), 801–813.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*(3), 879–891.

Prenzel, M., Eitel, F., Holzbach, R., Schoenheinz, R.-J., & Schweiberer, L. (1993). Lernmotivation im studentischen Unterricht in der Chirurgie. *Zeitschrift Für Pädagogische Psychologie*, *7*(2/3), 125–137.

Pressley, M., Wood, E., Woloshyn, V. E., Martin, V., King, A., & Menke, D. (1992). Encouraging Mindful Use of Prior Knowledge: Attempting to Construct Explanatory Answers Facilitates Learning. *Educational Psychologist*, *27*(1), 91–109.

Profetto-McGrath, J. (2005). Critical Thinking and Evidence-Based Practice. *Journal of Professional Nursing*, *21*(6), 364–371.

Puntambekar, S., & Hubscher, R. (2005). Tools for Scaffolding Students in a Complex Learning Environment: What Have We Gained and What Have We Missed? *Educational Psychologist*, *40*(1), 1–12.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., … Soloway, E. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *Journal of the Learning Sciences*, *13*(3), 337–386.

Rehder, B., & Hastie, R. (2001). Causal knowledge and categories: The effects of causal beliefs on categorization, induction, and similarity. *Journal of Experimental Psychology: General*, *130*(3), 323–360.

Reilly, B. M. (2007). Inconvenient truths about effective clinical teaching. *The Lancet*, *370*(9588), 705–711.

Reimann, P., & Chi, M. T. H. (1989). Human expertise. In K. Gilhooly (Ed.), *Human and machine problem solving* (pp. 161–191). New York: Plenum.

Reiss, K., Hellmich, F., & Thomas, J. (2002). Individuelle und schulische Bedingungsfaktoren für Argumentationen und Beweise im Mathematikunterricht. In *Bildungsqualität von Schule: Schulische und außerschulische Bedingungen mathematischer, naturwissenschaftlicher und überfachlicher Kompetenzen* (Vol. 45, pp. 51–64). Weinheim: Beltz.

Renkl, A. (in press). Toward an Instructionally Oriented Theory of Example-Based Learning. *Cognitive Science*

Renkl, A. (1997). Learning from worked-out examples: A study on individual differences. *Cognitive Science: A Multidisciplinary Journal*, *21*(1), 1–29.

Renkl, A. (1999). Learning mathematics from worked-out examples: Analyzing and fostering self-explanations. *European Journal of Psychology of Education*, *14*(4), 477–488.

Renkl, A. (2002). Worked-out examples: instructional explanations support learning by self-explanations. *Learning and Instruction*, *12*(5), 529–556.

Renkl, A., & Atkinson, R. K. (2010). Learning from worked-out examples and problem solving. In J. L. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive load theory* (pp. 91–108). New York, NY US: Cambridge University Press.

Richey, J. E., & Nokes-Malach, T. J. (2013). How much is too much? Learning and motivation effects of adding instructional explanations to worked examples. *Learning and Instruction*, *25*, 104–124.

Riehl, C. (2006). Feeling Better: A Comparison of Medical Research and Education Research. *Educational Researcher*, *35*(5), 24–29.

Rikers, R. M. J. P., Loyens, S. M. M., & Schmidt, H. G. (2004). The role of encapsulated knowledge in clinical case representations of medical students and family doctors. *Medical Education*, *38*(10), 1035–1043.

Rittle-Johnson, B. (2006). Promoting transfer: effects of self-explanation and direct instruction. *Child Development*, *77*(1), 1–15.

Rittle-Johnson, B., Siegler, R. S., & Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology*, *93*(2), 346–362.

Robinson, V. M. J. (1998). Methodology and the Research-Practice Gap. *Educational Researcher*, *27*(1), 17–26.

Roelle, J., Berthold, K., & Renkl, A. (in press). Two instructional aids to optimise processing and learning from instructional explanations. *Instructional Science*, 1–22.

Roll, I., Aleven, V., McLaren, B. M., & Koedinger, K. R. (2011). Improving students' help-seeking skills using metacognitive feedback in an intelligent tutoring system. *Learning and Instruction*, *21*(2), 267–280.

Rummel, N., & Spada, H. (2005). Learning to Collaborate: An Instructional Approach to Promoting Collaborative Problem Solving in Computer-Mediated Settings. *The Journal of the Learning Sciences*, *14*(2), 201–241.

Rummel, N., Spada, H., & Hauser, S. (2009). Learning to collaborate while being scripted or by observing a model. *International Journal of Computer-Supported Collaborative Learning*, *4*(1), 69–92.

Sackett, D. L., Rosenberg, W. M. C., Gray, J. A. M., Haynes, R. B., & Richardson, W. S. (1996). Evidence based medicine: what it is and what it isn't. *BMJ*, *312*(7023), 71–72.

Sánchez, E., & García-Rodicio, H. (2013). Using online measures to determine how learners process instructional explanations. *Learning and Instruction*, *26*, 1–11.

Schank, R. C. (1999). *Dynamic Memory Revisited* (2nd ed.). Cambridge University Press.

Scheiter, K., & Gerjets, P. (2007). Learner Control in Hypermedia Environments. *Educational Psychology Review*, *19*(3), 285–307.

Schiff, G. D., Hasan, O., Kim, S., Abrams, R., Cosby, K., Lambert, B. L., … McNutt, R. A. (2009). Diagnostic error in medicine: analysis of 583 physician-reported errors. *Archives Of Internal Medicine*, *169*(20), 1881–1887.

Schmidt, H. G., Norman, G. R., & Boshuizen, H. P. A. (1990). A cognitive perspective on medical expertise: theory and implications. *Academic Medicine*, *65*(10), 611–21.

Schmidt, H. G., & Rikers, R. M. J. P. (2007). How expertise develops in medicine: knowledge encapsulation and illness script formation. *Medical Education*, *41*(12), 1133–1139.

Schmidt, R. A., & Bjork, R. A. (1992). New Conceptualizations of Practice: Common Principles in Three Paradigms Suggest New Concepts for Training. *Psychological Science*, *3*(4), 207–217.

Schrader, F.-W. (2009). Anmerkungen zum Themenschwerpunkt Diagnostische Kompetenz von Lehrkräften. *Zeitschrift Für Pädagogische Psychologie*, *23*(3), 237–245.

Schrader, F.-W. (2011). Lehrer als Diagnostiker. In E. Terhart, H. Bennewitz, & M. Rothland (Eds.), *Handbuch der Forschung zum Lehrerberuf* (pp. 683–698). Münster: Waxmann.

Schrader, F.-W., & Helmke, A. (2001). Alltägliche Leistungsbeurteilung durch Lehrer. In F. Weinert (Ed.), *Leistungsmessungen in Schulen* (pp. 45–58). Weinheim: Beltz.

Schrader, J., & Hartz, S. (2003). Professionalisierung - Erwachsenenbildung - Fallarbeit. In R. Arnold & I. Schüssler (Eds.), *Ermöglichungsdidaktik in der Erwachsenenbildung* (pp. 142–155). Baltmannsweiler: Schneider Verlag Hohengehren.

Schwartz, A., & Elstein, A. S. (2008). Clinicial reasoning in medicine. In J. Higgs, M. A. Jones, S. Loftus, & N. Christensen (Eds.), *Clinical reasoning in the health professions* (3rd ed., pp. 223–234). Amsterdam: Elsevier (Butterworth Heinemann).

Schworm, S., & Renkl, A. (2006). Computer-supported example-based learning: When instructional explanations reduce self-explanations. *Computers & Education*, *46*(4), 426–445.

Schworm, S., & Renkl, A. (2007). Learning Argumentation Skills through the Use of Prompts for Self-Explaining Examples. *Journal of Educational Psychology*, *99*(2), 285–296.

Seidel, T., & Prenzel, M. (2007). Wie Lehrpersonen Unterricht wahrnehmen und einschätzen - Erfassung pädagogisch-psychologischer Kompetenzen mit Videosequenzen. *Kompetenzdiagnostik*, 201–216.

Seidel, T., & Shavelson, R. J. (2007). Teaching effectiveness research in the past decade: The role of theory and research design in disentangling meta-analysis results. *Review of Educational Research*, *77*(4), 454–499.

Shavelson, R. J., & Stern, P. (1981). Research on Teachers Pedagogical Thoughts, Judgments, Decisions and Behavior. *Review of Educational Research*, *51*(4), 455–98.

Sherin, M. G., & van Es, E. A. (2009). Effects of Video Club Participation on Teachers' Professional Vision. *Journal of Teacher Education*, *60*(1), 20–37.

Siegler, R. S. (2002). Microgenetic studies of self-explanation. In N. Granott & J. Parziale (Eds.), *Microdevelopment: Transition processes in development and learning.* (pp. 31–58). New York, NY US: Cambridge University Press.

Siegler, R. S., & Chen, Z. (2008). Differentiation and integration: guiding principles for analyzing cognitive change. *Developmental Science*, *11*(4), 433–448.

Simmons, B. (2010). Clinical reasoning: concept analysis. *Journal of Advanced Nursing*, *66*(5), 1151–1158.

Simmons, B., Lanuza, D., Fonteyn, M., Hicks, F., & Holm, K. (2003). Clinical reasoning in experienced nurses. *Western Journal of Nursing Research*, *25*(6), 701–719; discussion 720–724.

Slavin, R. E. (2008). Perspectives on Evidence-Based Research in Education—What Works? Issues in Synthesizing Educational Program Evaluations. *Educational Researcher*, *37*(1), 5–14.

Slocum, T. A., Spencer, T. D., & Detrich, R. (2012). Best Available Evidence: Three Complementary Approaches. *Education & Treatment of Children (West Virginia University Press)*, *35*(2), 153–181.

Sniderman, A. D., Lachapelle, K. J., Rachon, N. A., & Furberg, C. D. (2013). The Necessity for Clinical Reasoning in the Era of Evidence-Based Medicine. *Mayo Clinic Proceedings. Mayo Clinic*, *88*(10), 1108–1114.

Sobel, M. E. (1986). Some new results on indirect effects and their standard errors in covariance structure models. In N. Tuna (Ed.), *Sociological methodology* (American Sociological Association.). Washington.

Spencer, T. D., Detrich, R., & Slocum, T. A. (2012). Evidence-based practice: A framework for making effective decisions. *Education & Treatment of Children*, *35*(2), 127–151.

Spinath, B. (2005). Akkuratheit der Einschätzung von Schülermerkmalen durch Lehrer und das Konstrukt der diagnostischen Kompetenz. *Zeitschrift Für Pädagogische Psychologie*, *19*(1), 85–95.

Stark, R. (1999). *Lernen mit Lösungsbeispielen*. Göttingen: Hogrefe-Verlag.

Stark, R. (2001). *Analyse und Förderung beispielbasierten Lernens – Anwendung eines integrati-ven Forschungsparadigmas*. Unveröffentlichte Habilitationsschrift, Ludwig-Maximilians-Universität München, München.

Stark, R., & Fischer, M. R. (2008). *Förderung diagnostischer Kompetenz durch beispielbasiertes Lernen: Einfluss von Prozessorientierung und Fehler*. unveröffentlichter Arbeitsbericht über die Projektarbeit im Förderzeitraum 1

Stark, R., Gruber, H., Mandl, H., & Hinkofer, L. (2001). Wege zur Optimierung eines beispielbasierten Instruktionsansatzes: Der Einfluss multipler Perspektiven und instruktionaler Erklärungen auf den Erwerb von Handlungskompetenz. *Unterrichtswissenschaft*, *29*(1), 26–40.

Stark, R., Kopp, V., & Fischer, M. R. (2011). Case-based learning with worked examples in complex domains: Two experimental studies in undergraduate medical education. *Learning and Instruction*, *21*(1), 22–33.

Stark, R., Mandl, H., Gruber, H., & Renkl, A. (1999). Instructional means to overcome transfer problems in the domain of economics: empirical studies. *International Journal of Educational Research*, *31*(7), 591–609.

Stark, R., Tyroller, M., Krause, U.-M., & Mandl, H. (2008). Effekte einer metakognitiven Promptingmaßnahme beim situierten, beispielbasierten Lernen im Bereich Korrelationsrechnung. *Zeitschrift Für Pädagogische Psychologie*, *22*(1), 59–71.

Stürmer, K., Könings, K. D., & Seidel, T. (2013). Declarative knowledge and professional vision in teacher education: Effect of courses in teaching and learning. *British Journal of Educational Psychology*, *83*(3), 467–483.

Südkamp, A., Kaiser, J., & Möller, J. (2012). Accuracy of teachers' judgments of students' academic achievement: A meta-analysis. *Journal of Educational Psychology*, *104*(3), 743–762.

Südkamp, A., Möller, J., & Pohlmann, B. (2008). Der Simulierte Klassenraum. *Zeitschrift Für Pädagogische Psychologie*, *22*(3), 261–276.

Sweller, J. (2010). Cognitive load theory: Recent Theoretical Advances. In J. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive Load Theory* (pp. 29–47). New York: Cambridge University Press.

Sweller, J., Van Merriënboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*(3), 251–296.

Tanner, C. A. (2006). Thinking like a nurse: a research-based model of clinical judgment in nursing. *The Journal of Nursing Education*, *45*(6), 204–211.

Taylor, C. (1997). Problem solving in clinical nursing practice. *Journal of Advanced Nursing*, *26*(2), 329–336.

Thompson, C., & Dowding, D. (2001). Responding to uncertainty in nursing practice. *International Journal of Nursing Studies*, *38*(5), 609–615.

Timmermans, S., & Mauck, A. (2005). The Promises And Pitfalls Of Evidence-Based Medicine. *Health Affairs*, *24*(1), 18–28.

Timmers, C. F., Braber-van den Broek, J., & van den Berg, S. M. (2013). Motivational beliefs, student effort, and feedback behaviour in computer-based formative assessment. *Computers & Education*, *60*(1), 25–31.

Tsovaltzi, D., McLaren, B. M., Melis, E., & Meyer, A. (2012). Erroneous examples: effects on learning fractions in a web–based setting. *International Journal of Technology Enhanced Learning*, *4*(3), 191–230.

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. *Science*, *185*(4157), 1124–1131.

Van De Wiel, M., Boshuizen, H. P. A., & Schmidt, H. G. (2000). Knowledge restructuring in expertise development: Evidence from pathophysiological representations of clinical cases by students and physicians. *European Journal of Cognitive Psychology*, *12*(3), 323–355.

Van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, *24*(2), 244–276.

Van Gog, T., Paas, F., & Sweller, J. (2010). Cognitive load theory: Advances in research on worked examples, animations, and cognitive load measurement. *Educational Psychology Review*, *22*(4), 375–378. doi:10.1007/s10648-010-9145-4

Van Gog, T., Paas, F., & van Merriënboer, J. J. G. (2008). Effects of studying sequences of process-oriented and product-oriented worked examples on troubleshooting transfer efficiency. *Learning and Instruction*, *18*(3), 211–222.

Van Gog, T., Paas, F., & Van Merriënboer, J. J. G. (2004). Process-Oriented Worked Examples: Improving Transfer Performance through Enhanced Understanding. *Instructional Science: An International Journal of Learning and Cognition*, *32*(1), 83–98.

Van Gog, T., & Rummel, N. (2010). Example-based learning: Integrating cognitive and social-cognitive research perspectives. *Educational Psychology Review*, *22*(2), 155–174.

Van Merriënboer, J. J. G. (2013). Perspectives on problem solving and instruction. *Computers & Education*, *64*, 153–160.

Van Merriënboer, J. J. G., & Sweller, J. (2010). Cognitive load theory in health professional education: design principles and strategies. *Medical Education*, *44*(1), 85–93.

Van Merriënboer, J. J. G. van, & Kirschner, P. A. (2013). *Ten Steps to Complex Learning: A Systematic Approach to Four-component Instructional Design*. Routledge.

VanLehn, K. (1996). Cognitive Skill Acquisition. *Annual Review of Psychology*, *47*(1), 513–539.

VanLehn, K. (1999). Rule-learning events in the acquisition of a complex skill: An evaluation of cascade. *Journal of the Learning Sciences*, *8*(1), 71–125.

VanLehn, K., Siler, S., Murray, C., Yamauchi, T., & Baggett, W. B. (2003). Why Do Only Some Events Cause Learning during Human Tutoring? *Cognition and Instruction*, *21*(3), 209–249.

Veenman, M. V. J., Hout-Wolters, B. H. A. M. V., & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition and Learning*, *1*(1), 3–14.

Vogt, F., & Rogalla, M. (2009). Developing Adaptive Teaching Competency through coaching. *Teaching and Teacher Education*, *25*(8), 1051–1060.

Webb, N. M., & Mastergeorge, A. (2003). Promoting effective helping behavior in peer-directed groups. *International Journal of Educational Research*, *39*(1–2), 73–97.

Wecker, C., Rachel, A., Heran-Dörr, E., Waltner, C., Wiesner, H., & Fischer, F. (2013). Presenting theoretical ideas prior to inquiry activities fosters theory-level knowledge. *Journal of Research in Science Teaching*, *50*(10), 1180–1206.

Wisniewski, E. J., & Medin, D. L. (1994). On the Interaction of Theory and Data in Concept Learning. *Cognitive Science*, *18*(2), 221–281.

Wittwer, J., & Renkl, A. (2008). Why Instructional Explanations Often Do Not Work: A Framework for Understanding the Effectiveness of Instructional Explanations. *Educational Psychologist*, *43*(1), 49–64.

Wittwer, J., & Renkl, A. (2010). How Effective are Instructional Explanations in Example-Based Learning? A Meta-Analytic Review. *Educational Psychology Review, 40*(4), 393-409.

Wood, D., Bruner, J. S., & Ross, G. (1976). The Role of Tutoring in Problem Solving*. *Journal of Child Psychology and Psychiatry*, *17*(2), 89–100.

Woods, N. N. (2007). Science is fundamental: the role of biomedical knowledge in clinical reasoning. *Medical Education*, *41*(12), 1173–1177.

Zottmann, J. M., Goeze, A., Frank, C., Zentner, U., Fischer, F., & Schrader, J. (2012). Fostering the Analytical Competency of Pre-Service Teachers in a Computer-Supported Case-Based Learning Environment: A Matter of Perspective? *Interactive Learning Environments*, *20*(6), 513–532.

Tables

Figures

Appendix

A. Example Case Medicine

Medicine
Situation 1: Im Rahmen Ihrer Tätigkeit als Assistenzarzt kommen Sie in der Ambulanz als nächstes zu Herrn Kultau, einem 43-jährigen Patienten, der angibt sich seit einer Erkältung vor 5 Wochen müde und erschöpft zufühlen. Er bekäme Atemnot schon nach dem Steigen von ca. 10 Stufen. Manchmal könne er nachts nicht schlafen, weshalb er 2 Kissen bräuchte. Eine Anginasymptomatik verneint er genauso wie weitere Vorerkrankungen bzw. eine regelmäßige Medikation. Während des gesamten Gesprächs hustet Herr Kultau mehrmals. Herr Kultau ist Raucher (10 packyears), nachlässig gekleidet, leicht übergewichtig, sportlich inaktiv und lebt in Scheidung, er berichtet, dass seine Frau und Tochter gerade ausgezogen seien. Beruflich arbeitet er im Vertrieb und nach der Arbeit träfe er sich am liebsten mit ein paar Freunden zum Bier und Fernsehen.
Error of fictitious student 1: Sie sind genervt. Es wundert Sie wenig, dass so eine Type keine Luft bekommt: "Soll er doch erst einmal weniger Rauchen, Sport treiben, abnehmen und sich die Nächte nicht mehr um die Ohren schlagen. Waschen könnte er sich auch einmal", denken Sie insgeheim bei sich. Sie wollen Herrn Kultau bezüglich seines Lebensstils beraten und sich abschließend von ihm verabschieden.
Feedback 1: *Level 1:* Nun, richtig, seine Patienten kann man sich leider nicht aussuchen. Aber gerade bei Patienten, die Ihnen auf den ersten Blick nicht so angenehm erscheinen oder die ihre Sprache nicht so beherrschen, *sollten* Sie sich Zeit nehmen und auch die Symptomatik gebührend ernst nehmen. *Level 2:* Mit einer Häufigkeit von 6 bis 27 % stellt Dyspnoe ein häufiges und ernst zu nehmendes Symptom im ärztlichen Behandlungsalltag dar. Eine Dyspnoe bedarf immer einer Klärung, wobei nicht nur somatische Ursachen sondern auch psychische Hintergründe von Bedeutung sein können. Allgemein gilt, dass Luftnot ein subjektives Syndrom darstellt, welches von jedem Menschen unterschiedlich empfunden wird. Das Ausmaß der

subjektiven Beeinträchtigung ist u.a. abhängig vom Trainings- und Ernährungszustand, psychischen und sozialen Faktoren oder der Einnahme von Medikamenten, beispielsweise Opiaten und Sedativa.

Level 3:
Dyspnoe wird eine als unangenehm empfundene, erschwerte Atemtätigkeit bezeichnet. Treten solche Beschwerden nur unter Belastung auf, handelt es sich um eine Belastungsdyspnoe. Wird schon das Sprechen zur Belastung, handelt es sich um eine Sprechdyspnoe. Bei Atemnot bereits in Ruhe spricht man von einer Ruhedyspnoe, bei einer Orthopnoe hingegen kann die bestehende Ruhedyspnoe nur durch aufrechtes Sitzen und den Einsatz der Atemhilfsmuskulatur gebessert werden.
Atemnot wird im Gegensatz dazu als Luftmangel mit akuter Lebensbedrohung bezeichnet und erfordert als Zeichen eines abwendbar gefährlichen Verlaufes, wie akutes Herzversagen, lebensbedrohliche Arrythmien, Lungenembolien oder einem dissezierenden Aortenaneurysma, sofortige Notfallbehandlung.

Situation 2:

Sie bitten Herrn Kultau also, ihn noch untersuchen zu dürfen und stellen folgende Befunde fest:
- AZ akut reduziert
- RR 170/130mmHG rechts, 173/126mmHG links, P 90/min, Größe 1,84m, Gewicht 95kg
- Cor rhythmisch, keine pathologischen Geräusche
- Pulmo mit leichter Spastik und basalen Rasselgeräuschen, Orthopnoe
- Abdomen unauffällig
- Diskrete Knöchelödeme bds.

Error of fictitious student 2:

Insgeheim fühlen Sie sich bestärkt darin, dass Sie ihn schon nach Hause entlassen wollten - geben die Befunde doch nicht viel Neues her und zu einem Raucher passt schließlich auch die Spastik und die Atemnot. Sie veranlassen zur Sicherheit noch ein Röntgenbild der Lunge und planen bereits die Einleitung einer bronchodilatatorischen Therapie.

Feedback 2:

Level 1:
Sie haben durchaus richtige Teilbefunde erhoben und auch richtige Konsequenzen gezogen. Beachten Sie aber auch die Knöchelödeme, die Blutdruckwerte und die Orthopnoe und bedenken Sie andere Ursachen der Atemnot.

Level 2:
Raucher haben fast immer eine Dyspnoe, aber nicht jeder Dyspnoepatient ist Raucher, ebenso wenig wie alles Gold ist, was glänzt! Deshalb sollten Sie auch bei unauffälligem Untersuchungsbefund stets die Ursache der Dyspnoe weiter abklären.
Bei den meisten Lungenerkrankungen ist Luftnot neben Husten das erste Symptom, das den Patienten zum Arzt führt, wie beispielsweise Asthma bronchiale, COPD oder die Lungenfibrose. Bei bösartigen Erkrankungen ist Luftnot fast immer ein Spätsymptom. Bei

Herzerkrankungen hingegen ist Luftnot bei Belastungen häufig ein Frühsymptom, bei einer Depression kann diese in jedem Stadium auftreten. Sie sehen, eine Dyspnoe abzuklären ist von großer medizinischer Bedeutung sowohl für die Diagnose als auch für den Krankheitsverlauf, darauf sollten sie stets achten.

Level 3:
Die vier häufigsten Ursachen für Luftnot sind:

- Asthma bronchiale
- Chronisch obstruktive Lungen-erkrankungen,
- Lungengerüsterkrankungen (Lungenfibrose u.ä.),
- Herzinsuffizienz.

Asthma ist mit einer Prävalenz von 5% bei Erwachsenen eine häufige chronische Erkrankung, obstruktive Lungenerkrankungen sind in Deutschland für 25 Millionen Arbeitsunfähigkeitstage und 2,7 Millionen Krankenhaustage pro Jahr mit Kosten von ca. 6 Milliarden Euro verantwortlich und die Prävalenz der Herzinsuffizienz beträgt in westlichen Industrienationen 2%, wobei die 1-Jahres Mortalität nach Diagnosestellung im NYHA Stadium II und III unter Medikation bei 9-12% liegt. Herzinsuffizienz gehört in Deutschland zu den häufigsten Diagnosen bei vollstationären Patienten. Während bei Männern diese Diagnose im Jahr 2007 an dritter Stelle stand, ist sie bei Frauen im gleichen Jahr die häufigste Diagnose gewesen. Die Herzinsuffizienz gehört in Deutschland zu den häufigsten Todesursachen. Während sie bei den Männern im Jahr 2007 die vierthäufigste Todesursache war, rangiert sie bei den Frauen an zweiter Stelle der Todesursachen.

Situation 3:

Radiologisch zeigt sich ein deutlich über die Norm vergrößertes und mitralkonfiguriertes Herz ohne Infiltrate, leichte Stauungszeichen, die Randwinkel sind frei. Sie sind nun doch etwas erschrocken, dass die Dyspnoe wohl doch schwerwiegendere Ursachen hat. Sie beginnen mit einer Sauerstofftherapie und besprechen mit Herrn Kultau, der sehr erleichtert wirkt, ernst genommen zu werden, die stationäre Aufnahme. Sie veranlassen weiterhin:

- Labor (Blutbild, CRP, Gamma-GT, GPT, Harnsäure, Kreatinin, TSH, Cholesterin, HDL-Cholesterin, LDL-Cholesterin, Natrium, Kalium, Quick, PTT, BNP, Troponin, Glukose, Serumalbumin)
- Urinstix
- Sauerstoffsättigung
- EKG
- Farbdopplerechokardiographie
- Langzeit-EKG
- Lungenfunktionsprüfung

Im EKG finden Sie einen Linkstyp, Sinusrhythmus, normale Zeitintervalle und unspezifische Endteilveränderungen, im Labor sind lediglich die Leberwerte und das BNP mäßig erhöht. Die Echokardiographie des linken Ventrikels zeigt eine globale Hypokinesie mit hochgradiger Einschränkung der systolischen Funktion; Dilatation auf 68/59mm; Stauungszeichen; kein Erguss. Allenfalls geringe Zeichen einer bis vor die Spitze des Mitralsegels reichenden Aorteninsuffizienz; die Lungenfunktionsprüfung zeigt normale

Volumina ohne Hinweise einer obstruktiven oder restriktiven Ventilationsstörung, die Sauerstoffsättigung ist unauffällig. Das LZ-EKG ist im Wesentlichen unauffällig, die Blutdruckwerte wiederholt zu hoch.

Error of fictitious student 3:

Sie sind etwas ratlos. Weder das EKG, das LZ- EKG noch das Labor zeigen klare Hinweise einer Herzerkrankung bei Herrn Kultau und passen nicht zum Befund des Echos, weshalb Sie von Ihrer Arbeitshypothese Herzinsuffizienz Abstand nehmen.

Feedback 3:

Level 1:
Sie haben die richtigen Befunde erhoben, aber diese nicht ganz richtig interpretiert. Denn auch hier gilt: Im Wesentlichen wird eine Herzinsuffizienz durch Anamnese und das körperliche Untersuchungsbefund verifiziert, technische Untersuchungen können lediglich zusätzliche Informationen erbringen. Im Umkehrschluss führen aber andererseits herzspezifisch-apparative Befunde nicht zum Befund einer Herzinsuffizienz, wenn Klinik und Anamnese nicht übereinstimmen.

Level 2:
Klinisch treten bei einer Herzinsuffizienz oft die unspezifischen Symptome Dyspnoe, Müdigkeit und Flüssigkeitsretention neben pulmonalen Rasselgeräuschen, die nach Husten persistieren, oder Tachykardien über 90-100/min auf. Darum sollten Sie speziell auf zuverlässigere klinische Zeichen, wie ein erhöhter Jugularvenendruck, ein verlagerter Herzspitzenstoß oder einen vorhandenen dritten Herzton achten. Denken Sie auch stets daran, dass ein normales EKG zwar eine Herzinsuffizienz weitgehend ausschließt, meistens finden sich aber unspezifische Veränderungen, wie:

- Rhythmusstörungen (Bradykardie/ Tachykardie/ Extrasystolie/Vorhofflimmern);
- Erregungsleitungsstörungen (Schenkelblock, AV-Blockierungen);
- Herzhypertrophie oder Schädigungszeichen (Sokolow-Index, Q-Zacken, ST-T-Alterationen);
- Infarktzeichen.

Ebenso können im Labor allenfalls unspezifische Veränderungen vorkommen. Von der DEGAM wird explizit darauf hingewiesen, dass in der hausärztlichen Praxis die routinemäßige Bestimmung des BNPs nicht empfohlen wird, pathologische Spiegel sind nicht beweisend für eine Herzinsuffizienz.

Level 3:
Bei der Herzinsuffizienz ist das Herz nicht mehr in der Lage den Organismus mit ausreichend Blut und damit mit genügend Sauerstoff zu versorgen, um den Stoffwechsel unter Ruhe- wie unter Belastungsbedingungen zu gewährleisten. Die **Diagnosesicherung** bei dem **klinischen Verdacht einer Herzinsuffizienz** erfolgt über die **Echokardiographie**. Hiermit kann eine Aussage über Ursache, Art und Ausmaß des Syndroms und die genaue Diagnose getroffen werden, die konsekutiv zur Einleitung der Kausaltherapie, bzw. zur Indikation einer nachfolgenden invasiven Diagnostik führen kann. Die Echokardiographie ist nicht invasiv, verursacht keine Strahlenbelastung und ist

relativ breit verfügbar.
Sie sollte folgende Aspekte beinhalten:

- Beurteilung der linksventrikulären systolischen Funktion inklusive möglicher regionaler Wandbewegungsstörungen;
- Beurteilung der diastolischen Funktion;
- Bestimmung der linksventrikulären Wandstärke;
- dopplergestützte Untersuchung auf signifikante Vitien;
- nach Möglichkeit Schätzung des pulmonalarteriellen Drucks;
- Nachweis oder Ausschluss intrakardialer Thromben.

Situation 4:

Aufgrund des ausgeprägten echokardiographischen Befundes stellen Sie Herrn Kultau bei den kardiologischen Kollegen vor, die nach Zusammenfassung aller Befunde eine Herzinsuffizienz NYHA II-III auf dem Boden einer stattgehabten Myokarditis bzw. einer hypertensiven Herzerkrankung diskutieren. Auch eine dilatative Kardiomyopathie steht als Diagnose noch im Raum.
Nach Stabilisierung seines Zustandes wird Herrn Kultau eine Koronarangiographie zum Ausschluss einer KHK empfohlen, ggf. eine Biopsie.

Error of fictitious student 4:

Therapeutisch leiten Sie neben körperlicher Schonung eine Medikation für die Herzinsuffizienz ein. Mit einem ACE-Hemmer, Beta-Rezeptorenblocker und Diuretika handeln Se gemäß dem Herzinsuffizienzschema. Eine Stunde später werden Sie notfallmäßig angepiepst, da Herr Kultau kollabiert sei. Sie eilen hinzu und finden den Patienten kaltschweißig auf dem Boden liegend, die Pflegeperson misst gerade Blutdruck und Puls: RR 80/60mmHg, P 110/min.

Feedback 4:

Level 1:
Richtig ist der medikamentöse Beginn der Herzinsuffizienztherapie gemäß Schema. Wichtig ist bei Erstgabe gerade von ACE Hemmern, als Monosubstanz oder in Kombination, die Kreislaufüberwachung der Patienten in den ersten Stunden.

Level 2:
Alle symptomatischen sowie asymptomatischen Patienten mit einer nachgewiesenen systolischen Dysfunktion (EF< 35 %-40 %) und fehlenden Kontraindikationen sollen ACE-Hemmer erhalten. Dabei sollte bis zur höchsten in Studien ermittelten Zieldosis oder, falls diese nicht erreicht werden kann, bis zur maximal tolerierten Dosis schrittweise gesteigert werden.
Bei trockenem Husten sollte der ACE-Hemmer abgesetzt bzw. gegen ein anderes Medikament entsprechend der Indikation ausgetauscht werden. Unter der Therapie mit ACE-Hemmern kann es allerdings auch Bradykinin unabhängig zu einer Hypotonie, d. h. zu einer zu starken Blutdrucksenkung kommen. In Folge dessen können gelegentlich Schwindel, Kopfschmerz und Benommenheit beobachtet werden. Dieser Nebenwirkung, die bevorzugt bei Patienten mit Herzinsuffizienz auftritt, können Sie mit

Vorsichtsmaßnahmen vorbeugen: bei Flüssigkeitsmangel zuerst Flüssigkeitsgabe, dann mit der Einnahme von ACE-Hemmern beginnen, und zwar bei Herzinsuffizienzpatienten mit einer geringen Startdosierung unter Kreislaufüberwachung, dann langsame Dosissteigerung.

Level 3:
Die wichtigsten Nebenwirkungen von ACE -Hemmern sind
- trockener Husten,
- Hypotonie,
- akutes Nierenversagen und
- Hyperkaliämie
- angioneurotischen Ödem

Die meisten Nebenwirkungen werden mit einem verlangsamten Abbau und Anreicherung von Bradykinin durch ACE-Hemmer in Verbindung gebracht.
Die medikamentöse Therapie der Herzinsuffizienz ist sehr komplex, grob zusammengefasst lässt sich folgende Einteilung aufstellen:

NYHA 1	ACE-Hemmer, Betablocker
NYHA 2	ACE-Hemmer, Betablocker, Diuretika, ggf. orale Antikoagulation
NYHA 3-4	ACE-Hemmer, Betablocker, Diuretika, ggf. orale Antikoagulation, Spironolacton, Digitalis

Eine gesicherte prognostische Indikation heißt, dass die dauerhafte Gabe eines Medikamentes gemäß Studienlage einen eindeutig lebensverlängernden Effekt besitzen. Bei der chronischen Herzinsuffizienz sind dies:
- ACE-Hemmer/AT1-Antagonisten in allen Stadien,
- Beta-Rezeptorenblocker ab NYHA II,
- Aldosteronantagonisten ab NYHA III.

Bei Gabe von Aldosteronantagonisten sollte die Hyperkalämie als Nebenwirkung beachtet werden, da sie unter Alltagsbedingungen eine erhebliche Einschränkung der Therapiesicherheit darstellen kann.

Outlook:

Herr Kultau erholt sich glücklicherweise schnell von seinem Kreislaufkollaps und sie dosieren nun die Medikamente entsprechend einschleichender. Die Biopsie erbrachte den Nachweis einer stattgehabten Myokarditis, eine KHK konnte koronarangiographisch ausgeschlossen werden. Nun gilt es noch die nicht-medikamentöse Therapie zu managen: Herr Kultau sollte
- Aufhören zu Rauchen
- Gewicht abnehmen
- Sich regelmäßig körperlich betätigen (Koronarsport)
- Zu gegebener Zeit langsame Wieder-Teileingliederung ins Berufsleben
- Regelmäßige Gewichts- bzw. Blutdruckkontrollen/Flüssigkeitsrestriktion
- Hausärztliche Einbindung zur Überprüfung kardialer Parameter
- Soziale Wiedereingliederung gerade jetzt, während der Scheidungsphase

All diese Punkte besprechen Sie mit dem Patienten, der Sozial- und Pflegeabteilung des Krankenhauses, der Krankenkasse und dem Hausarzt. Sie wissen, ohne Herrn Kultaus

Eigeninitiative und Motivation ist ihr Plan zum Scheitern verurteilt. Sie einigen sich deshalb zusammen auf eine stationäre Rehabilitation, bei der Herr Kultau medizinisch überwacht und bezüglich der Lebensstilmodifikation beratend beigestanden werden soll. Außerdem ist geplant, dass er danach erst einmal zu seiner Schwester ziehen soll, bis er sich eine neue Wohnung gesucht hat und mit seiner Familie konnten Sie erreichen, dass seine Tochter ihn vorerst regelmäßig besuchen darf.
Sie für sich lernen daraus, einen Patienten und seine Symptome nie zu unterschätzen, auch wenn anfangs alles ganz banal aussieht.

B. Test for Declarative-Conceptual Knowledge in Medicine

1. Herr Haberland sackt zuhause im Bad zusammen. Die Ehefrau beobachtet, wie er nach einigen Sekunden das Bewusstsein wieder erlangt und ruft den Notarzt. Der Patient kann sich an den Vorfall nicht erinnern. Der Notarzt misst einen Blutzucker von 6,1 mmol/l, ein Zungenbiss ist nicht nachweisbar. Auf der Fahrt in die Klinik ist Herr Haberland wach, orientiert, kreislaufstabil und hat keine körperlichen Einschränkungen.
Welche der folgenden Verdachtsdiagnosen ist/sind am ehesten zutreffend?

- ☐ Transiente ischämische Attacke
- ☐ Hypoglykäme Stoffwechselentgleisung
- ☐ Einfach fokaler Krampfanfall
- ☐ Rhythmogene Synkope

2. Ein 90-jähriger Patient wird nach Synkope in der Notambulanz vorgestellt. Im EKG zeigt sich ein regelmäßiger Rhythmus mit 24 Schlägen/min mit QRS-Verbreiterung. Pro Minute sind außerdem 80 P-Wellen zu erkennen.
Welche Interpretation/en ist/sind sinnvoll?

- ☐ Sinusbradykardie
- ☐ drittgradiger Sinoatrial-Block
- ☐ zweitgradiger Atrioventrikular-Block vom Typ Mobitz
- ☐ drittgradiger Atrioventrikular-Block

3. Ein 65 jähriger Patient berichtet über eine kurze Bewusstlosigkeit, die auftrat, als er beim Einparken nach hinten über die Schulter blickte. Die Bewusstlosigkeit dauerte nur wenige Sekunden, danach war er sofort wieder voll orientiert. Er ist bis auf eine gut eingestellte arterielle Hypertonie gesund. Welche/r diagnostische/n Schritt/e führt/en zur wahrscheinlichsten Diagnose?

- ☐ 24-Stunden-Blutdruckmessung
- ☐ Eine Koronarangiographie
- ☐ Ein Carotis-Druck-Versuch
- ☐ Ein Echokardiogramm

4. Eine 60-jährige Patientin wird vom Rettungsdienst wegen eines plötzlichen, etwa fünfminütigen Bewusstseinsverlustes in die Notfallambulanz gebracht. Bei Ankunft ist die Patientin wach, ansprechbar und voll orientiert. Welche Erkrankung/en muss/müssen als Ursache der Synkope in Betracht gezogen werden?

- ☐ Aortendissektion
- ☐ Lungenarterienembolie
- ☐ Meningitis
- ☐ Fokale Epilepsie

5. Welche der folgenden Beschreibungen ist/sind am ehesten mit einer Herzinsuffizienz der Stufe III nach der Klassifikation der New York Heart Association (NYHA) vereinbar?

- ☐ Keine Beschwerden in Ruhe
- ☐ Luftnot beim Aufstehen aus sitzender Position
- ☐ Pectanginöse Symptome bei täglicher Gartenarbeit
- ☐ Verschnaufpause nach 2 Treppenstiegen

6. Welche Untersuchung/en eignet/eignen sich am ehesten zur genaueren Abklärung und Quantifizierung einer Herzinsuffizienz?

- ☐ Elektrokardiogramm
- ☐ Echokardiographie
- ☐ Röntgenthoraxaufnahme
- ☐ Positronenemissionstomographie

7. Wie tragen ACE-Hemmer zur Verbesserung der Symptome bei Herzinsuffizienz bei?

- ☐ ACE-Hemmer verursachen eine Vasodilatation durch direkte NO-Freisetzung
- ☐ ACE-Hemmer bewirken eine Verbesserung der diastolischen Relaxation
- ☐ Nach ACE-Hemmung kommt es zu einem Anstieg des Angiotensin I
- ☐ ACE-Hemmer führen zu einer Abnahme des Bradykininspiegels

8. Welche/r der folgenden pathologischen Befunde kann/können typischerweise durch Einnahme von ACE-Hemmern hervorgerufen werden?

- ☐ Hyperkalzämie
- ☐ Hypophosphatämie
- ☐ Hypernatriämie
- ☐ Hypokaliämie

9.	Welche/s Medikament/e soll/en im Herzinsuffizienzstadium NYHA II nach der Klassifikation der New York Heart Association gegeben werden ☐ Spironolacton ☐ ACE-Inhibitoren ☐ ß-Adrenozeptorenblocker ☐ Furosemid
10.	Ein 65 jähriger Patient kommt zur Neueinstellung einer manifesten Herzinsuffizienz (NYHA III) in Ihre Praxis. Welche/s der folgenden Medikamente ist/sind in diesem Falle am ehesten zur Entlastungstherapie indiziert? ☐ Digitalis ☐ Diuretika ☐ Katecholamine ☐ ACE-Hemmer
11.	Welche/s klinische/n Symptom/e einer solitären, abnehmenden linksseitigen Kontraktilität des Myokards ist/sind korrekt? ☐ Tachykardie ☐ Nykturie ☐ Periphere Ödeme ☐ Belastungsdyspnoe
12.	Bei Patienten mit symptomatischer Herzinsuffizienz bewirkt die Therapie mit Digitalisglykosiden: ☐ Eine symptomatische Besserung ☐ Eine Verbesserung der Hämodynamik ☐ Eine Senkung der Herzfrequenz ☐ Eine Senkung der Mortalität
13.	Die therapeutische Wirkung von ACE-Hemmern bei schwerer Herzinsuffizienz beruht auf welche/n der folgenden Effekte? ☐ Abnahme der Nachlast ☐ Abnahme der Vorlast ☐ Verbesserung der Überlebensrate ☐ Verbesserung der Lebensqualität

14. Ein 68 jähriger Patient leidet seit 15 Tagen unter zunehmender Dyspnoe. Vorerkrankungen: langjährige arterielle Hypertonie und Zigarettenabusus. Untersuchungsbefund: Deutliche Fußrücken- und Unterschenkelödeme und vergrößerte Leber. Lunge: feuchte inspiratorische Rasselgeräusche beidseits. Blutdruck 164/92 mmHg; Labor: Serumelektrolyte und -lipide normal. Serumkreatinin 2,2 mg/dl.
Welches ist die wahrscheinlichste Diagnose?

- ☐ Akutes Nierenversagen
- ☐ Dekompensierte Herzinsuffizienz
- ☐ Hochgradige Nierenarterienstenose
- ☐ Nephritisches Syndrom

15. Bei welcher/welchen der folgenden Krankheiten sind beta-Adrenozeptorantagonisten primär Bestandteil des Therapiekonzeptes?

- ☐ Glaukom
- ☐ Migräne
- ☐ Diabetes mellitus
- ☐ Herzinsuffizienz

16. Der 76-jährige Herr Janssen stellt sich in Ihrer Praxis mit den typischen Symptomen eines Myokardinfarktes vor. Die Symptome bestehen seit etwa 30 Stunden.
Durch welches Ereignis ist Herr Janssen akut bedroht?

- ☐ Akute Perikarditis
- ☐ Vergrößerung des Infarktareals
- ☐ Akute Herzinsuffizienz
- ☐ Auftreten von Kammerflimmern

17. Welche/r Parameter eignet/eignen sich zur Beurteilung der Herzfunktion?

- ☐ Ejektionsfraktion des Herzens
- ☐ Pro-BNP im Verlauf
- ☐ Troponin I im Verlauf
- ☐ Wanddicke des linken Ventrikels

18. Welche/s der folgenden Symptome kann/können im Rahmen einer ausgeprägten Rechtsherzinsuffizienz auftreten?

- ☐ Hepatomegalie
- ☐ Gestaute Halsvenen
- ☐ Lungenödem
- ☐ Nykturie

19. Eine 40jährige Raucherin stellt sich mit plötzlichem Thoraxschmerz mit Husten und einem geschwollenen linken Bein in der Notaufnahme vor.
Welche Diagnose/n ist/sind am wahrscheinlichsten?

- ☐ Akute Herzinsuffizienz
- ☐ Lungenarterienembolie
- ☐ Embolie der Arteria femoralis communis
- ☐ Pneumothorax

20. Ein 55jähriger adipöser Patient wird mit Dyspnoe und Thoraxschmerzen, in die Notaufnahme eingeliefert. In leichterer Form sind diese Beschwerden in der Vergangenheit gelegentlich bei Belastungen schon aufgetreten.
Welche Diagnose/n ist/sind am wahrscheinlichsten?

- ☐ Dekompensierte Herzinsuffizienz
- ☐ Lungenarterienembolie
- ☐ Akutes Koronarsyndrom
- ☐ paroxysmales Vorhofflimmern

21. Eine 75-jährige Patientin klagt über geschwollene Beine bei bekannter Rechtsherzinsuffizienz.
Worauf sind diese Ödeme pathogenetisch zurückzuführen?

- ☐ Auf eine Verminderung des onkotischen Druckes
- ☐ Auf eine Verminderung des hydrostatischen Druckes im venösen System
- ☐ Auf Kapillarwandschädigungen
- ☐ Auf eine Erhöhung der Diffusion aus den kleinen Gefäßen

C. Test for Strategic Knowledge in Medicine

Pretest

Key Feature Task 1_1: Patient Ms. Weimer Frau Weimer, eine 76jährige Patientin, stellt sich mit seit Tagen progredienter Dyspnoe sowie Unterschenkelödemen beidseits in der Notaufnahme Ihres Krankenhauses vor. Die Dyspnoe tritt mittlerweile auch beim Gehen in der Wohnung auf. Sie verneint ein retrosternales Druckgefühl, jedoch habe sie beobachtet, dass ihr Körpergewicht seit Wochen langsam zunehme, obwohl sie nicht mehr Nahrung verzehre als sonst. Auf welchen Befund sollten Sie bei der körperlichen Untersuchung besonders achten?
Key Feature Task 1_2: Patient Ms. Weimer Bei der Untersuchung auskultieren Sie deutliche feuchte inspiratorische Rasselgeräusche v.a. in den basalen Lungenabschnitten auf beiden Seiten. Radiologisch zeigt sich eine deutliche pulmonal-venöse Stauung bei insbesondere linksventrikulärer Herzvergrößerung. Echokardiographisch kann eine linksventrikulär eingeschränkte Pumpfunktion nachgewiesen werden. Welches Diuretikum würden Sie verabreichen?
Key Feature Task 1_3: Patient Ms. Weimer Sie verabreichen Furosemid 40mg intravenös und nehmen die Patientin stationär auf. Welche weiteren Medikamente sollten im Rahmen des stationären Aufenthaltes zusätzlich gegeben werden?
Key Feature Task 2_1: Patient Ms. Wagner Als nächstes wird Ihnen in der Ambulanz eine 59-jährige Patientin, Frau Wagner, mit Luftnot zugewiesen, der es heute beim Einkaufen "schwarz vor Augen" wurde, woraufhin sie kollabierte und vom Notarzt ins Krankenhaus eingeliefert wurde. Die Verwaltungsangestellte gibt an, Tabletten für ihren hohen Blutdruck einzunehmen, weitere Vorerkrankungen verneint sie. Sie leiten zuerst eine Sauerstoffgabe und vorsichtige Infusionstherapie ein. Was führen Sie als nächstes durch?
Key Feature Task 2_2: Patient Ms. Wagner In der körperlichen Untersuchung finden Sie eine schlanke Patientin mit • RR 157/92 mmHG, Puls 92/min, Sauerstoffsättigung 95%, körperliche Temperatur 36,8°C

• Gestaute Jugularvenen • Cor mit 3. Herzton, verbreiteter Herzspitzenstoß • Pulmo mit basalen Rasselgeräuschen • Diskrete Knöchelödeme Als nächstes veranlassen Sie eine Laborabnahme. Welche Parameter bestimmen Sie?
Key Feature Task 2_3: Patient Ms. Wagner Im Labor finden Sie normale Werte für Blutglukose, GPT, Kreatinin, Natrium, Kalium, Blutbild und Urinstix. Welche drei diagnostischen Schritte planen Sie weiter?

Posttest: all pretest items and in addition the following items

Key Feature Task 3_1: Patient Ms. Lüders_ Im Nachtdienst werden Sie zur 74-jährigen Frau Lüders gerufen, welche mit ausgeprägter Dyspnoe im Bett sitzt. Sie hören bereits ohne Auskultation ein pulmonales Rasselgeräusch und es ist eine Lippen-zyanose auffällig. Bei der Auskultation sind über beiden Lungenflügeln feuchte Rasselgeräusche vorhanden. Über dem Herzen hören Sie ein 3/6 Systolikum mit P.m. über Erb mit Fortleitung in die Axilla. Zudem sind bds. deutliche Unterschenkelödeme vorhanden. Der Blutdruck ist 110/80 mmHg, und der Puls ist 104/Min. Welche Therapie würden Sie einleiten?
Key Feature Task 3_2: Patient Ms. Lüders Leider sehen Sie trotz Ihrer Akutmaßnahmen keinen schnellen Erfolg. Eine erhöhte Ausscheidung ist nicht ersichtlich, die Luftnot und die Zyanose nehmen weiter zu. Über welche Schritte müssen Sie sich nun Gedanken machen?
Key Feature Task 3_3: Patient Ms. Lüders Zusammen mit den Angehörigen haben Sie entschieden die Patientin auf die Intensivstation zu verlegen. Nachdem Sie für Frau Lüders auf der Intensivstation ein Bett reserviert haben, geben Sie der Bereichspflegeperson darüber Bescheid. Was gilt es bei der Verlegung zu beachten?

Key Feature Task 4_1: Patient Ms. Metz_
Als Assistenzarzt gelangen Sie auf Ihrer Visite als nächstes zu Frau Metz, einer 47-jährigen Büroangestellten, die am Vortag wegen zunehmender Schwäche, Herzklopfen und Dyspnoe beim Treppensteigen stationär aufgenommen wurde. Der Blutdruck war letztes Mal beim Hausarzt zu hoch gewesen, weshalb sie mit Diät und Bewegung ihren Lebensstil ändern wollte. Kardiale bzw. pulmonale Grunderkrankungen sind bisher ihr nicht bekannt. Nach Ihrer Anamneseerhebung vermuten Sie eine Herzinsuffizienz. Welche Differentialdiagnosen, die zum Symptom der Herzinsuffizienz führen, fallen Ihnen ein?
Key Feature Task 4_2: Patient Ms. Metz
Hauptsächlich kardiovaskuäre Ursachen führen zum Bild der Herzinsuffizienz. Deshalb führen Sie im nächsten Schritt die Untersuchung von Frau Metz durch. Die Blutdruckwerte liegen aktuell bei 145/90 re. Arm, 142/90 li Arm, Puls 108/min; Größe der Patientin 168cm, Gewicht 72 kg; Der AZ ist leicht reduziert, die Haut ist blass und warm, Cor tachykard ohne pathologische Geräusche, Pulmo frei; Zur Diagnosesicherung veranlassen Sie neben einem EKG, Röntgenthorax und Herzecho natürlich auch eine Blutabnahme. Welche Laborparameter lassen Sie in Folge bestimmen?
Key Feature Task 4_3: Patient Ms. Metz
Im Röntgenbild des Thorax zeigt sich ein normalkonfiguriertes Herz ohne pulmonal-venöse Stauungszeichen, keine Infiltrate oder Ergüsse. Auch im EKG und in der Echokardiographie lassen sich keine Auffälligkeiten nachweisen. Die Zusammenschaue Ihrer diagnostischen Ergebnisse, inklusive der Laborwerte CK/CK-MB, Trop I, Natrium, Kalium, Nüchtern-Blutzucker, Blutbild, GOT und Kreatinin, schließt ein kardiales bzw. pulmonales Geschehen als Ursache der Herzinsuffizienz weitgehend aus. Sie denken jetzt noch an weitere Möglichkeiten, die bei Frau Metz in Zusammenschau aller Befunde zu Ihrer Beschwerdesymptomatik geführt haben kann. Welche Untersuchungen veranlassen Sie deshalb noch?
Key Feature Task 5_1: Patient Ms. Meixner
Frau Meixner, eine 80-jährige Patientin mit einer langjährigen obstruktiven Lungenerkrankung klagt über zunehmende Abgeschlagenheit und Nykturie. Ihre bekannte Belastungsdyspnoe habe sich auch etwas verschlechtert seit ca. einer Woche. Bei der körperlichen Untersuchung fällt Ihnen eine vergrößerte Leber auf. Welche weiteren Untersuchungsbefunde erwarten Sie?
Key Feature Task 5_2: Patient Ms. Meixner
Bei der weiteren Untersuchung können Sie gestaute Halsvenen und mäßige Beinödeme

beidseits feststellen. An Lunge und Herz können Sie außer einem ubiquitär leisen Atemgeräusch bei dem bekannten Emphysem keine auffälligen Befunde erheben. Welche Verdachtsdiagnose stellen Sie?
Key Feature Task 5_3: Patient Ms. Meixner Im EKG zeigen sich keine Auffälligkeiten, im Labor fallen leicht erhöhte Transaminasen und eine erhöhte Gamma-GT auf. CK/CK-MB und Trop I sind unauffällig. Welche weitere Diagnostik führen Sie durch um mögliche Ursachen der Rechtsherzinsuffizienz abzuklären?
Key Feature Task 6_1: Patient Mr. Gmeiner Herr Gmeiner, ein 67-jähriger Patient kommt wegen Dyspnoe in die Notaufnahme und berichtet über einen heftigen stechenden Schmerz in der rechten Brust, zwei Stunden zuvor. Anschließend hätte der Schmerz nachgelassen. Jetzt hätte er den Eindruck, dass er schon bei leichter Belastung (Treppensteigen) schnell kurzatmig wird. Akut-Befunde: Sinusrhythmus, 95/min; RR:180/95; Troponin-T: negativ. Welche Verdachtsdiagnose ist die wahrscheinlichste?
Key Feature Task 6_2: Patient Mr. Gmeiner Sie untersuchen Herrn Gmeiner. Welche Befunde erwarten Sie bei der körperlichen Untersuchung?
Key Feature Task 6_3: Patient Mr. Gmeiner Bei der körperlichen Untersuchung fallen ein abgeschwächtes Atemgeräusch auf der rechten Seite und ein hypersonorer Klopfschall auf. Rasselgeräusche über der Lunge oder Herzgeräusche können Sie nicht feststellen. Welche technischen Untersuchungen sollten sofort durchgeführt werden? Bitte nennen Sie die zwei wichtigsten.

D. Test for Conditional Knowledge in Medicine

Pretest

Knowledge Decomposition Task 1_1: Mr. Michel Am Morgen beim Betreten Ihrer Station kommt Ihnen ganz aufgeregt Schwester Beate entgegen. Sie berichtet von Herrn Michel, einem 77-jährigen Neuzugang in der Nacht. Er kam mit zunehmender Luftnot, welche initial vom Notarzt etwas gelindert werden konnte. Nun ist sie wieder deutlich zunehmend. Schmerzen gebe er keine an. Im Aufnahmebogen lesen Sie, dass eine art. Hypertonie und ein Z.n. Myokardinfarkt bekannt sind. Beim Betreten des Patientenzimmers sehen Sie einen Patienten mit deutlicher Ruhedyspnoe und Zyanose. Eine Untersuchung in Rückenlage toleriert der Patient nicht, da der Patient das Gefühl zu ersticken hätte. Im Sitzen fallen Ihnen über den basalen und mittleren Lungenabschnitten feuchte Rasselgeräusche beidseits sowie ein Galopprhythmus auf. Der Blutdruck beträgt 170/100 mmHg, die Sauerstoffsättigung am Pulsoxymeter 87 % mit 2 l Sauerstoff per Nasensonde. Was ist die wahrscheinlichste Ursache der Dyspnoe?
Knowledge Decomposition Task 1_2: Mr. Michel Am Folgetag geht es Herrn Michel schon wieder etwas besser. Auf die sofortige Verabreichung eines Diuretikums hatte er gut ausgeschieden, die Dyspnoe besserte sich rasch und es kam bereits zu einer Gewichtsreduktion. Der Patient ist in Ruhe beschwerdefrei, geht jedoch noch in Begleitung der Pflegeperson zur Toilette, da die Luftnot bei leichter Belastung wieder zunimmt und er sich so sicherer fühle. Bei der erneuten körperlichen Untersuchung überdenken Sie Ihre Diagnose vom Vortag noch einmal. Welche Befunde oder Fakten sprachen initial bzw. sprechen aktuell für eine dekompensierte Linksherzinsuffizienz und gegen eine primäre pulmonale Ursache?
Knowledge Decomposition Task 1_3: Mr. Michel Bei der Oberarztvisite am nächsten Tag ist die Belastungsdyspnoe weiter rückläufig und der Patient wieder zunehmend belastbarer. Welche 4 häufigsten Ursachen für eine Ruhedyspnoe nicht kardialer Genese müssen Sie ausgeschlossen haben bzw. ausschließen?
Knowledge Decomposition Task 2_1: Mr. Vogel Herr Vogel, ein 65-jähriger Diabetiker mit einer Herzinsuffizienz wird mit ACE-Hemmer und einem beta-Blocker behandelt. Zusätzlich besteht eine eingeschränkte Nierenfunktion mit einem Kreatininwert von ca. 1,93 mg/dl. Zur Regulation seines Volumenstatus ist der Einsatz eines Diuretikums angezeigt. Der aktuelle Kaliumwert ist mit 5,7 mmol/l etwas

erhöht. Warum entscheiden Sie sich für die Gabe eines Schleifendiuretikums?
Knowledge Decomposition Task 2_2: Mr. Vogel Als Ursachen der Ödeme erscheinen Ihnen seine bekannte Niereninsuffizienz und die Herzinsuffizienz wahrscheinlich. Bitte erläutern Sie die pathophysiologischen Mechanismen die zu den Ödemen führen.
Knowledge Decomposition Task 2_3: Mr. Vogel Herr Vogel bekommt von Ihnen Furosemid 40mg i.v. verabreicht, woraufhin er gut ausscheidet und der Kaliumwert in der kurzfristigen Kontrolle auf 4,5mmol/l sinkt. Sie veranlassen eine Echokardiographie und die Durchführung von einem 24-h-Sammelurin. Begründen Sie Ihre Entscheidung.

Posttest: all pretest items and in addition the following items

Knowledge Decomposition Task 3_1: Mr. Strack Sie sind als Internist in einem Medizinischen Versorgungszentrum (MVZ) tätig. Zu Ihren Patienten gehört der 59-jährige KFZ-Mechaniker Willi Strack, den Sie jedoch nur selten in Ihrer Praxis sehen. Heute kommt Herr Strack zu Ihnen, da er endlich etwas gegen seinen ständigen Husten unternehmen möchte. Seit letztem Jahr werde es immer schlimmer, bei jeder Anstrengung bleibe ihm die Luft weg, und es komme zu regelrechten Hustenattacken. Die tägliche Arbeit in der Werkstatt falle ihm immer schwerer. Aus Ihren Unterlagen entnehmen Sie, dass Herr Strack schon vor 15 Jahren angab, täglich 2 Päckchen Zigaretten zu rauchen, und Sie erfahren, dass sich seither daran nichts geändert hat. Sie vermuten eine dekompensierte Linksherzinsuffizienz. Bitte erläutern Sie die pathophysiologischen Mechanismen, die bei dieser Verdachtsdiagnose die Symptome erklären.
Knowledge Decomposition Task 3_2: Mr. Strack Angesichts der Anamnese denken Sie sich, dass es am ehesten mit dem Nikotinkonsum zu tun und Herr Strack wahrscheinlich zusätzlich eine chronische Bronchitis hat. Bei der körperlichen Untersuchung hören Sie inspiratorisch feinblasige Rasselgeräusche beidseits vor allem basal. Die Vitalparameter sind: RR 167/98mmHg, Puls 98/min, arrhythmisch, AF 24/min, afebril. Passen diese Befunde zu Ihrer Arbeitsdiagnose? Bitte begründen Sie Ihre Antwort.

Knowledge Decomposition Task 3_3: Mr. Strack Neben einer Blutentnahme führen Sie ein EKG und eine Röntgenaufnahme des Thorax durch. Bitte begründen Sie Ihre Anforderungen.
Knowledge Decomposition Task 4_1: Mr. Block Als nächstes kommen Sie auf Ihrer Visite zu Herrn Block, einem 80-jährigen Patienten mit bekannter Herzinsuffizienz. Er klagt: "Früher konnte ich ja wenigstens noch ohne Probleme gehen und hatte nur beim Treppensteigen diese Atemnot und Herzklopfen. Aber jetzt, in letzter Zeit, macht mir schon das Laufen draußen und in der Wohnung Probleme und das Tragen von Einkaufstaschen geht gar nicht mehr. Sofort wird mir schwindelig und ich kriege keine Luft mehr. Ich denke, ich sterbe jeden Augenblick!" Sie erkennen sofort, dass Herr Block sehr beunruhigtist. Der aufgeschlossene Patient lebt alleine, aus seiner medizinischen Vorgeschichte ist eine seit ca. zwei Jahren bekannte, kardiologisch abgeklärte Herzinsuffizienzund einearterielle Hypertonie bekannt. Eine Schilddrüsenerkrankung liegt nicht vor. Warum ist die Frage nach einer Schilddrüsenerkrankung sinnvoll?
Knowledge Decomposition Task 4_2: Mr. Block Sie erklären Herrn Block, dass eine körperliche Untersuchung zur Abschätzung der Diagnostik- und Therapieindikation seines anamnestischen NYHA III Stadiums notwendig sei, woraufhin er einwilligt. Bei der Untersuchung finden sich u.a. • RR 155/90mmHg, Puls 96/min • ausgeprägte Knöchelödeme beidseits • gestaute Jugularvenen • 3. Herzton/verlagerter Herzspitzenstoß • basale pulmonale Rasselgeräusche Auf Nachfrage erklärt Herr Block, auch an Gewicht zugenommen zu haben. Die Medikamente, die er gemäß seines Herzinsuffizienzstadiums erhielt, hätte er regelmäßig eingenommen. Zeichen einer Schilddrüsenerkrankung finden sich nicht, auch haben Sie nicht den Eindruck, dass es sich um eine akute Herzischämie handelt. Als nächsten Schritt planen Sie somit eine weiterführende Diagnostik mit Labor (Blutglukose, Blutbild, GPT, Natrium, Kalium, BNP, CK, CK-MB, Troponin I, TSH, Kreatinin und Urinstix) und EKG. Warum ist die Durchführung eines EKGs sinnvoll?
Knowledge Decomposition Task 4_3: Mr. Block Da im EKG der Sokolow-Lyon Index mit S in V1 + R in V5 >3,5mV erhöht war, das

Labor weitgehend normal, finden Sie außerdem in der Echokardiographie typische Zeichen einer fortgeschrittenen systolischen Herzinsuffizienz, die sich seit der letzten Untersuchung so verschlechtert hätte, dass die Medikation des Patienten entsprechend der neuen Ausgangssituation angepasst bzw. gesteigert werden muss. Außerdem erklären Sie Herrn Block Basisverhaltensweisen, u.a. sich täglich zu wiegen. Warum ist das tägliche Gewichtsmanagement sinnvoll?
Knowledge Decomposition Task 5_1: Mr. Klade Als nächstes werden Sie zu Herrn Klade gerufen, einem 92-jährigen Pflegeheimbewohner, der wegen akut zunehmender Atemnot und geschwollenen Beinen notfallmäßig eingeliefert wurde. Anamnestisch erfahren Sie, dass bereits geringe körperliche Belastung zu Atemnot führte. In der Vorgeschichte sind bekannt: mit Tabletten eingestellter Diabetes mellitus Typ2, arterielle Hypertonie, Herzinsuffizienz NYHA II, Hyperurikämie, Hyperlipidämie und zunehmende Schwäche. Nach Gabe von Sauerstoff beginnen Sie mit der körperlichen Untersuchung: ● RR 142/84mmHg, Puls 80/min, Körpertemperatur 37,6°C ● Pulmo mit basalen Rasselgeräuschen ● Herztöne arrhythmisch, 3. Herzton ● Knöchelödeme ● Gestaute Jugularvenen ● Blasse Schleimhäute Warum ist die Untersuchung der Schleimhäute hier sinnvoll?
Knowledge Decomposition Task 5_2: Mr. Klade Um die Anämie abzusichern führen Sie eine Laboruntersuchung mit den Parametern Blutbild, Ferritin, Glukose, Kreatinin, GPT, Natrium, Kalium, Urinstix. Warum bestimmen sie das Ferritin?
Knowledge Decomposition Task 5_3: Mr. Klade Im Labor finden Sie bei Herrn Klade ein erniedrigtes HB, MCV und Ferritin, sowie ein erhöhtes Kreatinin und GPT. Als nächstes führen Sie ein EKG, Röntgen-Thorax und eine Echokardiographie durch. Warum ist die Echokardiographie so bedeutend hinschtlich der Diagnostik einer Herzinsuffzienz?
Knowledge Decomposition Task 6_1: Mr. Merck Das Ehepaar Merck wird vom Hausarzt in die Notaufnahme geschickt, in der Sie gerade Dienst haben. Auf dem Einweisungsschein von Herrn Merck steht "Z.n. mehrfachen Kollaps, DD Synkope, bitte um Abklärung".

Wie können Sie einen Kollaps von einer Synkope unterscheiden?
Knowledge Decomposition Task 6_2: Mr. Merck Herr Merck, 72 Jahre alt, berichtet, dass er bereits mehrmals plötzlich bewusstlos geworden sei ohne vorherige Symptomatik wie Schwindel, Schmerzen oder besondere Auslöser. Er könne sich bei allen Ereignissen erst wieder daran erinnern, dass er auf dem Boden gelegen habe und seine Frau ihn besorgt angesehen und angesprochen habe. Verletzt habe er sich glücklicherweise nie. Seine Frau bestätigt, dass er ca. 1-2 Minuten nicht ansprechbar, dann jedoch sofort wieder wach und orientiert gewesen sei. Beim letzten Mal vor 2 Tagen habe er auch für einige Stunden Schwierigkeiten beim Sprechen gehabt, diese seien aber wieder von alleine weggegangen. Bisher sei er eigentlich immer gesund gewesen und nehme bisher regelmäßig Medikamente ein. An welche Ursachen einer Synkope müssen Sie bei Herrn Merck insbesondere denken und warum? Nennen Sie mindestens zwei.
Knowledge Decomposition Task 6_3: Mr. Merck Bei der körperlichen Untersuchung fallen Ihnen keine besonderen Auffälligkeiten auf, insbesondere kein Herzgeräusch oder neurologische Ausfälle. Sie veranlassen ein EKG und ein CCT. Begründen Sie warum diese Untersuchungen wichtig sind.

E. Example Case Nursing

Nursing
Situation 1: Sie holen am Freitagabend Herrn Kultau mit dem Sitzwagen zur stationären Aufnahme aus der Notaufnahme ab. Er wird zur Abklärung seiner Dyspnoe aufgenommen. Herr Kultau ist ein 43-jähriger Patient, der sich seit einer Erkältung vor 5 Wochen müde und erschöpft fühlte. Er bekäme Atemnot schon nach Steigen von ca. 10 Stufen. Manchmal könne er nachts nicht schlafen, weshalb er 2 Kissen bräuchte. Eine Anginasymptomatik verneint er genauso wie weitere Vorerkrankungen bzw. eine regelmäßige Medikation. Während des gesamten Gesprächs hustet Herr Kultau mehrmals. Herr Kultau ist Raucher (10 packyears), nachlässig gekleidet, leicht übergewichtig, sportlich inaktiv und lebt in Scheidung, seine Frau und Tochter wären gerade ausgezogen. Beruflich arbeitet er im Vertrieb und nach der Arbeit träfe er sich am liebsten mit ein paar Freunden zum Bier und Fernsehen.
Error of fictitious student 1: Sie sind genervt. Er sieht vernachlässigt, ungepflegt aus. Es wundert Sie nicht, dass er schlecht Luft bekommt. Hätte er mehr auf seine Gesundheit geachtet, weniger geraucht, mehr Sport getrieben und etwas weniger Gewicht wäre diese stationäre Aufnahme wahrscheinlich umsonst. Sie zeigen ihm sein Zimmer und lassen und sagen ihm er solle schon einmal seinen Koffer ausräumen bis Sie zum pflegerischen Anamnesegespräch kommen.
Feedback 1: *Level 1:* Da bei Herrn Kultau der stationäre Aufnahmegrund die Abklärung einer unklaren Atemnot ist, sollten Sie körperliche Anstrengung für den Patienten dringend vermeiden. Das Auspacken seines Koffers stellt eine hohe körperliche Anstrengung dar, die vermieden werden sollte. *Level 2:* Atemnot ist häufig mit körperlicher Anstrengung verbunden. Um die Atemnot besser zu beschreiben sollten Sie den Patienten fragen, • wann die Atemnot auftritt • ob die Atemnot besonders nachts vorkommt • ob die auslösenden Faktoren bekannt sind • ob die Atemnot abhängig ist von einer bestimmten Körperlage • wie sich die Atemnot zeigt und ob ein Zusammenhang mit körperlicher Aktivität besteht • ob Atemgeräusche wahrnehmbar sind • welche Methoden bisher eine Entlastung gebracht haben.

Eine Bewertung der Atemnot ist nur durch den Patienten möglich, da das Erleben immer auf subjektiver Ebene stattfindet

Level 3:
Die Beobachtung der Atmung ist Ihre pflegerische Aufgabe. Die normale Atmung wird als **Eupnoe** bezeichnet. **Dyspnoe** ist eine subjektive Kurzatmigkeit oder Lufthunger. Veränderungen der Atmung können sich beziehen auf den **Rhythmus**, die **Frequenz**, die **Atemtiefe**, den **Atemtyp**, **die Atemgeräusche,** sowie den **Geruch** des Atems. Eine Veränderung der Atmung kann auch eine Veränderung der **Hautfarbe** verursachen (Zyanose). Ebenso können Veränderungen des **Sputums** auf Störungen beim Atmen hinweisen.

Situation 2:

Der Arzt war vor Ihnen da und untersuchte Herrn Kultau eingehend.
- AZ mäßig
- RR 170/130mmHG rechts, 173/126mmHG links, P 90/min, Größe 1,84m, Gewicht 95kg
- Cor rhythmisch, keine pathologischen Geräusche
- Pulmo mit leichter Spastik und basalen Rasselgeräuschen, Orthopnoe
- Abdomen unauffällig
- Diskrete Knöchelödeme bds.

Error of fictitious student 2:

Sie wollen nun die pflegerische Anamnese erstellen und beginnen Herrn Kultau Fragen zu stellen. Er antwortet kurz und knapp auf Ihre Fragen, ein wirkliches Gespräch kommt nicht zustande. Trotzdem dauerte die Anamnese lange, weil Herr Kultau immer wieder Pausen machen muss. Sie vermerken in der Dokumentation, dass Herr Kultau wortkarg ist und wenig Interesse hat über seine Gesundheit nachzudenken.

Feedback 2:

Level 1:
Es mag sein, dass Ihre Vermutung richtig ist, aber Sie interpretieren lediglich ein Verhalten. Ein Misslingen von einem Gespräch könnte auch andere Ursachen haben.

Level 2:
Generell ist ein Anamnesegespräch neben einer Informationssammlung auch eine gute Möglichkeit für einen Beziehungsaufbau. Hierzu sollten Sie Einfühlungsvermögen und Wertschätzung vermitteln. Diese beiden Haltungen sind erforderlich um Vertrauen aufbauen zu können. Weiter ist erforderlich, dass Sie Kongruenz (Echtheit) und wirkliches Interesse am Patienten vermitteln.
Bedenken Sie, dass neben Ihrer Person auch das Umfeld entscheidend ist um ein gutes Gespräch führen zu können. Dazu ist ein ungestörter Rahmen erforderlich. Des Weiteren ist die Situation des Patienten zu bedenken. Wenn ein Patient Schmerzen oder Atemnot hat, wird er nicht wirklich an einem geduldigen Gespräch interessiert sein.

Level 3:
In Pflegesituationen haben Beziehungen eine besondere Bedeutung und haben eine entscheidende Rolle bei dem Gelingen von guter Pflege. Um pflegen zu können ist erforderlich, dass man Menschen versteht und sich mit dem Mensch-sein auseinandersetzt. Um diese Pflege-Patient-Beziehung gestalten zu können sind fachliche Kompetenzen, sowie soziale und persönliche Kompetenzen erforderlich. Patienten und Pflegende begegnen sich in Pflegesituationen in unterschiedlichen Rollen. Dabei sollen Pflegende in Begegnungen, die Erwartungen, Bedürfnisse und Erfordernisse der Patienten wahrnehmen und im Austausch durch Pflege zu einer Lösung führen. Wichtig für Pflegende dabei ist das Bewusstsein, dass Begegnungen gegenseitig sind und sich bedingen

Situation 3:

Bei Herrn Kultau wurde eine Herzinsuffizienz festgestellt. Sie befragen Herrn Kultau genauer wie es ihm geht. Sie fragen gezielt nach Ödemen und Reaktionen nach körperlicher Belastung. Er erzählt Ihnen von seinen eingelaufenen Beinen und dass er alles in letzter Zeit als anstrengend empfunden hat. Er sei aber auch sehr müde und schlafe sehr schlecht.

Error of fictitious student 3:

Um die Ödeme zu kontrollieren messen Sie die Beinumfänge und überlegen eine tägliche Gewichtskontrolle. Die zwei Stockwerke in seine Wohnung konnte Herr Kultau nur noch mit zweimaligen Pausen hochgehen. Derzeit ist er sogar nach dem Gang zur Toilette froh um eine Erholung.
Eine Schlafstörung beziehen Sie auf seine psychisch stressige Situation.

Feedback 3:

Level 1:
Es liegt nahe, dass Herr Kultau auf Grund seiner familiären Situation schlecht schlafen kann. Trotzdem sollten Sie die Ursache für die Schlafstörung genauer abklären.

Level 2:
Aus der Anamnese ist bekannt, dass Herr Kultau zwei Kissen zum Schlafen braucht und Beinödeme hat. Diese Merkmale können auf eine Herzinsuffizienz hinweisen. Eine Herzinsuffizienz mit Nykturie kann ebenso zu Schlafstörungen führen.
Bedenken Sie die Folgen eines Schlafmangels durch Nykturie. Ein häufig unterbrochener Schlaf führt zu Tagesmüdigkeit, Schwindel, Konzentrationsstörungen, Stimmungsveränderungen und einer Schwächung des Immunsystems.

Level 3:
Werden Patienten durch zwei oder mehrere Toilettengänge durch Harndrang geweckt, spricht man von 'Nykturie'. Das nächtliche Wasserlassen bei Herzinsuffizienz entsteht durch körperliche Entlastung (insbesondere in waagrechter Position). Dadurch wird die Auswurfleitung des Herzens erhöht, da nicht mehr das Gefälle von den Beinen zum Herzen überwunden werden muss. Tagsüber eingelagerte Flüssigkeit kann so nachts stärker ausgetrieben werden, was sich dann im häufigen nächtlichen Wasserlassen zeigt. Viele

Menschen nehmen Nykturie als 'Altersbeschwerde' hin. Wird jedoch die Lebensqualität durch das nächtliche, häufige Aufstehen durch Schlafmangel beeinträchtigt sollten Schritte zur Abklärung der Nykturie veranlasst werden. Für ältere Menschen bedeutet Nykturie eine erhebliche Steigerung von Sturzrisiko.
Situation 4: Nach einer Zusammenfassung aller Befunde zeigt sich eine Herzinsuffizienz NYHA II-III auf dem Boden einer stattgehabten Myokarditis bzw. einer hypertensiven Herzerkrankung. Auch eine dilatative Kardiomyopathie steht als Diagnose noch im Raum. Im Vordergrund bei Herrn Kultau steht die Einstellung des Blutdrucks auf Normalwerte. Dazu erhält er blutdrucksenkende Medikamente. Der Zimmernachbar ruft nach einer Pflegeperson, da Herr Kultau zusammengebrochen ist.
Error of fictitious student 4: Herr Kultau ist ansprechbar, kaltschweißig, hat einen RR von 80/60mmHg und P von 110/min. Ein von ihrer Kollegin gerufener Arzt kommt gerade hinzu als Sie die Werte ermittelt haben. Herr Kultau erholt sich schnell und Sie können ihn zum Bett begleiten. Trotz seines schlechten Zustands beginnt er zu schimpfen, das käme nur von diesen Tabletten. Seit er so viele Tabletten bekomme, ginge es ihm schlechter als vorher. Sie ärgern sich und vermerken in der Patientendokumentation, dass Herr Kultau unkooperativ ist und seine Medikamente verweigert.
Feedback 4: *Level 1:* Die Verärgerung von Herrn Kultau ist nachvollziehbar, sie sollten Herrn Kultau über Wirkungen, bzw. Nebenwirkungen der angeordneten Medikamente informieren. *Level 2:* Im Allgemeinen gehört es zu den Aufgaben des Arztes den Patienten über die medikamentöse Therapie zu informieren, bzw. mit ihm abzustimmen. Trotzdem ist es Ihre pflegerische Aufgabe Informationsdefizite zu erkennen und zu vermindern. Bedenken Sie, dass viele Patienten durch Aufregung oder Überforderung nicht in der Lage sind in dem ersten Gespräch alle Informationen zu verstehen, bzw. zu verarbeiten. Deshalb sollten Sie beim Patienten konkret nachfragen, ob alles verstanden wurde. Möglicherweise können Sie in einfachen Worten die fehlenden Informationen ergänzen oder den Arzt auf den Bedarf für ein wiederholtes Gespräch aufmerksam machen." *Level 3:* Merkmale von Wissensdefiziten sind • Unangemessene, übertriebene Verhaltensweisen • nachlässiges Ausführen von Anweisungen • ungenaue Testdurchführung • Äußerung des Problems Wird ein Wissensdefizit nicht erkannt, kann dies zu fatalen Folgen (physiologischen und psychologischen Auswirkungen) führen. Jedoch lässt sich die Gesamtheit der Folgen bei Wissensdefizit nicht erfassen. Was allerdings bekannt ist, ist dass Unwissenheit den

Therapieerfolg hemmt
Outlook: Herr Kultau hat durch Aufklärung eingesehen, wie wichtig die medikamentöse Behandlung für ihn ist. Nach der Feststellung der Ursache für die Herzinsuffizienz (eine stattgefundene Myokarditis) erarbeitet der Arzt mit Herrn Kultau einen Behandlungsplan. Die ersten Schritte waren dabei die Einleitung einer stationären Rehabilitation. Inzwischen können Sie Herrn Kultau unterstützen mit Beratung zu den Themen einer Raucherentwöhnung und Gewichtsabnahme. Sie schulen Herrn Kultau im Blutdruckmessen und empfehlen ihm ein Tagebuch zu führen. In dieses Tagebuch können ebenfalls die täglichen Gewichtskontrollen eingetragen werden. Bei möglicher Flüssigkeitsrestriktion können Sie ihm Maßnahmen empfehlen bei Durstgefühl. Um seine schwierige Familiensituation zu gut bewältigen zu können, informieren Sie Herrn Kultau über die Möglichkeit einer professionellen Begleitung.

F. Test for Declarative-Conceptual Knowledge in Nursing

1. Was sind Ursachen einer chronischen Herzinsuffizienz?

- ☐ Dilatative Kardiomyopathie
- ☐ Koronare Herzkrankheit
- ☐ Asthma bronchiale
- ☐ Arterielle Hypertonie

2. Welche Symptome sind typisch für eine Linksherzinsuffizienz?

- ☐ Beinödeme
- ☐ Gestaute Halsvenen
- ☐ Asthma cardiale
- ☐ Dyspnoe

3. Welche Symptome haben eine Herz- und Linksherzinsuffizienz gemeinsam?

- ☐ Hoher Puls
- ☐ Appetitlosigkeit
- ☐ Schwächegefühl
- ☐ Aszites

4. Welche Symptome sind typisch für ein Lungenödem?

- ☐ Zyanose
- ☐ Blutig-schaumiger Auswurf
- ☐ Verlangsamter Puls
- ☐ Erstickungsangst

5. Welche Komplikationen können sich auf der Basis einer Herzinsuffizienz ergeben?

- ☐ Respiratorische Alkalose
- ☐ Vorhofflimmern
- ☐ Pneumonie
- ☐ Herzrhythmusstörungen

6. Welche Trainingsmaßnahmen können bei einer kompensierten Herzinsuffizienz New York Heart Association (NYHA) II empfohlen werden?

- ☐ Vorsichtiges Herz-Kreislauftraining
- ☐ Intervalltraining
- ☐ Krafttraining
- ☐ Hypertrophietraining

7. Auf welche pflegerischen Beobachtungskriterien achten Sie im Verlauf einer kompensierten Herzinsuffizienz?

- ☐ Blutdruck
- ☐ Atmung
- ☐ Flüssigkeitshaushalt
- ☐ Körpertemperatur

8. Welche Diagnostik ist bei Verdacht auf eine schwere Herzinsuffizienz wichtig?

- ☐ Klinische Untersuchung
- ☐ Röntgen Thorax
- ☐ Elektrokardiographie
- ☐ Bestimmung des BNP

9. Welche Medikamente werden häufig zur Behandlung der Herzinsuffizienz eingesetzt?

- ☐ Angiotensin Converting Enzyme- Inhibitoren
- ☐ Antihistaminika
- ☐ B-Adrenozeptorinhibitoren
- ☐ Diuretika

10. Herr Datz erhält seit langem Medikamente gegen seine Herzinsuffizienz. Welche Beobachtungskriterien sollten Sie laufend bezüglich möglicher Effekte durch seine Medikamente kontrollieren?

- ☐ Blutdruck und Puls
- ☐ ZVD
- ☐ Körpergewicht
- ☐ Ödeme

11. Durch den Bewegungsmangel bei Atemnot können sich welche Komplikationen ergeben?

- ☐ Harninkontinenz
- ☐ Obstipation
- ☐ Dekubitus
- ☐ Intertrigo

12. Frau Kuffner hat eine Orthopnoe im Rahmen ihrer Herzinsuffizienz. Auf welche Beobachtungskriterien sollten Sie achten?

- ☐ Gesichtsausdruck
- ☐ Sputum
- ☐ Hautfarbe
- ☐ Atemgeruch

13. Warum wird eine Herzbettlage durchgeführt?

- ☐ Entlastet Beinödeme
- ☐ Kann den venösen Rückfluss zum Herzen vermindern
- ☐ Entlastet das Herz
- ☐ Erleichterung der Atmung

14. In der Therapie von Herzinsuffizienz sind verschiedene Prophylaxen empfohlen. Frau Haber hat eine Herzinsuffizienz Stufe I nach der NYHA. Welche Art von Prophylaxen führen Sie bei Frau Haber durch?

- ☐ Dekubitusprophylaxe
- ☐ Pneumonieprophylaxe
- ☐ Thromboseprophylaxe
- ☐ Kontrakturenprophylaxe

15. Wie erkennen Sie, dass ein Patient Beinödeme hat?

- ☐ Schmerzen in den Beinen
- ☐ Sichtbare Schwellung der Beine
- ☐ Eindrückbare Schwellung
- ☐ Sichtbare Einschnürungen durch Socken

16. Welche Position empfehlen Sie Patienten mit einer kompensierten Herzinsuffizienz, NYHA III, zur Entlastung von Beinödemen? ☐ Beine tief lagern ☐ Sitzen ☐ Beine erhöht lagern ☐ Knie anwinkeln in Rückenlage
17. Was soll eine Trinkmengenbeschränkung bei Herzinsuffizienz bezwecken? ☐ Reduzierte Volumenbelastung für das Herz ☐ häufiges Wasserlassen zu vermeiden ☐ Intravasales Volumen zu erhöhen ☐ Schwitzen zu reduzieren
18. Welche Maßnahmen empfehlen Sie gegen Durstgefühl? ☐ Süße Speisen essen ☐ Salzarm essen ☐ Langsam trinken ☐ Große Trinkgefäße zum Trinken benutzen
19. Bezüglich welcher Gesundheitsthemen sollten Sie Patienten mit Herzinsuffizienz vor der Entlassung beraten? ☐ Anlegen der Kompressionsstrümpfe ☐ Wichtigkeit der Medikamenteneinnahme ☐ Spezielle Hautpflege ☐ Kontrolle des Körpergewichts
20. Welche Komplikationen können sich durch Nykturie ergeben? ☐ Sturzgefahr ☐ Schlafstörung ☐ Obstipationsgefahr ☐ Exsikkose
Welche Nahrungsmittel empfehlen Sie Patienten mit einer Herzinsuffizienz? ☐ Eiweißreich ☐ Kohlenhydratreich ☐ Calciumarm ☐ Fettarme

G. Test for Strategic Knowledge in Nursing

Pretest

Key Feature Task 1_1: Patient Ms. Huber Frau Huber ist 68 Jahre alt und ist auf Ihrer Station wegen einer hypertonen Krise (230/120 mmHg) vor zwei Tagen. Zudem ist bei ihr eine Linksherzinsuffizienz, eine Divertikulose und Hyperthyreose bekannt. Heute Morgen war ihr Blutdruck 160/85 mmHg. Jetzt klingelte die Bettnachbarin und meint zu Ihnen, dass Frau Huber im Bad ist und es ihr offensichtlich nicht gut gehe. Frau Huber sitzt vor dem Waschbecken und atmet schwer. Was sind Ihre nächsten Schritte?
Key Feature Task 1_2: Patient Ms. Huber Frau Huber ist nun im Bett und erholt sich schnell. Der Blutdruck ist 145/85 mmHg, der Puls ist 88/min und die Atmung ist 25/min und wird zusehends ruhiger. Auf Ihre Nachfrage meinte sie, dass sie sich wohl körperlich zu viel zugemutet hätte. Sie wollte sich schnell waschen, weil sie gleich eine Untersuchung hat. Trotz der Besserung ihrer Atemnot wirkt sie unzufrieden und ärgerlich. Wie gehen Sie auf die Situation ein?
Key Feature Task 1_3: Patient Ms. Huber Frau Huber bezeichnet sich selber als schwierige und ungeduldige Patientin. Sie berichtet Ihnen, dass sie es die letzte Zeit mit den Medikamenten nicht so genau genommen hat. Wie reagieren Sie darauf?
Key Feature Task 2_1: Patient Mr. Braun Herr Braun (59 Jahre) ist auf Ihrer Station zur Abklärung einer Herzinsuffizienz mit Verdacht auf eine Kardiomyopathie. Sie kommen zu ihm für eine Routinekontrolle des Blutdrucks. Er sitzt im Stuhl, ist blass, ihm ist schwindlig und er hat Atemnot. Was sollten Sie dringend tun?
Key Feature Task 2_2: Patient Mr. Braun

Beim Kontrollieren des Pulses fällt Ihnen eine Tachyarrhythmie auf. Was sind dazu Ihre nächsten Schritte?
Key Feature Task 2_3: Patient Mr. Braun Herr Braun möchte bevor der Arzt kommt ins Bad auf die Toilette gehen. Wie reagieren Sie auf seinen Wunsch?

Posttest: all pretest items and in addition the following items

Key Feature Task 3_1: Patient Mr. Conrad Herr Conrad (62 Jahre) ist wegen Herzrhythmusstörungen auf Ihrer Station. Er hat seit langem eine Herzinsuffizienz. Herr Conrad klingelt und berichtet Ihnen aufgeregt vom Stolpern seines Herzens. Wie ist Ihr Vorgehen in dieser Situation?
Key Feature Task 3_2: Patient Mr. Conrad Die Unregelmäßigkeiten des Herzschlags sind angstauslösend für Herr Conrad. Er befindet sich in der Angststufe III und ist kurz davor in Panik zu geraten. Wie gehen Sie vor um seine Angst zu reduzieren?
Key Feature Task 3_3: Patient Mr. Conrad Durch die Ruhe und Kompetenz die Sie vermitteln fühlt sich Herr Conrad sicher und entspannt sich etwas. Allerdings zeigen sich im Befund des EKG's vital bedrohliche Rhythmusstörungen. Herr Conrad wird umgehend auf Intensiv verlegt. Auf dem Weg dorthin erzählt er Ihnen, dass er fest der Meinung ist bald zu sterben. Wie reagieren Sie darauf?
Key Feature Task 4_1: Patient Mr. Benner Herr Benner (84 Jahre) ist auf Ihrer Station wegen einer Digitalisintoxikation. Er hat Durchfall, Erbrechen, starke Kopfschmerzen und Schwindel. Er besteht darauf, trotz seines schlechten Zustandes, auf die Toilette zu gehen.

Wie können Sie den Grund seines Verhaltens herausfinden?
Key Feature Task 4_2: Patient Mr. Benner Da Sie den Zusammenhang von seinem dringenden Wunsch auf die Toilette zu gehen und seiner Postatahypertrophie erkannt haben, ist Herr Benner von Ihrem Wissen beeindruckt und hat großes Vertrauen zu Ihnen. Er erzählt Ihnen, dass er selbständig das Digitalis erhöht hat, weil seine Beschwerden von der Herzinsuffizienz schlechter wurden. Wie verhalten Sie sich?
Key Feature Task 4_3: Patient Mr. Benner Sie erfahren von Herrn Benner, dass er seine eigenen Medikamente nehmen möchte, weil diese bisher gut geholfen hatten. Der Arzt habe ihm zwar die neuen Medikamente erklärt, aber er habe es gleich wieder vergessen. Welche Unterstützungsmöglichkeiten bieten Sie Herrn Benner, damit er die neuen Informationen über die Medikamente behalten kann?
Key Feature Task 5_1: Patient Mr. Weiß Herr Weiß (72 Jahre) ist auf Ihrer Station wegen dekompensierter Herzinsuffizienz, NYHA III. Er hat zusätzlich seit 15 Jahren einen Diabetes mellitus und einen BMI von 32. Eine Trinkmengenbeschränkung auf 1,5 l/tgl ist für ihn sehr belastend. Bereits vor dem Mittagessen waren die Wasserflaschen leer, die eigentlich für den ganzen Tag bestimmt waren. Wie ist Ihr Vorgehen in dieser Situation?
Key Feature Task 5_1: Patient Mr. Weiß Sie ermitteln bei Herrn Weiß am nächsten Morgen 2 kg mehr Körpergewicht, als am Vortag. Welche Maßnahmen überprüfen Sie, um sicher zu sein, dass Ihr Ergebnis korrekt ist?
Key Feature Task 5_1: Patient Mr. Weiß Sie sehen, dass Herr Weiß sich nicht an die Trinkmengenbeschränkung hält. Er trinkt zusätzlich Fanta und Saft. Was sind Ihre nächsten Schritte?

Key Feature Task 6_1: Patient Ms. Schwarz Frau Schwarz (82 Jahre) ist auf Ihrer Station wegen dekompensierter Herzinsuffizienz, NYHA III. Ihre körperliche Belastungsgrenze hat sich seit zwei Tagen verbessert, sie konnte sich wieder mit kleinen Pausen am Waschbecken selbständig waschen. Sie haben Nachtdienst. Um 2.15 Uhr meldet sich Frau Schwarz bei Ihnen, weil sie Atemnot hat. Damit Frau Schwarz besser atmen kann, stellen Sie ihr das Bettkopfteil hoch. Wie gehen Sie weiter vor?
Key Feature Task 6_2: Patient Ms. Schwarz Der Blutdruck ist 120/85 mmHg, Puls108/min. Die Atmung ist 30/min und sichtlich anstrengend für Frau Schwarz. Sie sieht ängstlich aus. Die Lippen sind leicht zyanotisch. Sie nehmen kein Brodeln beim Atmen wahr, aber sie hustet sehr und versucht dabei Sputum hochzubringen. Was sind Ihre nächsten Schritte?
Key Feature Task 6_3: Patient Ms. Schwarz Der Arzt hat ein beginnendes Lungenödem festgestellt. Inzwischen hat Frau Schwarz zwei Hübe Nitro-Spray und Furosemid i.v. verabreicht bekommen. Sie haben bei ihr bereits einen Blasenverweilkatheter gelegt. Leider verschlechtert sich der Zustand von Frau Schwarz, sie hat sichtlich Todesangst. Der Arzt organisiert gerade eine schnelle Verlegung auf die Intensivstation. Sie bemerken bei Frau Schwarz Schaum vor dem Mund. Was ist Ihr Vorgehen?

H. Test for Conditional Knowledge in Nursing

Pretest

Knowledge Decomposition Task 1_1: Ms. Hansen
Frau Hansen ist auf Ihrer Station wegen seiner Herzinsuffizienz, NYHA III. Sie begleiten Frau Hansen auf die Toilette. Dabei fällt Ihnen auf, dass der Weg zur Toilette doch ziemlich anstrengend für sie ist und eine Belastungsdyspnoe auslöst. Zurück im Bett stellen Sie ihr das Kopfteil vom Bett hoch. Warum führen Sie diese Maßnahme durch?
Knowledge Decomposition Task 1_2: Ms. Hansen Zudem kontrollieren Sie nach der Belastung bei Frau Hansen den Blutdruck, die Atmung, den Puls, die Hautfarbe. Begründen Sie, warum Sie diese Werte überprüfen.
Knowledge Decomposition Task 1_3: Ms. Hansen Frau Hansen geht es schlechter. Sie hat eine Ruhedyspnoe. Als Konsequenz legen Sie Frau Hansen in eine Herzbettlage. Warum entscheiden Sie sich für diese Lage?
Knowledge Decomposition Task 2_1: Mr. Behrmann Herr Behrmann ist auf Ihrer Station wegen seiner Herzinsuffizienz, NYHA III. Seine körperliche Belastungsgrenze ist, dass er bis zur Toilette gehen kann. Es fällt ihm schwer seine körperliche Belastungsgrenze zu akzeptieren. Er erzählt Ihnen seine Bedenken, wie es wohl mit ihm weitergehen würde. Offensichtlich hat er Angst oder fürchtet sich vor etwas. Warum ist eine Unterscheidung von Angst zu Furcht wichtig für Ihre weiteren pflegerischen Maßnahmen?
Knowledge Decomposition Task 2_2: Mr. Behrmann Sie haben Nachtdienst. Herrn Behrmann muss nachts wegen seiner Nykturie häufig auf die Toilette. Sie sehen, dass er sehr unsicher beim Gehen ist. Sie bitten ihn, dass er nicht alleine auf die Toilette gehen soll, sondern nach Ihnen klingeln soll.

Warum ist es Ihnen wichtig, dass sich Herr Behrmann für die Gänge zur Toilette meldet?
Knowledge Decomposition Task 2_3: Mr. Behrmann Herr Behrmann war heute Nacht nur einmal auf der Toilette. Bei der morgendlichen Übergabe bitten Sie Ihre Kolleginnen bei Herrn Behrmann das Gewicht zu überprüfen. Warum meinen Sie ist es wichtig eine Gewichtskontrolle durchzuführen?

Posttest: all pretest items and in addition the following items

Knowledge Decomposition Task 3_1: Mr. Bartlett Herr Bartlett ist auf Ihrer Station wegen seiner Herzinsuffizienz. Die Ursache ist eine dilatative Kardiomyopathie. Warum ist bei einer Mobilisation die Kontrolle des Pulses wichtig?
Knowledge Decomposition Task 3_2: Mr. Bartlett Herr Bartlett erzählt Ihnen, dass er in letzter Zeit öfters einfach umgefallen wäre. Bisher hatte er sich nicht verletzt Warum ist die Weitergabe dieser Information an den Arzt, außer der potentiellen Verletzungsgefahr, besonders wichtig?
Knowledge Decomposition Task 3_3: Mr. Bartlett Sie beobachten bei Herrn Bartlett eine Atemnot. Sie geben unverzüglich die Information über die Dyspnoe mit der aktuellen Atemfrequenz an den Arzt weiter. Warum sollten Sie auch die Situation beschreiben, in der Sie Herrn Bartlett antreffen?
Knowledge Decomposition Task 4_1: Mr. Lowenstein Herr Lowenstein, 72 Jahre, hat eine lange bekannte Herzinsuffizienz, NYHA III. Er hat massive Ödeme in beiden Beinen. Zur Ausschwemmung der Ödeme erhält Herr Lowenstein Furosemid. Sie begleiten Herrn Lowenstein beim Toilettengang um rechtzeitig bei der Gefahr eines Sturzes eingreifen zu können. Warum meinen Sie ist die Gefahr bei Herrn Lowenstein groß zu stürzen?

Knowledge Decomposition Task 4_2: Mr. Lowenstein

Im Rahmen des Anamnesegesprächs erfahren sie von seiner Nykturie.
Warum muss Herr Lowenstein nachts so häufig auf die Toilette?

Knowledge Decomposition Task 4_3: Mr. Lowenstein

Sie leiten Herrn Lowenstein an, dass er sein Gewicht zu Hause täglich selbst kontrollieren soll und klären ihn über mögliche Fehlerquellen auf.

Warum ist es wichtig, dass er sein Gewicht kontrolliert?

Knowledge Decomposition Task 5_1: Ms. Dulke
Frau Dulke hat eine Herzinsuffizienz, NYHA III auf der Basis einer langjährigen Hypertonie. Sie ist zur Blutdruckeinstellung auf Station. Frau Dulke wirkt sehr ängstlich und angespannt. Sie bitten Frau Dulke in einen anderen Raum um mit ihr das Anamnesegespräch zu führen.
Warum ist Ihnen das Umfeld so wichtig in der Durchführung des Anamnesegesprächs?

Knowledge Decomposition Task 5_2: Ms. Dulke
Im Anamnesegespräch erzählt Ihnen Frau Dulke, dass sie besonders ihre dicken Beine stören.
Warum achten Sie im Verlauf des Anamnesegespräch insbesondere auf Einschränkungen bei 'Ruhen und Schlafen'?

Knowledge Decomposition Task 5_3: Ms. Dulke
Es ist Frau Dulke unangenehm, aber sie erzählt Ihnen, dass sie bei der Aufnahme nicht verstand, was ihr der Arzt über die Blutdruckmedikamente gesagt hat.
Warum hat sie wahrscheinlich die Informationen des Arztes nicht aufnehmen können?

Knowledge Decomposition Task 6_1: Mr. Hauser

Herr Hauser, 75 Jahre, hat eine bekannte Herzinsuffizienz. Er meldet sich bei Ihnen, weil er zunehmend Atemnot hat, ohne sich körperlich zu belasten. Er sitzt aufrecht im Bett und atmet sichtlich schwer. Zudem hustet er stark.

Warum ist es wichtig, dass Sie umgehend den Arzt informieren und ihm Sauerstoff hochdosiert anbieten?

Knowledge Decomposition Task 6_2: Mr. Hauser

Es geht Herr Hauser inzwischen wieder besser und er kann sich inzwischen wieder gering

körperlich belasten. Da Sie Herr Hauser schon länger kennen, wissen Sie, dass sobald es ihm wieder gut geht, er sich nicht mehr so ganz an die Trinkmengenbeschränkung und Medikamenteneinnahme hält. Warum ist es wichtig, dass Sie Herrn Hauser überzeugen, dass er sich an die Therapieempfehlung hält?
Knowledge Decomposition Task 6_3: Mr. Hauser Sie stellen bei Herrn Hauser fest, dass er wenig über seine Erkrankung. Sie klären ihn auf und beraten ihn. Warum ist es so wichtig, ein Wissensdefizit zu reduzieren?

I. Example Case Teaching

Teaching
Situation 1: Im Rotenbach Gymnasium beginnen demnächst Projektwochen zum Themengebiet Zivilcourage und Gewaltbereitschaft. Herr Dauner bittet Sie zu einer Vorbesprechung. Zusammen überlegen Sie, welcher Instruktionsansatz passend sein könnte.
Error of fictitious student 1: Die Schüler sollen befähigt werden den Ausbruch von Gewalt durch Zivilcourage zu verhindern. Ziel der Lerneinheit ist, den Schülern Wissen zu vermitteln das sie in verschiedenen Alltagssituationen anwenden können. Träges Wissen, also Wissen das in der Praxis nicht für Problemlösungen angewandt werden kann, wollen Sie vermeiden. Sie schlagen direkte Instruktion vor.
Feedback 1: *Level 1:* Ich halte es auch für sinnvoll auf anwendbares Wissen zu achten. Allerdings würde ich Problem-based Learning vorschlagen**.** *Level 2:* Wenn ich Unterricht plane, analysiere ich zuerst die Lernziele und den Lerninhalt. Lernende sollen Wissen von einer Situation auf eine andere übertragen können, also zum Beispiel nicht nur auf dem Schulhof mehr Zivilcourage zeigen, sondern auch in der U-Bahn. Heuristiken also Daumenregeln sind dabei hilfreich. Bei dem Problem "mehr Zivilcourage zeigen" ist der Lerninhalt nicht klar bestimmbar, da es keine eindeutig richtige Lösung gibt. Für solche reichhaltigen offenen Probleme nutze ich ungern direkte Instruktion, da hier eine genaue Planung der einzelnen Aktivitäten erforderlich ist. Gerade dann eignet sich ein offener Ansatz wie das Problem-based Learning. *Level 3:* Problem-based Learning zählt zu den situierten Ansätzen. Bei diesen wird davon ausgegangen, dass die Anwendbarkeit von Wissen abhängig von der Situation ist, in der es erworben wurde. Wissen ist demzufolge nicht automatisch auf reale Problemstellungen anwendbar. Es kann träge bleiben wenn es vom Problemkontext losgelöst, also abstrakt erworben wird. Dadurch dass Schüler mit authentischen, reichhaltigen Problemen lernen, sollen Schüler eine umfangreiche und auf alltägliche Probleme anwendbare Wissensbasis erwerben.
Situation 2: Ihnen gefällt Herr Dauners Idee, den Problem-based Learning Ansatz zu nutzen. Herr Dauner gibt Ihnen eine Zusammenfassung des Problem-based Learning Ansatzes (siehe

Datei ZusammenfassungPBL.doc). Sie bereiten für Ihr nächstes Treffen einen Ablaufplan vor.
Error of fictitious student 2: Zuerst wollen Sie mit Herrn Dauner über ein geeignetes Problemszenario sprechen. In der Uni haben Sie von einem Zivilcouragetraining für Erwachsene gehört und kennen zufällig einen der Dozenten. Sie schlagen vor, dass Ihre Schüler dieses Zivilcouragetraining begleiten und dessen Wirksamkeit bewerten.
Feedback 2: *Level 1:* Es gefällt mir sehr gut, dass Sie ein Problem aus der Praxis gewählt haben. Nicht so sicher bin ich mir, ob dieses Problem für Jugendliche ausreichend relevant ist. *Level 2:* Ich versuche bei der Identifikation eines Problemszenarios meine Zielgruppe im Blick zu behalten. In diesem Fall Jugendliche. Mir fällt es schwer, zu überlegen was für Schüler ein relevantes Problem darstellt. Deswegen führe ich vor Problem-based Learning Einheiten eine Diskussionsrunde durch. *Level 3:* Um Motivation und Eigeninitiative der Schüler zu fördern sollte ein für Schüler relevantes Problem genutzt werden. Damit ein Problemszenario im Problem-based Learning möglichst einem Alltagsproblem entspricht, sollte es zudem realistisch, schlecht strukturiert und komplex sein. Dies ist förderlich für den Transfer des Gelernten in den Alltag. Die Präsentation des Problems soll zunächst unklar sein, so dass Schüler nachfragen müssen um das Problem tatsächlich zu verstehen. Durch diese Orientierung am notwendigen Vorgehen bei Alltagsproblem wird gefördert, dass neben Faktenwissen auch Problemlösestrategien gelernt werden.
Situation 3: Dieser Punkt leuchtet Ihnen ein. Es fällt Ihnen schwer, ein passendes Problem zu identifizieren.
Error of fictitious student 3: Vielleicht könnten die Schüler eine bundesweite Gewalt-Präventionskampagne mit Schülern als Zielgruppe entwerfen?" schlagen Sie Herrn Dauner vor.
Feedback 3: *Level 1:* Ja dieses Problem ist für Schüler relevanter ist. Allerdings zweifle ich, dass es als authentisch erlebt wird. Ein authentisches Problemszenario könnte sein, dass ein Schüler Opfer von Gewalt auf den Schulhof wird. *Level 2:* Ich überlege, was im täglichen Leben meiner Schüler wichtig ist. Es hilft mir, wenn ich mir

den Alltag eines Schülers vorstelle und dabei auf Probleme zu achte, die einem Schüler begegnen könnten.

Level 3:
Bei Problem-based Learning soll ein möglichst authentisches Problem gewählt werden. Dadurch weisen die Situation in der Wissen erworben wird und die Situation in der es später angewandt werden soll ähnliche Elemente auf. Dies fördert den Transfer des Gelernten. Ein persönlich relevantes Problem von mittlerer Schwierigkeit zu nutzen, hat zudem positive Effekte auf die Motivation der Schüler.

Situation 4:

Sie entscheiden sich als Einführung in das Problemszenario einen Filmausschnitt zu zeigen, in dem ein Schüler Opfer von Gewalt auf dem Schulhof wird. Sie haben bereits einen Ausschnitt im Kopf. Dieser erscheint Ihnen passend, da er sehr authentisch wirkt und das Alter des Schülers in dem Film, dem Alter Ihrer Schüler entspricht.

Error of fictitious student 4:

Sie erläutern Herrn Dauner den Plan für Ihren Unterricht.

- Nach dem Film analysieren Kleingruppen das Problem und unterscheiden wichtige von unwichtiger Information.
- Anschließend entwickeln Schüler Fragestellungen und leiten daraus Hypothesen also unbestätigte Vermutungen ab z.B. Bei maximal drei Beobachtern ist die Wahrscheinlichkeit höher, dass einer der Beobachter eingreift. Im Verlauf der Lerneinheit überprüfen die Schüler ihre Hypothese.
- Zuerst identifizieren die Schüler Wissenslücken die verhindern, dass die Hypothese beantwortet werden kann.
- Die daraus folgenden Lernthemen teilen die werden innerhalb der Gruppen aufgeteilt und selbstständig bearbeitet.
- Als letztes tragen die Lerner ihr Wissen zusammen und wenden es auf den Fall an.

Damit sollten alle Phasen des Problem-based Learning durchgeführt sein, denken Sie sich.

Feedback 4:

Level 1:
Ihre Unterrichtsplanung gefällt mir. Jedoch fehlen wichtige Phasen. Nach Anwendung des Wissens auf den Fall des Schülers auf dem Schulhof, fehlt die Übertragung auf ein ähnliches Problem. Dies wird als Abstraktion bezeichnet. Auch fehlt die Reflexion am Ende der Lerneinheit.

Level 2:
Wenn ich einen Unterricht nach einem bestimmten Ansatz plane, schreibe ich mir die wichtigsten Phasen und Kernprozesse auf. Wenn die Schüler ihr Wissen auf ein ähnliches Problem übertragen, reichen schon kleine Veränderungen z.B. ein anderer Ort. In der Reflexionsphase moderiere ich als Tutor die Diskussion.

Level 3:
Ziel der Abstraktionsphase ist, dass Lerner flexibel anwendbares Wissen erwerben und

somit der Transfer auf ähnliche Problemstellungen bzw. in den Alltag erleichtert wird. In der Reflexion werden alle Phasen des Problem-based Learning sowie die Kooperation reflektiert. Dadurch können Schüler metakognitive Kompetenzen sowie Problemlösekompetenz erwerben.
Situation 5: Sie haben ihre erste Unterrichtsstunde hinter sich. In der Mittagspause bittet Sie Herr Dauner die Stunde zu reflektieren.
Error of fictitious student 5: Im Großen und Ganzen sind sie zufrieden mit der Stunde. Interessiert und betroffen nahmen die Schüler das gestellte Problemszenario auf. Anschließend ließen Sie die Schüler in Kleingruppen relevante Fakten identifizieren. Allerdings hatten alle 3 Gruppen Probleme und fanden alle im Filmausschnitt enthaltenen Informationen wichtig. Sie halfen den Schülern, indem Sie in einem kurzen Vortrag die wichtigsten Fakten präsentierten.
Feedback 5: *Level 1:* Sehen Sie beim Problem-based Learning davon ab, den Schüler einzelne Schritte im Problemlöseprozess komplett abzunehmen. Unterstützen sie besser durch Hinweise. *Level 2:* Ich lasse die Schüler eine Tabelle aufstellen in der sie wichtige und unwichtige Fakten unterscheiden. Dafür hilft ein klares Kriterium z.B. könnte ich auffordern die relevanten Fakten in Bezug auf die Gewaltbereitschaft des Täters zu benennen. Zudem weise ich die Schüler auf die Möglichkeit Fakten nachzufragen hin. *Level 3:* Ziel dieser Vorgehensweise ist, dass Lerner selbst aktiv bleiben. Die Verantwortung für den Lernprozess verbleibt beim Schülern. Durch das Identifizieren der Fakten sollen Lerner ein Problemszenario besser verstehen. Dies ist zudem ein wichtiger Schritt bei der Lösung von realen Alltagsproblemen und deswegen für den Transfer relevant.
Outlook: In den weiteren Stunden halten Sie sich mit direktiver Hilfe zurück und unterstützen die Schüler, so dass deren Eigenaktivität nicht verringert wird. Am Ende der Unterrichtseinheit sind Sie zufrieden mit dem Lernerfolg Ihrer Schüler und gespannt auf die nächste Möglichkeit Ihr theoretisches Wissen praktisch anzuwenden.

J. Test for Declarative-Conceptual Knowledge in Teaching

1. Problembasiertes Lernen weckt Interesse und Motivation der Lernenden durch

- ☐ die Nutzung von realitätsnahen Problemen.
- ☐ die Auswahl von Problemen mittlerer Schwierigkeit.
- ☐ ein fassbares nicht abstraktes Lernziel.
- ☐ die Möglichkeit teilweise selbstgesteuert zu lernen.

2. Welche Rolle spielt selbstgesteuertes Lernen während Problem-based Learning?

- ☐ Es spielt eine geringe Rolle, da in jeder Phase strukturiert angeleitet wird.
- ☐ Es findet hauptsächlich während der Abstraktion statt.
- ☐ Es findet hauptsächlich während des Schließens der Wissenslücken statt.
- ☐ Es ist ein elementarer Teil jeder Phase im Problem-based Learning.

3. Ziel des Problem-based Learning ist es …

- ☐ Probleme zu lösen.
- ☐ flexibel anwendbares Wissen zu erwerben.
- ☐ viele realitätsnahe Probleme zu finden.
- ☐ Motivation und Interesse durch authentische Probleme zu wecken.

4. Welche Strategie(n) zum selbstgesteuerten und lebenslangen Lernen wird/werden beim Problem-based Learning gelernt?

- ☐ Kontrollstrategien, darüber was man weiß und was man noch nicht weiß.
- ☐ Fähigkeit Lernziele aufzustellen und den eigenen Lernprozess anzupassen.
- ☐ Fähigkeit den eigenen Lernprozess zu planen und passende Strategien einzusetzen.
- ☐ Fähigkeit den eigenen Lernprozess zu überwachen und abschließend zu evaluieren, ob die Lernziele erreicht wurden.

5. Welche Aussage(n) zum Erwerb einer umfangreichen und variabel anwendbaren Wissensbasis treffen/trifft zu?

- ☐ Eine umfangreiche und flexible Wissensbasis ist nur für Experten wichtig.
- ☐ Der Aufbau von trägem Wissen wird kann durch Problem-based Learning verhindert werden.
- ☐ Die Nutzung des Wissens im Rahmen mehrerer Probleme steigert die Transferierbarkeit.
- ☐ Durch den Aufbau auf Vorwissen wird die Anknüpfung neuen Wissens erleichtert.

6. Welche Aussage(n) zum Problem-based Learning treffen/trifft zu? Lernende...

- ☐ setzen sich angeleitet & kooperativ mit Problemen auseinander.
- ☐ setzen sich ausschließlich selbstgesteuert mit Problemen auseinander.
- ☐ setzen sich mit Problem auseinander.
- ☐ übernehmen Verantwortung für Ihren eigenen Lernprozess.

7. Was kann durch Problem-based Learning besonders gut gelernt werden?

- ☐ Kooperationsstrategien
- ☐ Metakognitive Strategien
- ☐ Problemlösestrategien
- ☐ Inhaltswissen

8. Wie sieht die Umsetzung von Problem-based Learning üblicherweise aus?

- ☐ Ein Lehrender entwickelt eine Lerneinheit um ein Problem herum, vermittelt relevante theoretische Inhalte und stellt das Verständnis mittels Verständnistests sicher.
- ☐ Ein Experte macht die zu erlernende Aktivität vor.
- ☐ Lernende bearbeiten eine Online-Lernumgebung, in der sie authentische Probleme generieren.
- ☐ Kleingruppen von Lernenden versuchen, unter Anleitung ein Problem zu lösen.

9. Welche Aussage(n) zum Problem-based Learning treffen/trifft zu?

- ☐ Lernende erhalten unangeleitet die Möglichkeit, durch den Umgang mit Versuchsapparaturen (z. B. Mikroskope) wissenschaftliches Wissen zu erwerben
- ☐ Lernende erwerben Inhaltswissen und Problemlöse-, Kooperations- und Denkstrategien
- ☐ Lernende werden zu „aktiven Lernenden“
- ☐ Selbstgesteuertes Lernen kann unerfahrene Lerner überfordern

10. Was ist Teil einer vollständigen Sequenz beim Problem-based Learning?

- ☐ Wissenslücken identifizieren
- ☐ Identifizieren von Fakten
- ☐ Abstraktion
- ☐ Modeling

11. Welche Aussage(n) zum Problemszenario beim Problem-based Learning treffen/trifft zu? Das Problemszenario...

- ☐ gibt den Rahmen vor, innerhalb dessen Wissen und Denkstrategien erworben werden.
- ☐ sollte realistische, komplex und schlecht strukturiert sein.
- ☐ sollte möglichst klar alle relevanten Fakten darstellen.
- ☐ sollte abstrakt sein, so dass das Wissen auch auf andere Probleme übertrage werden kann.

12. Welche Aussage(n) zum Identifizieren von Fakten beim Problem-based Learning treffen/trifft zu?

- ☐ Ziel ist es, dass Lernende danach ein klares Konzept des Problemszenarios haben.
- ☐ Der Lehrende präsentiert eine Aufstellung der wichtigsten Fakten des Problemszenarios.
- ☐ Lernende fragen selbstständig nach wichtigen Fakten des Problemszenarios.
- ☐ Lernende identifizieren die wichtigsten Fakten in Einzelarbeit.

13. Eine Hypothese beim Problem-based Learning sollte…

- ☐ an der Realität überprüfbar sein.
- ☐ möglichst authentisch sein.
- ☐ ein Aussagesatz sein.
- ☐ die Beziehung zwischen zwei Variablen ausdrücken.

14. Welche Aussage(n) zum Aufstellen von Hypothesen beim Problem-based Learning treffen/trifft zu?

- ☐ Eine Hypothese sollte möglichst allgemein formuliert sein.
- ☐ Das Aufstellen von Hypothesen erfolgt in Einzelarbeit.
- ☐ Eine Hypothese wird aus einer Fragestellung abgeleitet.
- ☐ Hypothesen werden vom Lehrer aufgestellt.

15. Welche Aussage(n) zum identifizieren von Wissenslücken treffen/trifft zu?

- ☐ Der Lehrende gibt Wissenslücken vor, die geschlossen werden sollen.
- ☐ Lernende identifizieren gemeinsam Wissenslücken.
- ☐ Relevant sind die Wissenslücken die für die Beantwortung der Hypothese nötig sind.
- ☐ Wissenslücken verhindern die Beantwortung der Hypothese.

16. Selbstgesteuertes Lernen beim Problem-based Learning lässt sich vor allem in der Phase …

- ☐ in der Phase der Problemfindung.
- ☐ beim Aufstellen von Hypothesen.
- ☐ beim Identifizieren von Wissenslücken.
- ☐ in der Evaluationsphase.

17. Welche Aussage zur Anwendung des neuen Wissens beim Problem-based Learning treffen/trifft zu?

- ☐ Neues Wissen wird direkt im Alltag angewandt.
- ☐ Das Wissen wird vom Lehrenden auf ein ähnliches Problemszenario angewandt.
- ☐ Die Problemlösungen der einzelnen Gruppen werden diskutiert.
- ☐ Das erworbene Wissen wird auf die Problemstellung angewandt.

18. Welche Aussage(n) zur Abstraktion beim Problem-based Learning treffen/trifft zu?

- ☐ In der Abstraktion diskutieren die Gruppen ihre Lösungen.
- ☐ Ziel der Abstraktion ist, dass das erworbene Wissen vom Problem abstrahiert wird.
- ☐ Um die Abstraktion zu kontrollieren wird ein deklarativer Wissentest durchgeführt.
- ☐ Abstrahieren ist ein rein individueller Prozess

19. Welche Aussage(n) zur Rolle des Lehrenden treffen/trifft zu? Der Lehrende...

- ☐ ist unterstützender Tutor.
- ☐ hat dieselbe Rolle wie alle anderen Gruppenmitglieder.
- ☐ greift während der selbstgesteuerten Phasen nicht ein.
- ☐ hilft vor allem mit Theorieinput.

20. Welche Aussage(n) zur Rolle des Lehrenden beim Problem-based Learning treffen/trifft zu? Der Lehrende...

- ☐ beobachtet die Schüler bei jedem Schritt.
- ☐ hilft bei der Auswahl von geeignetem Recherchematerial.
- ☐ moderiert Diskussionen wenn die Schüler in eine Sackgasse geraten.
- ☐ benötigt kein Inhaltswissen.

21. Welche Aussage(n) zum Erwerb von Kooperationskompetenzen beim Problem-based Learning treffen/trifft zu?

- ☐ Kooperationskompetenz wird hauptsächlich durch die Steuerung der Zusammenarbeit durch den Lehrenden gefördert.
- ☐ Kooperation soll kognitive Belastung zwischen den Gruppenmitgliedern verteilen und Entwicklung individueller Expertise begünstigen, die dann wieder in die Gruppenphasen eingebracht wird.
- ☐ Kooperationskompetenz wird durch die Teilhabe an Lernprozessen in einer Gruppe gefördert.
- ☐ Kooperationskompetenz wird durch die gemeinsame Reflexion & Diskussion der Zusammenarbeit in der Evaluation gefördert.

K. Test for Strategic and Conditional Knowledge in Teaching

Key Feature Task 1 Sie arbeiten als Praktikant im Elisengymnasium. Ihre Betreuerin ist die erfahrene Lehrerin Frau Hummel. Sie sollen eine Unterrichtseinheit zum Thema "Erstellen einer Website" planen. Die Schüler sollen lernen, eine Website zu planen, selbstständig umzusetzen und anschließend zu bewerten. Zusammen mit Frau Hummel überlegen Sie, welcher Instruktionsansatz passend sein könnte. Für welchen Instruktionsansatz entscheiden Sie sich und wie gehen Sie bei dieser Auswahl vor?
Knowledge Decomposition Task 1 Sie entscheiden Sich für den Problem-based Learning Ansatz. Bei der Analyse der Lernziele und des Lerninhalt ist Ihnen klar geworden, dass komplexe Fähigkeiten benötigt werden um eine Website zu erstellen. Das Wissen muss flexibel an die Situation angepasst werden, da Lernende nicht nur eine Website zu einem festgelegten Thema erstellen können sollen. Bei dem vorgestellten Problem ist der Lerninhalt nicht klar bestimmbar, da es keine eindeutig richtige Lösung gibt. Welcher theoretische Hintergrund liegt der Auswahl Ihres Instruktionsansatzes zugrunde und was sind die Ziele dieses Instruktionsansatzes?
Key Feature Task 2 Frau Hummel, die generell sehr an situierten Instruktionsansätzen interessiert ist, gefällt Ihr Vorschlag sehr gut. Frau Hummel bittet Sie, einen Plan für die Unterrichtseinheit auszuarbeiten. Sie stellt Ihnen nun spezifische Fragen zu den 8 Phasen Ihrer Problem-based Lerneinheit. Wie gehen Sie bei der Auswahl eines geeignetes Problemszenarios vor? Was wäre ein geeignetes Problemszenario?
Knowledge Decomposition Task 2 Welcher theoretische Hintergrund liegt der Auswahl Ihres Problemszenarios zugrunde? Welches Ziel verfolgen Sie mit der Auswahl Ihres Problemszenarios?
Key Feature Task 3 Frau Hummel ist erfreut darüber, dass Sie Ihre didaktischen Entscheidungen auch

theoretisch begründen können. Sie bittet Sie: Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse bei der Identifizierung von Fakten.
Knowledge Decomposition Task 3 Welcher theoretische Hintergrund liegt Ihrem Vorgehen beim Identifizieren von Fakten zugrunde? Welches Ziel verfolgen Sie mit dieser Phase?
Key Feature Task 4 Interessiert lauscht Frau Hummel Ihren Ausführungen und geht über zur nächsten Phase. Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse beim Aufstellen von Hypothesen.
Knowledge Decomposition Task 4 Welcher theoretische Hintergrund liegt Ihrem Vorgehen beim Aufstellen von Hypothesen zugrunde? Welches Ziel verfolgen Sie mit dieser Phase?
Key Feature Task 5 Interesssiert lauscht Frau Hummel und bittet Sie mir der nächsten Phase fortzufahren. Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse bei der Identifizierung von Wissenslücken.
Knowledge Decomposition Task 5 Welcher theoretische Hintergrund liegt Ihrem Vorgehen beim Identifizieren von Wissenslücken zugrunde? Welches Ziel verfolgen Sie mit dieser Phase?
Key Feature Task 6 Nach einer kleinen Kaffeepause widmet sich Frau Hummel der nächsten Phase. Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse bei der Anleitung zum selbstgesteuerten Lernen.

Knowledge Decomposition Task 6 Welcher theoretische Hintergrund liegt Ihrem Vorgehen beim selbstgesteuerten Lernen zugrunde? Welches Ziel verfolgen Sie mit dieser Phase?
Key Feature Task 7 Frau Hummel fragt Sie nach der nächsten Phase. Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse bei der Anwendung des neuen Wissens.
Knowledge Decomposition Task 7 Welcher theoretische Hintergrund liegt Ihrem Vorgehen bei der Anwendung des neuen Wissens zugrunde? Welches Ziel verfolgen Sie mit dieser Phase?
Key Feature Task 8 Frau Hummel fragt Sie nach der nächsten Phase. Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse bei der Abstraktion.
Knowledge Decomposition Task 8 Welcher theoretische Hintergrund liegt Ihrem Vorgehen bei der Abstraktion des neuen Wissens zugrunde? Welches Ziel verfolgen Sie mit dieser Phase?
Key Feature Task 9 Frau Hummel freut sich über Ihre bisherigen Ideen und möchte von Ihnen nun eine Beschreibung der letzten Phase. Bitte beschreiben Sie Ihre Vorgehensweise in der Klasse bei der Evaluation.

Knowledge Decomposition Task 9

Welcher theoretische Hintergrund liegt Ihrem Vorgehen bei der Evaluation zugrunde?

Welches Ziel verfolgen Sie mit dieser Phase?

L. Test for Metacognitive Competence

	stimmt überhaupt nicht	stimmt weitgehend nicht	stimmt eher nicht	stimmt ein wenig	stimmt weitgehend	stimmt genau
Ich weiß, in welchen Stoffgebieten ich gut bin.	❍	❍	❍	❍	❍	❍
Ich weiß, in welchen Stoffgebieten meine Schwächen liegen.	❍	❍	❍	❍	❍	❍
Wenn ich etwas Neues lerne, kann ich gut einschätzen, ob ich es im Alltag brauchen kann.	❍	❍	❍	❍	❍	❍
Ich weiß, wie ich beim Lernen vorgehen muss, damit ich am besten lerne.	❍	❍	❍	❍	❍	❍
Ich weiß, unter welchen Bedingungen ich am besten lernen kann.	❍	❍	❍	❍	❍	❍
Ich kann gut einschätzen, zu welchen Zeitpunkten ich am besten lernen kann.	❍	❍	❍	❍	❍	❍
Es fällt mir leicht einzuschätzen, wie lang ich für eine Aufgabe ungefähr brauche.	❍	❍	❍	❍	❍	❍
Ich kann meinen Lernfortschritt gut selbst beurteilen.	❍	❍	❍	❍	❍	❍
Beim Lernen kann ich gut einschätzen, was ich verstanden habe und was nicht.	❍	❍	❍	❍	❍	❍
Ich habe mich beim Lernen schon oft in der Einschätzung meines Wissensstands getäuscht.	❍	❍	❍	❍	❍	❍
Ich kann gut abschätzen, was ich alles (noch) nicht weiß.	❍	❍	❍	❍	❍	❍
Bevor ich mit dem Lernen beginne, lege ich fest, was ich genau schaffen möchte.	❍	❍	❍	❍	❍	❍
Wenn ich lerne, überlege ich zu Beginn genau, wie ich vorgehen möchte.	❍	❍	❍	❍	❍	❍
Ich lerne meistens einfach „drauf los“.	❍	❍	❍	❍	❍	❍
Wenn ich lerne, überlege ich zwischendurch, ob ich eigentlich sinnvoll vorgehe.	❍	❍	❍	❍	❍	❍
Ich frage mich beim Lernen immer wieder, ob ich das Gelesene auch wirklich verstanden habe.	❍	❍	❍	❍	❍	❍
Wenn ich lerne, mache ich mir nicht extra Gedanken, wie ich dabei vorgehe.	❍	❍	❍	❍	❍	❍
Wenn ich lerne, überprüfe ich hin und wieder, ob ich wirklich bei der Sache bin.	❍	❍	❍	❍	❍	❍
Wenn ich beim Lernen nicht vorankomme, überlege ich, wie ich anders vorgehen könnte.	❍	❍	❍	❍	❍	❍

Wenn ich einen schwierigen Text vorliegen habe, passe ich meine Lerntechnik den höheren Anforderungen an (z.B. durch langsameres Lesen).	❍	❍	❍	❍	❍	❍
Wenn ich etwas nicht verstehe, versuche ich herauszufinden, was es genau ist, das ich nicht verstehe.	❍	❍	❍	❍	❍	❍
Wenn ich beim Lernen etwas nicht verstehe, suche ich nach zusätzlicher Information, um die Sache klar zu machen.	❍	❍	❍	❍	❍	❍
Wenn mir beim Lesen Widersprüche oder Ungereimtheiten auffallen, versuche ich, diesen auf den Grund zu gehen.	❍	❍	❍	❍	❍	❍
Beim Lernen spüre ich, ob ich gerade besonders aufnahmefähig bin.	❍	❍	❍	❍	❍	❍
Beim Lernen weiß ich intuitiv, wie am besten zu verfahren ist.	❍	❍	❍	❍	❍	❍
Ich merke intuitiv, wann ich genug gelernt habe.	❍	❍	❍	❍	❍	❍
Nach einer Lernphase weiß ich, ob mein Lernen effektiv war oder nicht.	❍	❍	❍	❍	❍	❍

M. Test for Cognitive Load

	sehr leicht	leicht	eher leicht	weder leicht noch schwer	eher schwer	schwer	sehr schwer
Wie leicht oder schwer finden Sie das Thema „Herzinsuffizienz“?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer fällt es Ihnen, mit dieser Lernumgebung zu arbeiten?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer fällt es Ihnen, in der Lernumgebung wichtige und unwichtige Information zu unterscheiden?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer fanden Sie es, alle Informationen, die Sie brauchten, im Lernprogramm zusammenzutragen?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer war es, die Lösung der letzten Beispielaufgabe zu verstehen?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer fanden Sie es, die neuen Informationen mit dem, was Sie bereits über das Thema wussten, zu verknüpfen?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer fanden Sie es, den Gesamtzusammenhang des Lernmaterials zu verstehen?	❍	❍	❍	❍	❍	❍	❍
Wie leicht oder schwer fanden Sie es, sich den Gesamtablauf einer Lernsequenz vorzustellen?	❍	❍	❍	❍	❍	❍	❍

N. Test for Motivation

	fast nie			sehr häufi g
	0	1	2	4
Während der bisherigen Lernsitzung erlebte ich mich als neugierig oder wissbegierig.	❍	❍	❍	❍
Während der bisherigen Lernsitzung machte mir das Arbeiten Spaß.	❍	❍	❍	❍
Während der bisherigen Lernsitzung war ich von der Sache so fasziniert, dass ich alles um mich herum vergaß.	❍	❍	❍	❍
Während der bisherigen Lernsitzung fand ich das Lernen richtig spannend.	❍	❍	❍	❍
Während der bisherigen Lernsitzung hatte ich das Gefühl, mich kaum von der Sache lösen zu können.	❍	❍	❍	❍
Während der bisherigen Lernsitzung empfand ich das Lernen als anstrengend.	❍	❍	❍	❍
Während der bisherigen Lernsitzung hatte ich das Gefühl, mich zum Arbeiten zwingen zu müssen.	❍	❍	❍	❍
Während der bisherigen Lernsitzung fühlte ich mich ernst genommen.	❍	❍	❍	❍
Während der bisherigen Lernsitzung fühlte ich mich stark kontrolliert.	❍	❍	❍	❍
Während der bisherigen Lernsitzung hatte ich das Gefühl, etwas zu tun, was ich auch selber tun wollte.	❍	❍	❍	❍
Während der bisherigen Lernsitzung hatte ich das Gefühl, Entscheidungsspielräume zu haben.	❍	❍	❍	❍