digitalEDUCATION review

Designing and Evaluating Tutoring Feedback Strategies for digital learning environments on the basis of the Interactive Tutoring Feedback Model

Susanne Narciss

susanne.narciss@tu-dresden.de

Psychology of Learning and Instruction

Technische Universität Dresden, Germany

Abstract

This paper describes the interactive tutoring feedback model (ITF-model; Narciss, 2006; 2008), and how it can be applied to the design and evaluation of feedback strategies for digital learning environments. The ITF-model conceptualizes formative tutoring feedback as a multidimensional instructional activity that aims at contributing to the regulation of a learning process in order to help learners acquire or improve the competencies needed to master learning tasks. It integrates findings from systems theory with recommendations of prior research on interactive instruction and elaborated feedback, on task analyses, on error analyses, and on tutoring techniques. Based on this multi-dimensional view of formative tutoring feedback methodological implications for designing and investigating multiple effects of feedback under multiple individual and situational conditions are described. Furthermore, the paper outlines how the implications of the ITF-model have been applied in several studies to the design and evaluation of tutoring feedback strategies for digital learning environments (e.g., Narciss, 2004; Narciss & Huth, 2006; Narciss, Schnaubert, Andres, Eichelmann, Goguadze, & Sosnovsky, 2013).

Keywords

Formative tutoring feedback; Interactive instruction; Digital learning

I. Introduction

Feedback is considered one of the most powerful factors influencing learning in various instructional contexts including digital learning environments (e.g., Hattie & Timperley, 2007; Hattie & Gan, 2011). In instructional contexts the term *feedback* refers to all post-response information which informs learners about their actual state of learning or performance in order to regulate the further process of learning in the direction of the learning standards strived for (Narciss, 2008; 2012a; Shute, 2008). This notion of feedback can be traced back to early cybernetic views of feedback (e.g., Wiener, 1954), and implies that a core aim of feedback is to reduce gaps between current and desired states of learning (see also Ramaprasad, 1983; Sadler, 1989; Hattie 2009).

Feedback can be provided by various external sources of information (i.e., teachers, peers, parents, computer-based trainings) in a large variety of ways, and by internal sources of information (i.e. information perceivable by the learner while task processing). Modern information technologies increase the range of feedback strategies that can be implemented in digital learning environments.

The interactive potential of modern information technology makes it possible to provide learners not only with outcome feedback types but also with tutorial feedback strategies. *Tutorial feedback strategies* combine formative elaborated feedback with tutoring and mastery learning strategies: They provide formative evaluative feedback components that help learners to become aware of any gaps that exist between their desired and their current state of knowledge, understanding, or competencies. Additionally, they provide elaborated feedback components (e.g., hints, explanations, attribute-isolation examples) that are aimed at supporting learners in acquiring the knowledge and competencies necessary for mastering learning tasks. Thus, the focus of this elaborated information is on tutoring students to detect errors, overcome obstacles and apply more efficient strategies for solving learning tasks. In doing so *tutorial feedback strategies* offer strategically useful information for task completion without immediately providing the correct solution. Tutorial feedback strategies prompt the learner to use this strategic information to solve the learning task in a next trial. Furthermore, after successful task completion, they provide confirmatory positive feedback components (cf. Narciss, 2006; 2008; 2012a, 2012b; Narciss & Huth, 2006 describe in detail such a tutorial feedback strategy).

However, research on intelligent tutoring systems illustrates that designing and evaluating tutorial feedback strategies for digital learning environments is a very challenging task (e.g., Arroyo, Woolf, & Beal, 2006; Arroyo, Woolf, Royer, Tai, Muldner, Burleson, & Cooper, 2011; Goldin, Koedinger, & Aleven, 2012; Mitrovic, Ohlsson & Barrow, 2013). Thus, until now, many digital educational systems do not provide tutorial feedback strategies but simple feedback strategies offering knowledge of result, (e.g., by merely stating or indicating if the response is correct or incorrect, or by flagging errors), and/or knowledge of the correct response. To provide an empirical and theoretical basis for the design and evaluation of tutorial feedback strategies, Narciss (2006, 2008, 2012a, 2012b) has developed a multidimensional feedback model, hereafter referred to as the *Interactive tutoring feedback model (ITF-model).*

The purposes of this paper are first to describe the ITF-model and its implications for the design and investigation of tutoring feedback strategies. Second, studies and findings from my own research team (e.g., Narciss, 2004; Narciss, & Huth, 2006; Strijbos, Narciss & Duennebier, 2010; Narciss, Schnaubert, Andres, Eichelmann, Goguadze, & Sosnovsky, 2013) will be summarized to illustrate how the implications derived from this model can be applied to the design and evaluation of tutorial feedback strategies for digital learning environments. Finally, implications for further research and instructional design will be discussed.

II. The Interactive Tutoring Feedback Model

Recent feedback frameworks consider a learner as an active constructor of knowledge, and thus claim that the most important function of feedback is to provide learners with formative or tutoring information on their current state of learning which help them to regulate their learning process successfully (e.g., Butler & Winne 1995; Hattie & Timperley, 2007; Narciss, 2008; Nicol & Macfarlane-Dick, 2006; Hattie & Gan, 2011; Shute 2008).

Based on this view of feedback, Narciss (2006; 2008) has synthesized the theoretical and empirical insights of feedback frameworks and research (e.g., Butler & Winne, 1995; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Kulhavy & Stock, 1989; Mory, 2004) as well as research on formative assessment (e.g., Black & Wiliam, 1998; Sadler, 1989) by the **I**nteractive **t**utoring **f**eedback model. This ITF-model conceptualizes feedback as a multidimensional instructional activity that aims at contributing to the regulation of a learning process in such a way that learners acquire the knowledge and competencies needed to master learning tasks.

Conceptualizing feedback as an instructional activity that aims at contributing to the regulation of a learning process makes it possible to use the core insights provided by instructional research to analyze possible factors and effects of (tutoring) feedback strategies (see also Hattie & Gan, 2011; Hattie, 2009). Instructional models and research suggest that the effects an instructional activity can have are determined by the quality of the instructional activity (e.g. scope, nature, and structure of the information provided, and the form of presentation), individual learning conditions (e.g. prior knowledge or level of competencies, meta-cognitive strategies, motivational dispositions and strategies), as well as situational conditions of the instructional setting (e.g., instructional goals, learning content and tasks). The ITF-model links these issues with insights on feedback from systems theory (e.g., Ramaprasad, 1983) while, on the other hand, aims at integrating findings from systems theory with recommendations of prior research on formative assessment and feedback (e.g., Black & Wiliam, 1998; 2009; Nicol & Macfarlane-Dick, 2006; Sadler, 1989; Shute 2008), on self-regulated learning and feedback (e.g., Butler & Winne, 1995, Winne & Hadwin, 1998), on task analyses (cf. Jonassen, Tessmer, & Hannum, 1999), on error analyses (e.g., VanLehn, 1990), and on tutoring techniques (e.g., McKendree, 1990; Merrill, Reiser, Ranney, & Trafton, 1992; VanLehn, 2011).

Based on regulatory paradigms from systems theory, the ITF-model views feedback as one of several basic components of a generic feedback loop. However, when regulatory paradigms from systems theory are applied to an instructional context, in which learners are provided with feedback by an external feedback source (e.g., teacher, peer-student or digital instructional medium), two interacting feedback loops must be considered (see Figure 1): the learner's feedback loop and the feedback loop of the external feedback source.

The ITF-model describes the interaction among these two loops as follows:

The *controlled process* for the two interacting feedback loops consists of the acquisition of competencies (i.e., conceptual and procedural knowledge, as well as cognitive, meta-cognitive and motivational strategies and skills), necessary to master the demands associated with learning tasks. Building on models of self-regulated learning (e.g., Butler & Winne, 1995; Boekarts, 1996; Winne & Hadwin, 1998) and on current multidimensional notions of competencies (e.g., Klieme, Leutner, & Kenk, 2010), the ITFL-framework assumes that the acquisition of competencies has to be controlled on several levels, namely the cognitive, motivational, and meta-cognitive level. To determine the controlled variables in a learning process with regard to these control levels it is necessary to identify and specify the cognitive, motivational, and meta-cognitive variables which are relevant for acquiring the desired competencies.

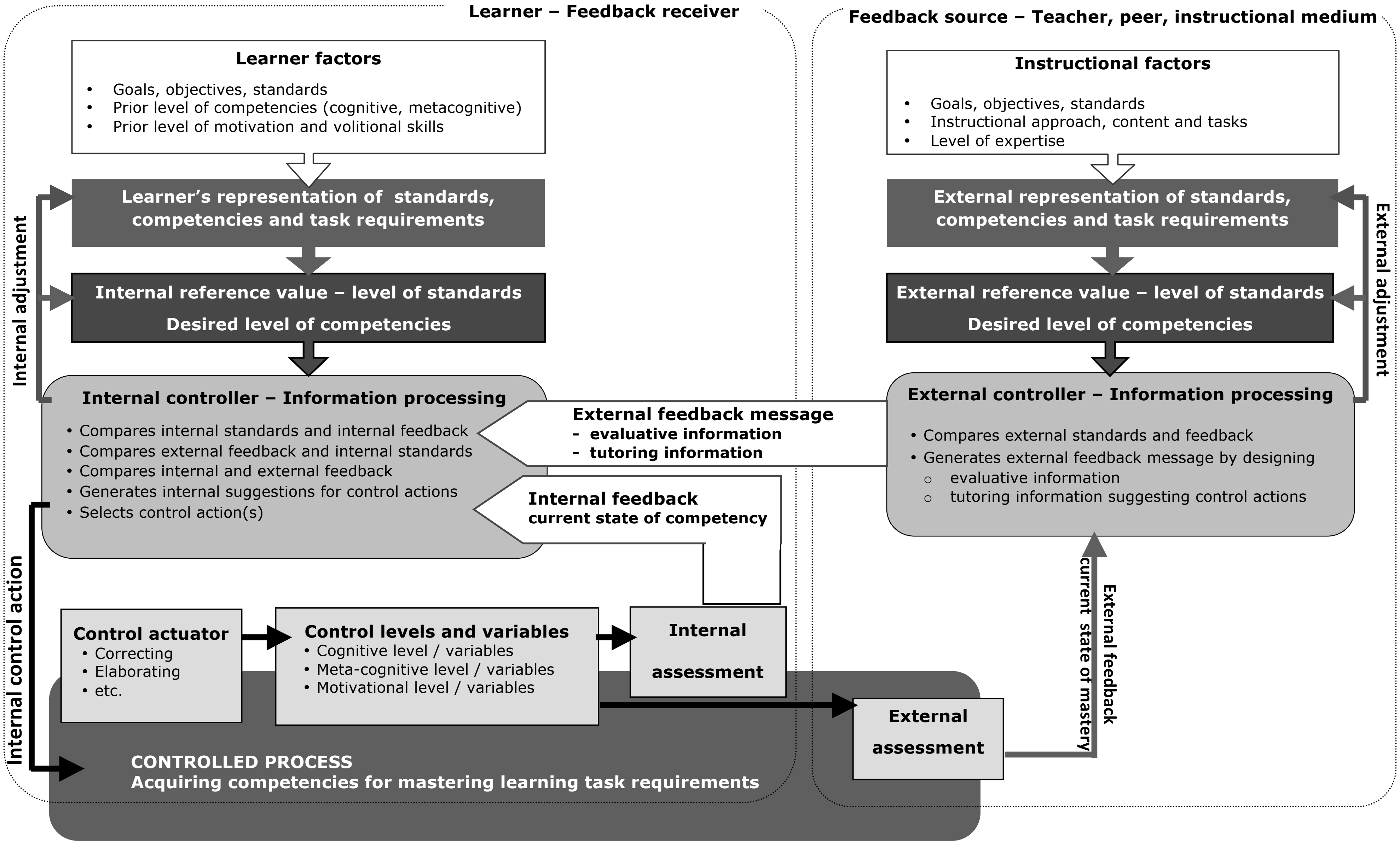

Figure 1: Components of the Interactive tutoring feedback model (ITF-model; translated and modified from Narciss, 2006, p. 70)

To regulate and control the acquisition of competencies the following elements of the internal and external feedback loops are needed:

First, for each of the controlled variables a *standard or reference level* has to be determined. The ITF-model assumes that in the learner's loop *internal standard or reference levels* are determined by the learner's *subjective representation of competencies and the related standards*. Individual learner factors such as learner's goals and prior level of competencies influence these subjective representations of competencies. In a similar manner the *external standard or reference levels* are determined by the *external representation of competencies,* and the latter are influenced by situational features of an instructional context, particularly by instructional goals or standards, approaches, content and tasks. If a teacher or peer serves as an external source of feedback their respective level of expertise or competencies has to also be considered as a factor influencing the external representation of competencies.

Second, internal and external feedback loops require that the actual state of competencies is (continuously) assessed by both the learner (*internal assessment)* and also by the external feedback source (*external assessment*). These assessments result in an *internal* and an *external feedback of the actual state of the learner's competency*.

Third, the internal and the external feedback can only be used to regulate the process of competence acquisition if in both loops there exist a controlling information processing unit *(i.e., internal and external controller* in cybernetic terms). In both controllers the feedback on the current state of competencies has to be compared to the respective desired level of competencies in order to evaluate to what extent the desired level of competence has been achieved. Based on this comparison, the *external controller* has to generate an *external feedback message.* If there is no discrepancy between the desired and the current competency state, this external feedback message may simply consist of appraising or confirming that the desired competency state has been achieved. If a gap between the desired and the current level of competencies has been detected, this external feedback message may provide evaluative information pertaining to this gap, as well as tutoring information (i.e., all kinds of suggestions for control actions that help close the gap). It is important to emphasize here that there is a very large variety of external feedback messages that can be generated by an external feedback source, and that just delivering the result of the external assessment in terms of evaluative information (e.g., grades; ranks) is only one possibility.

Fourth, the external feedback message has to be processed in the learner's *internal controller* along with the internal feedback. This means that learners have to do several comparisons before they can generate their suggestions for control actions, and select the most appropriate one: They have to compare (a) their desired and their internally assessed current state of competencies (=internal feedback), (b) their desired level of competencies with the external feedback message, and (c) their internal feedback with the external feedback message. From these processes the learner has to generate an *internal control action*. To do so, the learner has to identify the source(s) of any discrepancies that are detected between the various internal and external values. Such discrepancies can occur when, for instance, internal or external assessments are inaccurate, the quality of internal or external feedback is poor, or the subjective task representation is incorrect or imprecise and thus leads to incorrect reference values. Consequently, the external feedback message may confirm or complement the internal feedback, or it may be discrepant to the internal feedback. Based on the results of these comparisons, learners have to generate their ideas or suggestions regarding one or several control actions that may help them to proceed in the direction of the desired level of competency.

Fifth, learners have to select and transmit the *internal control action(s)* to the controlled process, where these control action(s) (e.g., error correction strategies; revision activities) have to be implemented. If learners have selected adequate control action(s), their controlled process, that is, their competence acquisition process should be improved. This improvement should result in a reduction of the discrepancy between the desired and the actualized state of competency.

III. Factors affecting feedback efficiency

The assumptions of the ITF-model outlined above lead to the conclusion that the efficient regulation of competence acquisition with external feedback may be affected by factors of both the learner (=internal loop), and the external feedback source (=external loop). Both feedback loops contribute to the regulation of the same controlled process which is characterized by the competencies necessary to accomplish the requirements of the learning task(s). Thus, the requirements of learning tasks and the related competencies constitute a third group of factors influencing the effects of a feedback strategy.

a. Requirements of learning tasks and competence acquisition

As outlined above, the starting point for both feedback loops is the process of acquiring the competencies necessary to master learning tasks in a given instructional context. This process can be more or less complex depending on the requirements of the learning tasks and the instructional objectives. In order to regulate a system successfully, it is crucial to describe its controlled process carefully and precisely. Describing the process of competence acquisition involves initially analyzing exactly what requirements are associated with the learning tasks, and what competencies are needed to master these requirements. Moreover, in order to generate control actions for the regulation of the process of competence acquisition, the errors and difficulties that could arise in connection with mastering task requirements must also be identified, as well as the information and strategies that are needed to overcome these errors or difficulties.

Bloom’s revised version of the taxonomy of learning objectives may serve as a basis for analyzing task requirements (cf. Anderson & Krathwohl, 2001). Analyzing learning task requirements on the basis of this taxonomy makes it evident that it is more difficult to precisely identify the content-related, cognitive, meta-cognitive, and/or motivational requirements for complex tasks (i.e. require higher-order knowledge and operations) than for simple tasks. Hence, identifying and precisely describing the underlying competencies is more difficult for complex than for simple tasks. Yet, a precise description of competencies provides the basis for (a) identifying the relevant control variables and their respective standards, (b) assessing the current state of these control variables, and (c) generating control actions. In other words, if a precise description of competencies is missing, a learner and also an external feedback source (e.g., teacher, peer, instructional medium) cannot know which competencies are needed to master task requirements, and thus can neither reliably assess them, nor generate feedback or actions for improving these competencies. When designing formative feedback strategies for learning environments it is thus crucial to conduct thorough task analyzes in order to describe the competencies necessary for mastering the tasks.

b. Internal loop factors – learner factors

The ITF-model suggests that the quality of processing in the internal loop (= learner’s loop) depends on several learner factors:

- *Learner’s representation of standards, competencies, and task requirements*: learners have to understand and represent task requirements and the related competencies. Whether learners are able to represent task requirements adequately and precisely depends on the complexity of these requirements, but also on individual factors such as *learner’s prior level of competencies* (i.e., knowledge, meta-cognitive knowledge and strategies, motivation).

- *Learner’s self-assessment skills:* Learners have to monitor and assess their process of learning or competence acquisition in order to generate their internal feedback. This internal feedback can be compared to the learner’s desired level of competence, and to the external feedback. It may thus serve, at least to some extent, as a frame of reference for the external feedback. Hence, learner’s monitoring or self-assessment skills have to be considered an important factor for the processing of the external feedback.

- *Learner’s skills and strategies in information processing:* Learners have to process the internal and external feedback and compare them to their desired level of competencies, and generate control actions. Thus, a further learner factor identified by several reviews and meta-analyses of feedback research is learner’s proficiency in mindfully processing and integrating information from several sources.

- *Learner's will and skills in overcoming errors and obstacles.* As shown in studies on feedback seeking, even the most sophisticated feedback is useless if learners do not attend to it (e.g., Aleven, Stahl, Schworm, Fischer, & Wallace, 2003; Narciss, Koerndle, Reimann, Mueller 2004) or are not willing to invest time and effort in error correction. Aside from will, students also need the skills necessary for accomplishing the requirements related to error correction. Butler and Winne (1995) derived six maladaptive ways of feedback seeking and processing from Chinn and Brewer's (1993) work on how misconceptions may hinder conceptual change: Students may (a) ignore the external feedback, (b) reject the external feedback, (c) judge the external feedback irrelevant, (d) consider external and internal feedback as unrelated, (e) reinterpret external feedback in order to make it conform to the internal feedback, (f) make superficial rather than fundamental changes to their knowledge and/or beliefs. In all these cases the effect of the external feedback will be small.

Note that all these internal factors may promote or constrain how well learners will be able to improve their competencies in the direction of the desired standards if they are provided with formative tutoring feedback messages by an external feedback source. Thus, the ITF-model suggests taking these learner factors into account when designing and investigating feedback strategies for (digital) learning environments.

c. External loop factors – factors of the external feedback source

The ITF-model also attracts attention to the following external loop factors which might contribute to the efficiency of both feedback loops:

- *Quality of external representation of standards, competencies, and task requirements:* As in the internal loop, the starting point for most processes in the external loop is a precise identification and description of the competencies necessary for mastering learning task requirements. Based on this description, an external representation of these competencies and requirements, as well as the external level of standards has to be determined by the external feedback source. In the case of a human external feedback source (e.g., a teacher or peer), the quality of this external representation and definition of standards may vary depending on the level of (instructional) expertise of this external feedback source. In a digital learning environment, the external feedback can also be provided by a digital device (e.g., pedagogical agent, computer-driven feedback). In this case, technical characteristics as well as the level of instructional design expertise, on which the design of this digital system has been based, will influence the quality of the external representation of standards and competencies. For complex tasks in particular, a precise representation of what constitutes a high level of competencies in mastering the task requirements may be difficult for teachers, peers or instructional designers (Sadler, 1989).

- *Quality of external assessment:* The accurate and reliable assessment of a learner's current level of competence is a necessary precondition for making meaningful comparisons between the desired and the current levels of competencies. To do so the external feedback sources have to work out which indicators are appropriate for measuring different levels of competencies in a valid and reliable way.

- *Quality of external data processing:* Making meaningful comparisons between the assessed level of competence and the desired level of competence also depends on how well the external feedback source processes the information at hand.

- *Quality of design and communication of external feedback:* A core factor influencing the power of a feedback strategy is the quality of the feedback message generated by the external feedback source. For example, if a discrepancy between the desired and the current level of competence is detected the external feedback source has to generate suggestions for control actions that may reduce this discrepancy. Key issues here are, how well does the external feedback source (a) understand why learners did not master the task requirements at the desired level, (b) identify which external feedback information may be provided to the learners in order to help them acquire the lacking competences or improve their week competences, and (c) communicate this external feedback to the learners in such a way that learners will attend to it and process it mindfully.

IV. Implications for the design of (tutoring) feedback strategies

The ITF-model implies that researchers and designers have to adopt a multidimensional view of feedback in order to design and investigate formative feedback strategies, in particular formative tutoring feedback strategies with complex elaborated feedback messages (Narciss, 2008; see also Narciss & Huth, 2004; Shute 2008; see also Hattie & Timperely, 2007; Hattie & Gan, 2011; Thurlings, Vermeulen, Bastiaens, & Stijnen, 2013).

This multidimensional view includes considering at least three facets of a feedback message to determine the nature and quality of the feedback message (Narciss & Huth, 2006, Narciss 2012b):

Feedback scope and functions: Feedback can affect the learning process at various levels, and can therefore have numerous different functions. It can for example acknowledge, confirm, or reinforce correct responses or high quality learning outcomes, and in doing so promote the acquisition of the knowledge and cognitive operations necessary for accomplishing learning tasks (e.g., Mitrovic, Ohlsson, & Barrow, 2013). Feedback can also contribute to correcting errors, misconceptions, or inadequate task processing strategies. Moreover, it can prompt the application of metacognitive strategies (e.g., Butler & Winne, 1995; Mathan & Koedinger, 2005), or encourage students in maintaining their effort and persistence (e.g., Hoska, 1993; Narciss, 2004; 2008). Based on the models of "good information processors" (Pressley 1986), "intelligent novices" (Mathan & Koedinger, 2005), self-regulated learning (Boekarts, 1996; Winne & Hadwin, 1998), as well as Kluger and DeNisi's feedback intervention theory (Kluger & DeNisi, 1996), Narciss (2006, 2008) suggests classifying the widely varying feedback functions as cognitive, meta-cognitive, and motivational (see fig. 2).

Feedback content: The large and quickly growing body of feedback research reveals that the above mentioned feedback functions have been addresses by a large variety of feedback types and strategies, which also vary widely regarding their content (see Hattie and Timperley, 2007; Mory, 2004, Narciss, 2008; Shute, 2008; Thurlings et al., 2013, for recent reviews). Rooted in different instructional approaches, instructional designers and researchers have for example investigated the conditions and effects of the following feedback types:

- knowledge of performance, providing learners with a summative feedback after they have responded to a set of tasks or accomplished a complex assignment (e.g., percentage of correctly solved tasks; number of errors; grade)
- knowledge of result, providing learners with information on the correctness or quality of their actual response or outcome (e.g., correct/incorrect; flagging errors; good job)
- knowledge of the correct response, providing the correct response or a sample solution to a given task
- elaborated feedback, providing additional information besides knowledge of result or knowledge of the correct response (e.g., hints, guiding questions, explanations, worked examples). Since there is a variety of elaborated information that might be added to knowledge of result, Narciss (2008) suggests using at least five different categories in order to make a more subtle distinction regarding feedback types with elaborated feedback content:
    - knowledge about task constraints, offering information on task rules, task constraints and/or task requirements
    - knowledge about concepts, addressing conceptual knowledge by providing for example response-contingent hints on concept attributes, or attribute-isolation examples
    - knowledge about mistakes, offering information on errors or mistakes (e.g., flagging location of errors; or providing hints on error type or error sources)
    - knowledge about how to process the task, addressing procedural knowledge (e.g., task-contingent hints about procedural skills or problem solving strategies)

- knowledge about meta-cognition, eliciting meta-cognitive knowledge and strategies necessary for self-regulating the learning process (e.g., topic-contingent hints about useful sources of information).

The findings of studies comparing several feedback types differing in their content are rather mixed. Some studies demonstrate for example positive effects of elaborated feedback types, while others show no effect or even negative feedback effects (for further details see the reviews by Kluger & DeNisi, 1986; Mory, 2004; Narciss, 2008; Shute, 2008; Thurlings et al. 2013).

Feedback presentation: Feedback types also vary widely in the way they present or communicate the feedback content to the learner. Formal and technical issues related to the presentation of the feedback content constitute another facet of feedback instructional designers or all other types of external feedback sources have to cope with. In order to present for example the feedback content, it is necessary to determine the (a) feedback timing (e.g., immediate, delayed), (b) feedback scheduling (e.g., single try, multiple try, answer until correct), (c) codes and modes of feedback representation and delivery, and (d) adaptation strategy (e.g., non-adaptive, adaptive, adaptable, mixed-initiative or shared-control adaptation).

Figure 2 summarizes the design implications of the ITF-model and reveals that in order to design a *tutoring feedback strategy,* instructional designers and researchers first have to develop an adequate understanding and representation of the relevant competencies, and determine the desired standards for these competencies. To do so, they have to analyze the conditions of the instructional context, for example, by conducting cognitive task analyses. Second, they have to analyze the conditions and characteristics of the learner or more generally, the feedback receiver, as well as of the available feedback source(s). Based on these analyses, instructional designers and researchers may design the tutoring feedback strategy by developing a coordinated plan which integrates clear and decisive statements regarding the following issues (Narciss, 2012):

(a) What facet(s) of competencies should the feedback help to improve (*feedback scope and functions*)?

(b) Given the selected functions, what external post-response information should the feedback provide (*feedback content*)?

(c) When and how should the selected feedback content be conveyed to the learner (*feedback timing and presentation*)?

Unfortunately, the large body of feedback research provides either rather inconsistent or not enough findings concerning the effects of feedback conditions and facets (for further details see Narciss, 2008). However, several authors have derived prescriptive principles for designing formative tutoring feedback strategies from recent feedback and formative assessment frameworks (e.g., Narciss & Huth, 2004; Narciss, 2008; 2012b; Nicol & MacFarlane-Dick, 2006; Shute, 2008). Narciss (2012b, p. 1292) summarizes these prescriptive principles as follows: "Good feedback strategies should empower students as self-regulated and productive lifelong learners. Consequently, they should be rather interactive than just transmission focused and include the following steps: First, communicate the criteria and standards of high quality task processing and completion in order to help students develop an adequate representation of how to accomplish successfully the task requirements related to a high level of performance. Second, initiate self-assessment with regard to the relevant assessment standards and make self-assessment overt. In other words, help students to generate and use internal feedback which elicits the criteria they have met as well as those they have not (yet) met. Third, indicate the externally assessed level of performance and relate it to both, the standards aimed for and the self-assessed level of performance. Fourth, initiate reflection on corrective actions for closing gaps between the current level of performance and the standards. Fifth, provide tutoring information (i.e., hints, guiding questions, explanations, analogies) to help students select and apply adequate corrective actions if they fail to do so without assistance. Sixth, offer occasions for engaging in corrective actions which apply the tutoring feedback information (i.e., further attempts to accomplish task requirements) in order to improve learning and the level of performance. Seventh, elicit progress and emphasize successful attainments of high quality standards."

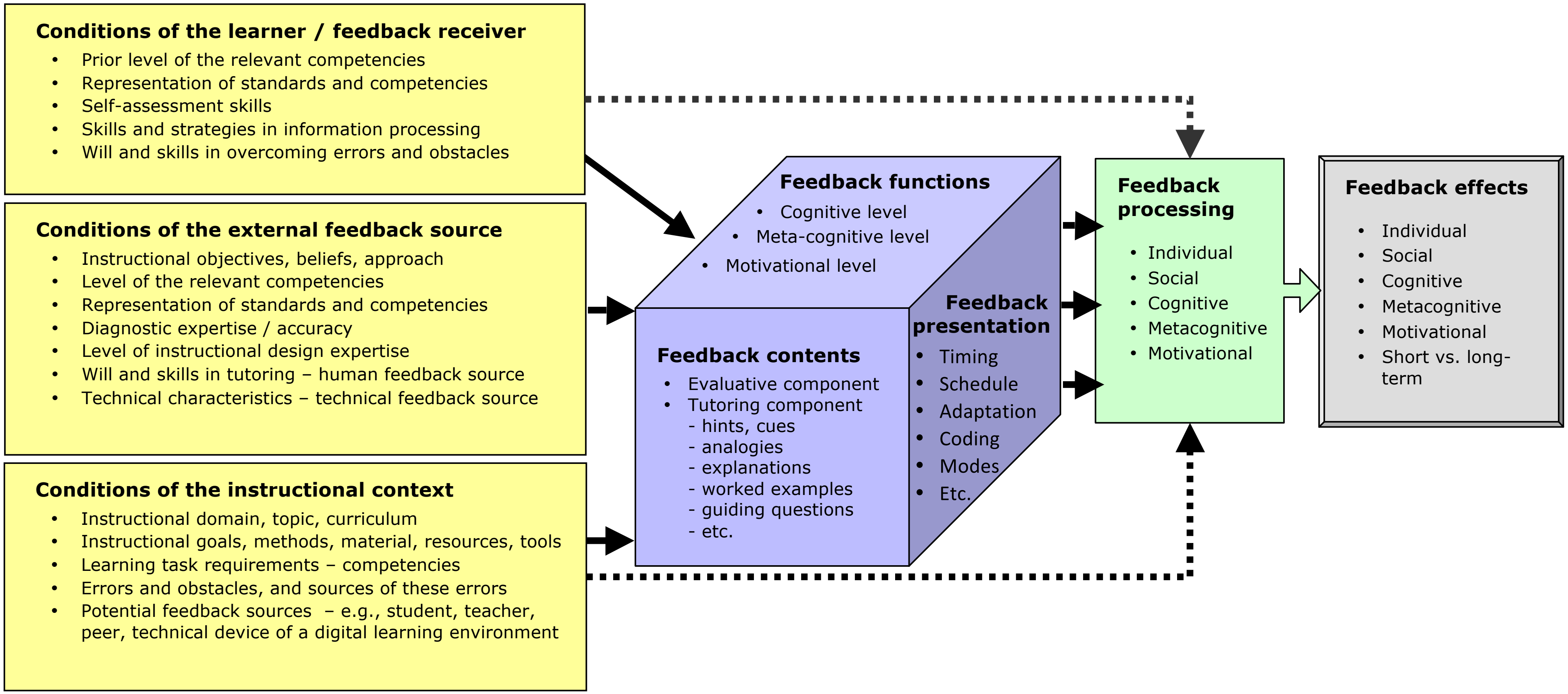

Figure 2: Conditions and factors influencing feedback processing and effects (modified from Narciss, 2012)

V. Implications for the evaluation of (tutoring) feedback strategies

The ITF-model suggests that the effects of a (formative tutoring) feedback strategy can be manifold depending on the properties of the feedback strategy, the various conditions and factors of the feedback receiver (i.e., learner), the feedback source, and the instructional context. In order to investigate the effects of various types of external feedback strategies, researchers are thus faced with the following challenges (Narciss, 2006):

- *Multiple design varieties:* Feedback messages and strategies, in particular, formative tutoring feedback strategies are multi-dimensional, and can thus be designed in many different ways. This large number of design varieties for external feedback strategies is reflected in a growing number of labels used to refer to the feedback messages or strategies investigated. Since new labels do not always refer to new kinds of feedback messages or strategies, it is very difficult to compare the findings of feedback studies. Thus, a first important step in evaluating the effects of feedback strategies is to describe accurately the content-related, formal and functional differences between the feedback messages or strategies under investigation. In terms of the various feedback dimensions and facets described above a detailed description of a feedback strategy also includes that the instructional setting under investigation must be carefully described, particularly its specific goals, typical learning tasks, and the competencies underlying these learning tasks. Moreover, the intended functions, the content of the selected feedback components, and the mode and form of feedback presentation must be described. Furthermore, it is necessary to indicate whether, and if applicable how instructional goals and feedback, typical errors and feedback, and individual learning level and feedback are tailored to each other.

Feedback functions	**Anticipated effects**	**Indicators for anticipated effects**	
		Observable	Reportable, i.e. assessed by items/scales
Cognitive level • inform • complete • correct • specify • restructure	• Recognize errors • Acquire lacking knowledge • Correct incorrect knowledge • Specify inaccurate knowledge • Correct incorrect associations	• Number of errors corrected • Number of trials until correct • Number of task types for which mastery is achieved • Number of tasks the learner needed to achieve mastery	• Response certitude • Assessment of number of errors • Assessment of feedback's usefulness
Metacognitive level • Informing • Completing • Correcting • Guiding	• Recognize incorrect strategies • Acquire missing strategies • Correct incorrect strategies • Attract attention to strategies	• Information retrieval • Specific task processing steps • Specific strategies • Conditions under which strategies are applied	
Motivational level • Increase incentive • Decrease task difficulty • Increase probability of success • Associate success to effort • Increase probability of positive perceptions of competence	• Task values increase • Task engagement increases • Expectations of success increase • Self-efficacy increases • Attribution patterns change • Effort increases • Perseveration increases • Positive self assessments are more likely	• Number of tasks processed • Amount of time spent on – task processing – feedback processing • Number of tasks learners gave up • Number of tasks skipped	• Assessment of task values • Assessment of task enjoyment • Assessment of willingness to task engagement • Assessment of task difficulty • Attributions • Expectations (e.g., self efficacy) • Perceived performance level • Degree of satisfaction with performance

Table 1: Overview on indicators for investigating cognitive, meta-cognitive, and motivational feedback effects (adopted from Narciss, 2006, p. 93)

- *Multiple effect levels and functions:* Effects of external feedback messages or strategies may occur on several levels of the process of competence acquisition, because during competence acquisition, feedback may not only promote changes in observable outcomes, but also in the cognitive, meta-cognitive, and motivational skills and strategies necessary to achieve these outcomes. Furthermore, these different effects may have a cumulative, complementary, or interactive impact on learning outcomes (e.g., level of knowledge, meta-cognitive and motivational skills, or transfer performance; see for example Goodman, Wood, & Chen, 2011). This in turn means that investigating the effects of external feedback necessitates not only global performance metrics but also specific indicators for the measurement of differential effects on the various effect levels and outcomes. Table 1 illustrates how such indicators can be worked.

- *Multiple effect times and periods:* Closely related to the issue of the effect levels and functions of feedback are the issues of when and how long the feedback messages or strategies have an impact on competency acquisition. External feedback can contribute to changes that occur (a) during the treatment of current problem performance (e.g., reduce the time or number of trials to achieve mastery; see for example Mitrovic et al. 2013; Narciss & Huth, 2006), (b) after a short delay (e.g., improve next problem performance, support performance in an immediate post-test), or (c) after a far delay (e.g., retention and/or transfer of competencies). Thus, a complete picture of the effects of various feedback strategies can be obtained only if researchers use complex designs including data collected during and after the treatment.

- *Multiple feedback conditions:* The ITF-model reveals that the effects of an external feedback message or feedback strategy do not occur in general, but emerge differentially depending on the various conditions and factors of the feedback receiver (i.e., learner), the feedback source, and the instructional context. For example, given the factors and conditions outlined above, the amount of time it takes for a student to correct an error with the help a tutoring feedback message is influenced by (a) the type of error and the sources of these errors, which originate in the type, complexity, and difficulty of the tasks and their underlying competencies, (b) the individual characteristics of the learner; (c) the quality of the tutorial feedback strategy; and (d) if and how the learner uses the feedback for correcting these errors. Consequently, studies on tutoring feedback strategies should either control the relevant feedback conditions or even investigate if they have moderating or mediating effects.

- *Multiple ways of feedback processing:* The effects of various feedback strategies largely depend on if and how learners process and interpret the information provided. In addition to the cognitive factors of the learner (e.g. prior knowledge, strategic knowledge), above all, individual motivational factors such as self-efficacy and perceived task values, and individual meta-cognitive factors such as monitoring competencies and strategies play a role here. Hence, in order to draw differentiated conclusions about the effects of various types of feedback, not only cognitive but also individual motivational and meta-cognitive factors and the nature of students’ feedback processing are worth being controlled.

- *Variability of error rate:* External tutoring feedback messages can only be effective if the students have occasions to receive them, that is, if they make errors, encounter obstacles, or experience uncertainty during task processing. If students are highly proficient and confident about their proficiency, they will make few or no errors, and thus have only few occasions to benefit, for example, from elaborated tutoring feedback messages. Hence, the individual error rate determines how often students are provided with feedback, in particular with tutoring feedback messages. To cope with this problem, several researchers have selected students with a high error rate for participating in their feedback studies and found that elaborated formative feedback components were more effective than simple outcome feedback (e.g., Collins, Carnine, & Gersten, 1987, Salas & Dickinson 1990, Narciss & Huth 2006).

- *Variability of error types:* External tutoring feedback messages are considered to be most effective if their content is tailored to task requirements and competencies, or even to systematic errors. However, in complex tasks a variety of different errors may occur (e.g., more or less severe errors, more or less systematic errors) and the sources of errors may vary (see for example Eichelmann, Narciss, Schnaubert, & Melis, 2012). Moreover, VanLehn's work on bug-migration reveals that, if students encounter an impasse (i.e., fail with regard to a difficult task requirement), the errors, which they make due to this impasse, may vary from trial to trial (VanLehn, 1990; see also Wittmann, 2013).

These challenges reveal that investigating the benefits of tutoring feedback strategies is a very difficult task, which can hardly be accomplished with simple experimental designs (see also Price, Handley, Millar, & O'Donovan, 2010).

VI. Design and research based on the Interactive tutoring feedback model

My research team has applied and is currently applying the implications from the ITF-model both to the design and investigation of system-provided tutoring feedback strategies (e.g., Narciss, 2004; Narciss, & Huth, 2006; Schnaubert, Andres, Narciss, Eichelmann, Goguadze, & Melis, 2011), as well as to the investigation of feedback strategies provided by teachers or peer-students (Strijbos, Narciss & Duennebier, 2010). The following sections summarize the methodological strategies, insights and findings of some of these studies.

a. Tutoring feedback for concept formation tasks (Narciss, 2004)

The ITF-model illuminates that individual and situational feedback conditions may influence if and how tutoring feedback strategies may be differentially beneficial. As mentioned above, it is thus necessary to control the relevant feedback conditions or examine if they moderate or mediate the effects of the feedback strategy. Thus, the two studies reported in Narciss (2004) aimed to investigate if and how, as well as, under what situational conditions learners' motivational characteristics (we focused on self-efficacy) influence the impact of tutoring feedback on learners' achievement and motivation when solving concept formation tasks.

More specifically, these studies examined the assumption that, dependent on learner's self-efficacy, there are differential effects of tutoring feedback strategies on achievement and motivation (namely, task engagement, effort, persistence, and satisfaction with performance). This assumption was derived from theories and research on motivation suggesting that students' self-perceptions of competence (e.g., academic self-efficacy, academic self-concept) affect subsequent motivation in an activity (Bandura, 1977, 1997; Heckhausen, 1991; Wigfield & Eccles, 2000; 2002).

To investigate this assumption we used Bruner's concept formation task (Bruner, Goodnow & Austin, 1956) for the following reasons: First, this experimental concept formation task was novel to learners and thus, it offered enough occasions for providing the tutoring feedback. Second, prior research using this task provides empirical insights into the cognitive requirements and typical errors of this task. Based on these insights we developed the content of the tutoring feedback hints. Third, this concept formation task uses subject-independent stimulus-material, and thus affords the ability to tackle the problem of subject-related motivational differences (i.e., high vs. low interest) that may interfere or mask the effects of the tutoring feedback.

In two experiments, students differing in their self efficacy for such concept formation tasks worked on a set of concept identification tasks. In cases of incorrect hypothesis about the concept, they received feedback according to their experimental conditions. These experimental feedback conditions were designed by combining several feedback components with a multiple-try strategy offering subsequent tries to the given item after incorrect hypothesis: The first feedback component provided outcome feedback (KR); subjects were told if their hypothesis about the concept was right or wrong. The second feedback condition consisted of outcome feedback and information on the location of mistakes (e.g., card 5 does not fit your hypothesis). The third feedback condition contained outcome feedback, location of mistakes, and a hint on how to proceed (i.e., do not ignore the cards that are negative instances of the given concept, as they provide useful information).

Since the major goal of the studies was the investigation of the motivational benefits of the tutoring feedback strategy, we used a free-choice procedure in the first experiment (i.e., students were totally free to decide the number of tasks they would engage and the amount of time and persistence they would invest). Since this free-choice paradigm allowed students to quit the learning process after the first task, we were faced with a drop-out problem, particularly for students with low and medium levels of self-efficacy. However, students who quit the process after the first task did not have enough occasions to benefit from the tutoring feedback strategy. In the first study, the tutoring feedback was thus only beneficial for students with high self-efficacy. Thus, in the second experiment, students were forced to spend 90 minutes working with the tasks. Within these 90 minutes they were however allowed to work at their own pace. Within this constraint-choice procedure, the tutoring feedback proved to be beneficial for all students' achievement and motivation (see Narciss, 2004, 2006 for further details). These two studies reveal that tutoring feedback strategies can only become fully effective for students with low self-efficacy if these students do not have the chance to quit the learning process too early.

b. Bug-related tutoring feedback for written subtraction (Narciss & Huth, 2004, 2006)

Bug-related feedback refers to all types of feedback messages providing corrective information in relation to typical systematic errors (cf. Schimmel, 1988). Based on the ITF-model and on prior research on written subtraction (e.g., Brown & VanLehn, 1980; VanLehn, 1990) Narciss and Huth (2004; 2006) developed a computer-based training with tutoring feedback strategies for written subtraction offering bug-related feedback messages. To do so, we first conducted cognitive task and error analyses in order to identify which requirements of written subtraction tasks might be considered a source of typical errors. Based on these analyses (a) the scope and functions of the tutoring feedback strategy (i.e., helping students to acquire the competencies necessary to solve written subtraction tasks, as well as fostering their motivation), (b) the contents of the bug-related feedback messages, and (c) formal and technical aspects of presenting the feedback messages were specified (see Narciss & Huth, 2004; 2006 for further details).

The resulting bug-related tutoring feedback strategy provided formative tutoring feedback messages with strategically useful information for correcting typical subtraction errors, and prompted the learners to apply this information to correct their error in the next trial with the given task. It was implemented using a multi-trial schedule with up to three trials:

After the first trial, learners solving a task incorrectly received knowledge of result (KR) and the prompt to try again (i.e., "Sorry, there is an error, try again"). Note that after the first trial the error is not immediately flagged, this is done in order to allow the correction of slips, and the self identification of errors. Furthermore, KR might be sufficient if learners are able to identify and check their own errors.

After the second trial, learners solving the task incorrectly again, were provided with KR together with bug-related strategic information. In cases of a systematic error, location of error is indicated through colored marking and a hint concerning the type and source of the error is provided. In cases of an unsystematic error, location of error is indicated and a hint to use a worked-out example is provided. In both cases learners are offered the possibility to try again.

After the third trial, if learners failed again to solve the task correctly, they received KR together with knowledge on how to proceed in the form of a walk-through worked-out example demonstrating step by step how to solve the given task correctly.

All the feedback messages were provided acoustically by "Subtratino" a pedagogical agent. Error flagging (i.e., colored marking of the error location) and hinting information were presented visually. To tailor the tutoring feedback levels to the learner's level of competency, the second and third levels of feedback were only provided if learners needed it. If learners solved the task correctly, they received confirmatory KR (i.e., "Great job! You correctly applied the rule (…)"). After students had correctly computed a task, corrected errors, or after they had received the third level of feedback, they were offered the opportunity to apply their (newly acquired) knowledge in a subsequent task with the same task requirement. Students were provided with a new type of task including another task requirement if they had achieved the mastery level, that is, if they succeeded in solving two subsequent tasks with the same task requirement on the first trial.

In two studies with fourth-graders, the effects of this bug-related tutoring feedback strategy on students' achievement and motivation were compared to the effects of a widely used computer-based feedback strategy providing knowledge of result after a first trial, and knowledge of the correct response after the second trial (KR-KCR-feedback strategy; see Narciss, 2006; Narciss & Huth, 2004; 2006 for a detailed description). In order to cope with the evaluation challenges outlined above, we selected students with a low level of competency as participants for these studies (i.e., students who had solved correctly less than 50% of the pre-test tasks). Furthermore, we used a multivariate pre-test – treatment – post-test design, including several achievement variables (i.e., pre- and post-test-performance, corrective efficiency, number of task types for which mastery level was achieved), as well as domain-specific motivational variables (i.e., perceived competence in solving written subtraction tasks). We assumed that the bug-related tutoring feedback strategy is more powerful than the KR-KCR-feedback strategy in promoting (a) error correction and achievement in the treatment phase, (b) post-test achievement and error correction from pre-test to post-test, and (c) students' motivation. The results of both studies confirmed these hypotheses (Narciss, 2006; Narciss & Huth, 2006).

c. Tutoring feedback for fraction tasks - Task with typical-errors paradigm

The studies summarized so far addressed the methodological problems related to the variability of students' error rate and error types by using either learning tasks students had no prior experience with (Narciss, 2004), or a selective sample of participants (Narciss & Huth, 2006). Another possibility to respond to the methodological complexity raised by the ITF-framework is to investigate the effects of tutoring feedback strategies in a task with typical-errors paradigm.

The core component of such a task with typical-errors paradigm is a set of specifically worked-out learning tasks which contain one (or several) specific task-requirements and one (or several) typical errors related to these task requirements. The selection of these task-requirements and typical errors should be based on cognitive task and error analyses.

These worked-out tasks with typical-errors (TWTE) can be used to collect data on how students with different levels of achievement, motivation, and meta-cognitive skills detect the sources of different types of errors and whether they correct these errors with or without different external (tutorial) feedback components and strategies.

Within the TWTE paradigm all students are provided with the same types of errors. Hence, it can be used to answer research questions which are particularly important for designing and evaluating (adaptive) tutoring feedback types. Such research questions are for example:

- Which errors have a high probability to be corrected without external tutorial feedback?
- Which external tutorial feedback components support error correction most effective for which kind of errors?
- How are learner variables, namely prior achievement, motivation, and meta-cognitive skills related to the corrective efficiency of the various feedback components?
- How do learners accept, attend to, and process different feedback components?

Furthermore, the TWTE paradigm allows for addressing not only generative skills (i.e. cognitive skills required for successful task processing) but also meta-cognitive skills (namely assessing worked-out task solutions, detecting errors and/or sources of errors, and correcting errors) necessary for effective feedback processing (cf. Mathan & Koedinger, 2005).

Given these potentials of the TWTE-paradigm we used it in our research project "Adaptive tutoring Feedback" (AtuF1). The main goal of this project is to develop and evaluate adaptive tutoring feedback strategies for fractions tasks provided by the web-based mathematics education system ActiveMath. ActiveMath offers access to various mathematical learning objects including a large variety of learning tasks and exercises with various types of feedback (for details on ActiveMath see Melis, Goguadze, Homik, Libbrecht, Ullrich, & Winterstein, 2006).

---

[1] This work was supported by the DFG - Deutsche Forschungsgemeinschaft (Grants *ME 1136/8-1* and *NA 738/10-1*.

In the first phase of the project AtuF we conducted cognitive task and error analyses of fraction tasks. These analyses resulted in the development of a domain ontology represented in OWL and in the definition of interoperable fraction competencies (Eichelmann, Narciss, Faulhaber, & Melis, 2008; Melis, Faulhaber, Eichelmann, & Narciss, 2008). In the next step we developed a set of interactive fraction tasks explicitly addressing some of the basic fraction competencies, and included in each of these tasks one of the typical errors identified through a review of empirical fraction error analyses (Eichelmann, et al. 2012). Furthermore, we developed, piloted, and iteratively revised a set of tutoring hints and explanations addressing the conceptual and procedural knowledge needed to correct these typical errors. These tutoring hints and explanations were then combined into multi-trial tutoring feedback strategies providing students with a tutoring hint after a first failure, and a tutoring explanation after a second failure. In order to be able to track in detail how students use the tutoring feedback for their task processing, we developed a special interface – providing students with structured templates that allow the progressive solutions of fraction exercises (STEPS-interface, for further details see Eichelmann, Narciss, Schnaubert, Melis, & Goguadze, 2011; Narciss, et al., 2013).

To gain information on (a) the effects of the developed tutoring feedback components and strategies, and (b) the relationships among learner variables and these effects, we conducted an experimental study with the set of TWTE and the developed tutoring feedback strategies. In a pre-test-treatment-post-test control group design, sixth and seventh graders worked in the treatment with TWTE-tasks. In the error-correction part of the TWTE, students were asked to replace the erroneous step by a correct solution. If their correction failed, they received tutoring feedback and were asked to try again. After the third trial or a correct solution, they received a worked-out solution and moved on to the next task.

We conducted detailed logfile-analyses with the data of this study in order to explore the influence of content-related properties of feedback (i.e., the type of knowledge communicated by the feedback-content: procedural vs. conceptual; and feedback specificity that is the level of elaboration of the feedback messages: hint vs. explanation), and learner characteristics (i.e., prior competency level, gender, motivational variables) on behavioural process variables; namely succeeding vs. failing in correcting the error of a TWTE, and skipping vs. trying to correct an error after feedback was provided. Both variables characterize the immediate learner reaction to the feedback messages observable in their problem solving activity, and, as such, can serve as indicators of the feedback effectiveness.

In summary, the main findings of these logfile analyses reveal that the impact of pre-assessed individual learner characteristics is rather variable across task types and task steps. Gender was the only learner characteristic with a relatively stable impact: male students’ knowledge gain was significantly lower under all feedback conditions, but particularly under feedback strategies providing first a conceptual hint. Moreover, after conceptual feedback hints or explanations students skipped more frequently, and succeeded less often to correct the error. All other differential effects occurred less consistently (Narciss et al., 2013). This result indicates that it is important to gain further insights into the dynamic interplay among the individual learner characteristics and situational feedback conditions.

VII. Conclusions

Using the ITF-model as the theoretical framework for the studies summarized above revealed that the ITF-model provides a valuable basis for systematically designing tutoring feedback strategies for various learning tasks including concept formation tasks, math tasks, as well as study tasks on learning theories (e.g., Narciss, Proske, & Körndle, 2007), and writing assignments (e.g., Strijbos, Narciss, Duennebier, 2010). For all the tasks we used so far it was possible to determine rather precisely, what constitutes a correct or highly competent solution of these tasks, and which competencies are needed to master them. Since, performing task and error analyses for ill-structured knowledge domains is difficult and rather costly, if and how the design implications of the ITF-model can be applied to the design of feedback strategies for supporting competence acquisition in ill-structured knowledge domains is an open issue for further research.

Furthermore, the application of the design principles derived from the ITF-model in further various instructional contexts raises further interesting issues for feedback design and research: Concerning computer-based or networked collaborative learning contexts empirical research on the effects of formative peer feedback strategies for both the feedback sender and the feedback receiver would be valuable. Moreover, with regard to technology enhanced blended learning environments, special interest should be devoted to teacher education and instructional design issues such as how to combine human and technical sources of feedback in order to design and implement formative multi-source feedback strategies.

Our studies illuminated some strengths but also limitations of applying the ITF-model to the evaluation of tutoring feedback strategies. The ITF-model shows that tutoring feedback messages can only have an impact on students' learning if students have occasions to use the feedback information for regulating their learning process. Thus, we implemented tutoring feedback messages in multi-trial feedback strategies in all our studies. These multi-trial feedback strategies provided students with up to three trials to correct errors, and students were free to skip trials and work at their own pace. Furthermore, they received the next level of feedback only if they needed it. Through the studies conducted with these multi-trial feedback strategies we obtained rich data sets which allowed us to investigate at least partly how feedback conditions, feedback properties and student's feedback processing may enhance or inhibit the process of competence acquisition. Yet, besides the methodological challenges outlined above, we were faced with further challenges, including students variability in working pace, number of trials needed to correct an error, as well as skipping and drop-out rates. Tackling these evaluation challenges as well as the one's described above opens interesting fields of research for interdisciplinary teams of cognitive and educational psychologists, instructional scientists and designers, artificial intelligence and computer science researchers.

References

Aleven, V., Stahl, E., Schworm, S., Fischer, F., & Wallace, R. (2003). Help seeking and help design in interactive learning environments. *Review of Educational Psychology*, *62*, 148-156.

Anderson, L.W., & Krathwohl, D.R., (Eds.) (2001). *A taxonomy for learning, teaching, and assessing. A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Arroyo, I. Woolf, B.P., & Beal, C.R. (2006). Addressing cognitive differences and gender during problem solving. *International Journal* of *Technology, Instruction, Cognition and Learning, 4, 31-63.*;

Arroyo, I., Woolf, B.P., Royer, J.M., Tai, M., Muldner, K., Burleson, W., & Cooper, D. (2011). The Impact of Animated Pedagogical Agents on Girls' and Boys' Emotions, Attitudes, Behaviors and Learning. In *Proceedings of the 2011 IEEE 11th International Conference on Advanced Learning Technologies (ICALT) (pp. 506-510).* doi: 10.1109/ICALT.2011.157

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. Psychological Review, 84(2), 191-215.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York, NY: W. H. Freeman/Times Books/Henry Holt & Co

Black, P., & Wiliam, D. (1998). Assessment and classroom learnig. *Assessment in Education, 5,* 7-74.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability,* 21*,* 5-31.

Boekaerts, M. (1996). Self-regulated learning at the junction of cognition and motivation. *European Psychologist*, *1*, 100-112.

Brown, J. S. & VanLehn, K. (1980). Repair theory: A generative theory of bugs in procedural skills. *Cognitive Science*, *4*, 379-426.

Bruner, J. S., Goodnow, J. J. & Austin, G. A. (1956). *A study of thinking.* Oxford, England: John Wiley and Sons.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, *65*, 245-281.

Chinn, C.A., & Brewer, W.F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research*, *63*, 1-49.

Collins, M., Carnine, D. & Gersten, R. (1987). Elaborated corrective feedback and the acquisition of reasoning skills: A study of computer-assisted instruction. *Exceptional Children*, *54*, 254-262.

Eichelmann, A., Andres, E., Schnaubert, L., Narciss, S., & Sosnovsky, S. (2012). Interaktive Fehler-Finde-und-Korrektur-Aufgaben - Eine Akzeptanz- und Usability-Studie bei Sechstund Siebtklässlern. In G. Csanyi, F. Reichl, & A. (Hrsg.), Digitale Medien Werkzeuge für exzellente Forschung und Lehre (S. 401-412). Münster: Waxmann.

Eichelmann, A., Narciss, S., Schnaubert, L., & Melis, E. (2012). Typische Fehler und Fehlerquellen bei der Addition und Subtraktion von Brüchen – Ein Review zu empirischen Fehleranalysen. *Journal für Mathematik-Didaktik,* 33, 29–57.

Eichelmann, A., Narciss, S., Schnaubert, L., Melis, E. & Goguadze, G. (2011). Design und Evaluation von interaktiven webbasierten Bruchrechenaufgaben. In H. Rohland, A. Kienle & S. Friedrich (Hrsg.), DeLFI 2011 – Die 9. e-Learning Fachtagung Informatik (S. 31-42). Bonn: Köllen Verlag.

Eichelmann, A., Narciss, S., Faulhaber, A., & Melis, E. (2008). Analyzing computer-based fraction tasks on the basis of a two-dimensional view of mathematics competencies. In J. Zumbach, N. Schwartz, T. Seufert, & L. Kester (Eds.), *Beyond knowledge: The legacy of competence. Meaningful computer-based learning environments* (pp. 125-134). Dordrecht: Springer.

Goldin, I.M., Koedinger, K.R., & Aleven, V. (2012) Learner differences in hint processing. In Yacef, K., Zaïane, O., Hershkovitz, H., Yudelson, M., & Stamper, J. (Eds.). *Proceedings of the 5th International Conference on Educational Data Mining* (pp. 73-80). ;

Goodman, J.S., Wood, R.E., & Chen, Z. (2011). Feedback specificity, information processing, and transfer of training. *Organizational behavior and human decision processes,* 115 253-267.

Hattie, J.A. (2009*). Visible Learning. A synthesis of over 800 meta-analyses relating to achievement.* London & New York: Routledge.

Hattie, J.A., & Gan, M. (2011). Instruction based on Feedback. In Mayer, R & Alexander, P. (Eds). *Handbook of Research on Learning and Instruction (*pp. 249–271*).* New York: Routledge

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*, 81-112.

Heckhausen, H. (1991). Motivation and action. Heidelberg: Springer.

Hoska, D. M. (1993). Motivating learners trough CBI feedback: Developing a positive learner perspective. In J. V. Dempsey, & G. C. Sales (Eds.), *Interactive instruction and feedback* (pp. 105-131). Englewood Cliffs, NJ: Educational Technology Publications.

Jonassen, D. H., Tessmer, M., & Hannum, W. H. (1999). Classifying knowledge and skills from task analysis. In D. H. Jonassen, M. Tessmer, & W. H. Hannum (Eds.), *Task analysis methods for instructional design* (pp. 25-32). Mahwah, NJ: Lawrence Erlbaum Associates.

Klieme, E., Leutner, D., & Kenk, M. (2010). Kompetenzmodellierung. *Zeitschrift für Pädagogik*. 56 , 9-11.

Kluger, A. N., & DeNisi, A. (1996). Effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, *119*, 254-284.

Kulhavy, R. W. & Stock, W. A. (1989). Feedback in written instruction: The place of response certitude. *Educational Psychology Review*, *1*, 279-308.

Mathan, S.A., & Koedinger, K.R. (2005). Fostering the intelligent novice: Learning from errors with meta-cognitive tutoring. *Educational Psychologist, 40*, 257-265.

McKendree, J. (1990). Effective feedback content for tutoring complex skills. *Human-Computer Interaction*, *5*, 381-413.

Melis, E., Faulhaber, A., Eichelmann, A., & Narciss, S. (2008). Interoperable Competencies Characterizing Learning Objects in Mathematics. In B. Woolf et al. (Eds.), *Intelligent Tutoring System, Lecture Notes in Computer Science 5091 (pp.* 416-425). Berlin: Springer.

Melis, E., Goguadze, G., Homik, M., Libbrecht, P., Ullrich, C. and Winterstein, S. (2006), Semantic-aware components and services of ActiveMath. British Journal of Educational Technology, 37: 405–423. doi: 10.1111/j.1467-8535.2006.00613.x

Merrill, D. C., Reiser, B. J., Ranney, M., & Trafton, J. G. (1992). Effective tutoring techniques: A comparison of human tutors and intelligent tutoring systems. *The Journal of Learning Sciences*, *2*, 277-305.

Mitrovic, A., Ohlsson, S., & Barrow, D.K. (2013). The effect of positive feedback in a constraint-based intelligent tutoring system. *Computers & Education,* 60, 264-272.

Mory, E.H. (2004). Feedback research revisited. In D.H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd Edition) (pp. 745-783). Mahwah, NJ: Lawrence Erlbaum Associates.

Narciss, S. (2004). The impact of informative tutoring feedback and self-efficacy on motivation and achievement in concept learning. *Experimental Psychology, 51*(3), 214-228.

Narciss, S. (2006). Informatives tutorielles Feedback. Entwicklungs- und Evaluationsprinzipien auf der Basis instruktionspsychologischer Erkenntnisse. Reihe Pädagogische Psychologie und Entwicklungspsychologie, Band 56. Münster: Waxmann.

Narciss, S. (2008). Feedback strategies for interactive learning tasks. In J.M. Spector, M.D. Merrill, J.J.G. van Merrienboer, & M.P. Driscoll (Eds.), *Handbook of Research on Educational Communications and Technology (3rd ed., pp. 125-144)*. Mahaw, NJ: Lawrence Erlbaum Associates.

Narciss, S. (2012a). Feedback in instructional contexts. In N. Seel (Ed.), *Encyclopedia of the Learning Sciences*, Volume F(6), pp. 1285-1289. New York: Springer Science & Business Media, LLC.

Narciss, S. (2012b). Feedback strategies. In N. Seel (Ed.), *Encyclopedia of the Learning Sciences*, Volume F(6), pp. 1289-1293. New York: Springer Science & Business Media, LLC.

Narciss, S. & Huth, K. (2004). How to design informative tutoring feedback for multi-media learning. In H. M. Niegemann, D. Leutner & R. Brünken (Eds.), *Instructional design for multimedia learning* (pp. 181-195). Münster: Waxmann.

Narciss, S. & Huth, K. (2006). Fostering achievement and motivation with bug-related tutoring feedback in a computer-based training on written subtraction. *Learning and Instruction*, 16, 310-322.

Narciss, S., Körndle, H. Reimann, G., & Müller. C. (2004). Feedback-seeking and feedback efficiency in web-based learning – How do they relate to task and learner characteristics? In P. Gerjets, P.A. Kirschner, J. Elen, & R. Joiner (Eds.), *Instructional design for effective and enjoyable computer- supported learning. Proceedings of the first joint meeting of the EARLI SIGs Instructional Design and Learning and Instruction with Computers (pp. 377-388).* Tuebingen: Knowledge Media Research Center.

Narciss, S., Proske, A. & Körndle, H. (2007). Promoting Self-regulated learning in Web-based Learning Environments. *Computers and Human Behavior. 23,* 1126-1144. doi:10.1016/j.chb.2006.10.006

Narciss, S., Schnaubert, L., Andres, E., Eichelmann, A., Goguadze, G., & Sosnovsky, S. (2013). Exploring feedback and student characteristics relevant for personalizing feedback strategies. *Manuscript submitted for publication to Computers & Education.*

Nicol, D.J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. *Studies in Higher Education,* 31, 199-218.

Pressley, M. (1986). The relevance of the good strategy user model to the teaching of mathematics. *Educational Psychologist*, *21*, 139-161.

Price, M., Handley, K., Millar, J., & O'Donovan, B. (2010). Feedback: all that effort, but what is the effect? *Assessment & Evaluation in Higher Education*, 35, 277–289

Ramaprasad, A. (1983). On the definition of feedback. *Behavioral Science,* 28, 4-13.

Sadler, D.R. (1989). Formative assessment and the design of instructional systems. *Instructional Science,* 18, 119-144.

Salas, S. B. & Dickinson, D. J. (1990). The effect of feedback and three different types of corrections on student learning. *Journal of Human Behavior & Learning*, *7*, 13-19.

Schimmel, B. J. (1988). Providing meaningful feedback in courseware. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 183-195). Hillsdale, NJ, England: Lawrence Erlbaum Associates.

Schnaubert, L., Andrès, E., Narciss, S., Eichelmann, A., Goguadze, G., & Melis, E. (2011). Student Behavior in Error-Correction-Tasks and Its Relation to Perception of Competence. In C. Delago Kloos, D. Gillet, R. Crespo Garcìa, F. Wild, & M. Wolpers (Eds.) *Towards Ubiquitous Learning, Proceedings of the 6th European Conference on Technology Enhanced Learning* (pp. 370 - 383). Berlin: Springer.

Shute, V.J. (2008). Focus on formative feedback. *Review of Educational Research*, 78, 153-189.

Strijbos, J.W., Narciss, S., & Duennebier, K. (2010). Peer feedback content and sender's competence level in academic writing revision tasks: Are they critical for feedback perceptions and efficiency? *Learning and Instruction, 20,* 291-303.

Thurlings, M., Vermeulen, M., Bastiaens, T., & Stijnen, S. (2013). Understanding feedback: A learning theory perspective. *Educational Research Review, 9*, 1-15.

VanLehn, K. (1990). Mind bugs: The origins of procedural misconceptions. Cambridge, MA: The MIT Press.

VanLehn, K., Lynch, C., Schulze, K., Shapiro, J.A., Shelby, R., Taylor, L., Treacy, D., Weinstein, A., &, Wintersgill, M. (2005). The Andes Physics Tutoring System: Lessons Learned. *International Journal of Artificial Intelligence in Education*, 15 147-204.

VanLehn, K. (2011). The Relative Effectiveness of Human Tutoring, Intelligent Tutoring Systems, and Other Tutoring Systems. *Educational Psychologist,* 46, 197-221.

Wiener, N. (1954). *The human use of human beings: Cybernetics and society.* Oxford, England: Houghton Mifflin.

Wigfield, A. & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, *25*, 68-81.

Wigfield, A. & Eccles, J. S. (2002). *Development of achievement motivation.* San Diego, CA: Academic Press.

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. Hacker, J. Dunlosky & A. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277-304). Mahwah, NJ: Lawrence Erlbaum.

Wittmann, G. (2013). The consistency of students' error patterns in solving computational problems with fractions. Retrieved 3.3.2013 from http://cerme8.metu.edu.tr/wgpapers/WG2/WG2_Wittmann.pdf

Acknowledgement

This work was partly supported by the DFG - Deutsche Forschungsgemeinschaft - project *ATuF: Adaptive Tutoring Feedback* (Grants *ME 1136/8-1* and *NA 738/10-1)*.

Recommended citation

Narciss, S. (2013). Designing and Evaluating Tutoring Feedback Strategies for digital learning environments on the basis of the Interactive Tutoring Feedback Model. In: *Digital Education Review*, *23,* 7-26. [Accessed: dd/mm/yyyy] http://greav.ub.edu/der

Copyright

Subscribe & Contact DER