Review of Educational Research

http://rer.aera.net

Focus on Formative Feedback

Valerie J. Shute

REVIEW OF EDUCATIONAL RESEARCH 2008; 78; 153
DOI: 10.3102/0034654307313795

The online version of this article can be found at:
http://rer.sagepub.com/cgi/content/abstract/78/1/153

Published on behalf of

American Educational Research Association

http://www.aera.net

By

SAGE

http://www.sagepublications.com

Additional services and information for *Review of Educational Research* can be found at:

Email Alerts: http://rer.aera.net/cgi/alerts

Subscriptions: http://rer.aera.net/subscriptions

Reprints: http://www.aera.net/reprints

Permissions: http://www.aera.net/permissions

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Review of Educational Research
March 2008, Vol. 78, No. 1, pp. 153–189
DOI: 10.3102/0034654307313795
© 2008 AERA. http://rer.aera.net

Focus on Formative Feedback

Valerie J. Shute
Florida State University

This article reviews the corpus of research on feedback, with a focus on formative feedback—defined as information communicated to the learner that is intended to modify his or her thinking or behavior to improve learning. According to researchers, formative feedback should be nonevaluative, supportive, timely, and specific. Formative feedback is usually presented as information to a learner in response to some action on the learner's part. It comes in a variety of types (e.g., verification of response accuracy, explanation of the correct answer, hints, worked examples) and can be administered at various times during the learning process (e.g., immediately following an answer, after some time has elapsed). Finally, several variables have been shown to interact with formative feedback's success at promoting learning (e.g., individual characteristics of the learner and aspects of the task). All of these issues are discussed. This review concludes with guidelines for generating formative feedback.

KEYWORDS: formative feedback, learning, performance.

It is not the horse that draws the cart, but the oats.

—Russian proverb

Feedback used in educational contexts is generally regarded as crucial to improving knowledge and skill acquisition (e.g., Azevedo & Bernard, 1995; Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Corbett & Anderson, 1989; Epstein et al., 2002; Moreno, 2004; Pridemore & Klein, 1995). In addition to its influence on achievement, feedback is also depicted as a significant factor in motivating learning (e.g., Lepper & Chabay, 1985; Narciss & Huth, 2004). However, for learning, the story on feedback is not quite so rosy or simple.

According to Cohen (1985) feedback "is one of the more instructionally powerful and least understood features in instructional design" (p. 33). In support of this claim, consider the hundreds of research studies published on the topic of feedback and its relation to learning and performance during the past 50 years (for excellent historical reviews, see Bangert-Drowns et al., 1991; Kluger & DeNisi, 1996; Kulhavy & Stock, 1989; Kulhavy & Wager, 1993; Mory, 2004; Narciss & Huth, 2004). Within this large body of feedback research, there are many conflicting findings and no consistent pattern of results.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Definition of Formative Feedback

Formative feedback is defined in this review as information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning. And although the teacher may also receive student-related information and use it as the basis for altering instruction, I focus on the student (or more generally, the "learner") as the primary recipient of formative feedback herein.

The premise underlying most of the research conducted in this area is that good feedback can significantly improve learning processes and outcomes, if delivered correctly. Those last three words—"if delivered correctly"—constitute the crux of this review.

Goals and Focus

The dual aims of this article are to (a) present findings from an extensive literature review of feedback to gain a better understanding of the features, functions, interactions, and links to learning and (b) apply the findings from the literature review to create a set of guidelines relating to formative feedback. The overarching goal is to identify the features of formative feedback that are the most effective and efficient in promoting learning, and to determine under what conditions that learning support holds. This is not an easy task. The vast literature reveals dozens of feedback types that have been subjected to experimental scrutiny—for example, accuracy of the solution, topic contingent, response contingent, attribute isolation, worked examples, hints, and partial solutions. However, different studies report disparate findings regarding the same feedback variable. In addition, formative feedback variables have been shown to interact with other variables, such as student achievement level, task level, and prior knowledge.

This review focuses on *task-level feedback* as opposed to general summary feedback. Task-level feedback typically provides more specific and timely (often real-time) information to the student about a particular response to a problem or task compared to summary feedback and may additionally take into account the student's current understanding and ability level. For instance, a struggling student may require greater support and structure from a formative feedback message compared to a proficient student. Summary information is useful for teachers to modify instruction for the whole class and for students to see how they are generally progressing. The intended audience for this article includes: educators (e.g., teachers and administrators) seeking to improve the quality of student learning in the classroom using well-crafted feedback, cognitive psychologists and instructional system designers interested in researching and developing more effective learning environments, graduate students in search of meaningful research to pursue, and others who are interested in harnessing the power of feedback to support teaching and learning—in the classroom, workplace, or even the home.

Some of the major questions addressed in this review include: What are the most powerful and efficient types of formative feedback, and under what conditions do these different types of feedback help a learner revise a skill or improve his or her understanding? What are the mechanisms by which feedback facilitates the transformation of rudimentary skills into the competence of a more expert

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

state? Answers to these questions can facilitate the design and development of teacher-delivered or automated feedback to support learning.

This article begins with a summary of the methods used to accomplish the literature review, followed by an extensive review of formative feedback research, which makes up the bulk of the article. Afterward, I showcase four important feedback articles, each associated with a theoretically and empirically based model of formative feedback. I conclude with specific recommendations for using formative feedback that are supported by the current literature review and discuss future research in the area.

Method

Procedure

Seminal articles in the feedback literature were identified (i.e., from sites that provide indices of importance such as CiteSeer), and then collected. The bibliography compiled from this initial set of research studies spawned a new collection-review cycle, garnering even more articles, and continuing iteratively throughout the review process.

The following online databases were employed in this search–collection effort:

- *ERIC,* a database on educational reports, evaluations, and research from the Educational Resources Information Center, consisting of Resources in Education Index, and *Current Index to Journals in Education.*
- *PsycINFO,* from the American Psychological Association, which carries citations and summaries of scholarly journal articles, book chapters, books, and dissertations, in psychology and related disciplines.
- *PsycARTICLES,* a source of full-text, peer-reviewed scholarly and scientific articles in psychology. The database covers general psychology and specialized, basic, applied, clinical, and theoretical research. It contains articles from 56 journals (45 published by the American Psychological Association and 11 from allied organizations).
- *Academic Search Premier,* a multidisciplinary full-text database offering information in many areas of academic study including: computer science, engineering, physics, language and linguistics, and so forth.
- *MasterFILE Premier,* designed specifically for public libraries, and covering a broad range of disciplines including general reference, business, education, health, general science, and multicultural issues.

In addition to these databases, online catalogs were used at the libraries of the Educational Testing Service and University of Pennsylvania to access their electronic collections of journals and research studies. Google Scholar was also employed—a Web site providing peer-reviewed papers, theses, books, abstracts, and articles from academic publishers, professional societies, preprint repositories, universities, and other scholarly organizations—to search for and acquire specific references.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Inclusion Criteria

The focus of the search was to access full-text documents using various search terms or keywords such as *feedback, formative feedback, formative assessment, instruction, learning, computer-assisted/based, tutor, learning,* and *performance.* The search was not limited to a particular date range, although slight preference was given to more recent research. In all, approximately 170–180 articles, dissertations, abstracts, books, and conference proceedings were collected. From this larger set, a total of more than 100 documents met the criteria for inclusion in the literature review. The inclusion criteria consisted of topical relevance, use of experimental design, and meta-analytic procedures. The majority of the documents were journal articles (103), followed by books and book chapters (24), conference proceedings (10), and "other" (e.g., research reports; 4).

Literature Review

There have been hundreds of articles written about feedback and its role in knowledge and skill acquisition. Many of these articles describe the results from experimental tests examining different features of feedback, and several represent important historical reviews (a few going back to the early 1900s, such as Kluger & DeNisi, 1996; Kulhavy & Stock, 1989; Mory, 2004). Despite the plethora of research on the topic, the specific mechanisms relating feedback to learning are still mostly murky, with very few (if any) general conclusions. Researchers who have tackled the tough task of performing meta-analyses on the feedback data use descriptors such as "inconsistent," "contradictory," and "highly variable" to describe the body of feedback findings (Azevedo & Bernard, 1995; Kluger & DeNisi, 1996). Ten years later those descriptors still apply.

Feedback has been widely cited as an important facilitator of learning and performance (Bandura, 1991; Bandura & Cervone, 1983; Fedor, 1991; Ilgen, Fisher, & Taylor, 1979), but quite a few studies have reported that feedback has either no effect or debilitating effects on learning (for examples of nonfacilitative effects of feedback on learning, see Bangert-Drowns et al., 1991; Kluger & DeNisi, 1996; Mory, 2004). In fact, about one third of the total studies reviewed in two landmark meta-analyses (i.e., Bangert-Drowns et al., 1991; Kluger & DeNisi, 1996) demonstrate negative effects of feedback on learning. For instance, feedback that is construed as critical or controlling (Baron, 1993) often thwarts efforts to improve performance (Fedor, Davis, Maslyn, & Mathieson, 2001). Other features of feedback that tend to impede learning include: providing grades or overall scores indicating the student's standing relative to peers, and coupling such normative feedback with low levels of specificity (i.e., vagueness) (Butler, 1987; Kluger & DeNisi, 1998; McColskey & Leary, 1985; Wiliam, 2007; Williams, 1997). In addition, when a student is actively engaged in problem solving and interrupted by feedback from an external source, this too has been shown to inhibit learning (Corno & Snow, 1986). In line with the definition in this review, *feedback that has negative effects on learning is not formative.*

Feedback Purposes

The main aim of formative feedback is to increase student knowledge, skills, and understanding in some content area or general skill (e.g., problem solving), and there are multiple types of feedback that may be employed toward this end

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

(e.g., response specific, goal directed, immediately delivered). In addition to various formats of feedback, there are different functions. According to Black and Wiliam (1998), there are two main functions of feedback: *directive* and *facilitative*. Directive feedback is that which tells the student what needs to be fixed or revised. Such feedback tends to be more specific compared to facilitative feedback, which provides comments and suggestions to help guide students in their own revision and conceptualization. The next section describes some of the ways feedback may exert influences on student learning.

Cognitive Mechanisms and Formative Feedback

There are several cognitive mechanisms by which formative feedback may be used by a learner. First, it can signal a gap between a current level of performance and some desired level of performance or goal. Resolving this gap can motivate higher levels of effort (Locke & Latham, 1990; Song & Keller, 2001). That is, formative feedback can reduce uncertainty about how well (or poorly) the student is performing on a task (Ashford, 1986; Ashford, Blatt, & VandeWalle, 2003). Uncertainty is an aversive state that motivates strategies aimed at reducing or managing it (Bordia, Hobman, Jones, Gallois, & Callan, 2004). Because uncertainty is often unpleasant and may distract attention away from task performance (Kanfer & Ackerman, 1989), reducing uncertainty may lead to higher motivation and more efficient task strategies.

Second, formative feedback can effectively reduce the cognitive load of a learner, especially novice or struggling students (e.g., Paas, Renkl, & Sweller, 2003; Sweller, Van Merriënboer, & Paas, 1998). These students can become cognitively overwhelmed during learning due to high performance demands and thus may benefit from supportive feedback designed to decrease the cognitive load. In fact, Sweller et al. (1998) provided support for this claim by showing how the presentation of worked examples reduces the cognitive load for low-ability students faced with a complex problem-solving task. Moreno (2004) provided additional support using explanatory feedback to support novice learners.

Finally, feedback can provide information that may be useful for correcting inappropriate task strategies, procedural errors, or misconceptions (e.g., Ilgen et al., 1979; Mason & Bruning, 2001; Mory, 2004; Narciss & Huth, 2004). The corrective function effects appear to be especially powerful for feedback that is more specific (Baron, 1988; Goldstein, Emanuel, & Howell, 1968), described next.

Feedback Specificity

Feedback specificity is defined as the *level of information* presented in feedback messages (Goodman, Wood, & Hendrickx, 2004). In other words, specific (or elaborated) feedback provides information about particular responses or behaviors beyond their accuracy and tends to be more directive than facilitative.

Several researchers have reported that feedback is significantly more effective when it provides details of how to improve the answer rather than just indicating whether the student's work is correct or not (e.g., Bangert-Drowns et al., 1991; Pridemore & Klein, 1995). Feedback lacking in specificity may cause students to view it as useless, frustrating, or both (Williams, 1997). It can also lead to uncertainty about how to respond to the feedback (Fedor, 1991) and may require greater information-processing activity on the part of the learner to understand the intended

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

message (Bangert-Drowns et al., 1991). Uncertainty and cognitive load can lead to lower levels of learning (Kluger & DeNisi, 1996; Sweller et al., 1998) or even reduced motivation to respond to the feedback (Ashford, 1986; Corno & Snow, 1986).

In an experiment testing feedback specificity and its relationship to learning, Phye and Sanders (1994) tested two types of feedback (i.e., *general* advice vs. *specific* feedback, the latter providing the learner with the correct answer). Students were assigned to one of the two learning conditions and received either general advice or specific feedback as part of a verbal analogy problem-solving task. In line with the research cited previously, they found that the more specific feedback was clearly superior to general advice on a retention task. However, they found no significant differences between feedback types on a transfer task. They caution against assuming that procedures that enhance performance during acquisition (e.g., providing specific feedback) will necessarily enhance transfer to new tasks.

In summary, providing feedback that is specific and clear, for conceptual and procedural learning tasks, is a reasonable, general guideline. However, this may depend on other variables, such as learner characteristics (e.g., ability level, motivation) and different learning outcomes (e.g., retention vs. transfer tasks). In addition, the specificity dimension of formative feedback itself is not very "specific" as described in the literature. More focused feedback features are now reviewed.

Features of Formative Feedback

In an excellent historical review on feedback, Kulhavy and Stock (1989) reported that effective feedback provides the learner with two types of information: verification and elaboration. Verification is defined as the simple judgment of whether an answer is correct, and elaboration is the informational aspect of the message, providing relevant cues to guide the learner toward a correct answer. Researchers appear to be converging toward the view that effective feedback should include elements of both verification and elaboration (e.g., Bangert-Drowns et al., 1991; Mason & Bruning, 2001). These features are now described in more detail.

Verification

Confirming whether an answer is correct or incorrect can be accomplished in several ways. The most common way involves simply stating "correct" or "incorrect." More informative options exist—some of which are explicit and some more implicit. Among explicit verifications, highlighting or otherwise marking a response to indicate its correctness (e.g., with a checkmark) can convey the information. Implicit verification can occur when, for instance, a student's response yields expected or unexpected results (e.g., within a simulation). This review focuses more on explicit than implicit feedback as it is more readily subject to experimental controls.

Elaboration

Feedback elaboration has even more variations than verification. For instance, elaboration can (a) address the topic, (b) address the response, (c) discuss the particular error(s), (d) provide worked examples, or (e) give gentle guidance. The first three types of elaborated feedback are more specific and directive, and the last two types are more general and facilitative.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Elaborated feedback usually addresses the correct answer, may explain why the selected response is wrong, and may indicate what the correct answer should be. There seems to be growing consensus that one type of elaboration, response-specific feedback, appears to enhance student achievement, particularly learning efficiency, more than other types of feedback, such as simple verification or "answer until correct" (e.g., Corbett & Anderson, 2001; Gilman, 1969; Mory, 2004; Shute, Hansen, & Almond, 2007). However, as is discussed in a later section, feedback specificity has been shown to affect performance by way of an interaction with learners' goal orientations.

Feedback Complexity and Length

Although more specific feedback may be generally better than less specific feedback (at least under certain conditions), a related dimension to consider is length or complexity of the information. For example, if feedback is too long or too complicated, many learners will simply not pay attention to it, rendering it useless. Lengthy feedback can also diffuse or dilute the message. Feedback complexity thus refers to how much and what information should be included in the feedback messages.

Many research articles have addressed feedback complexity, but only a few have attempted to array the major variables along a dimension of complexity (albeit, see Dempsey, Driscoll, & Swindell, 1993; Mason & Bruning, 2001; Narciss & Huth, 2004). I have aggregated information from their respective lists into a single compilation (see Table 1), arrayed generally from least to most complex information presented. Terms appearing in the "feedback type" column are used throughout the remainder of this article.

If formative feedback is to serve a corrective function, even in its simplest form it should (a) verify whether the student's answer is right or wrong and (b) provide information to the learner about the correct response (either directive or facilitative). Studies that have examined the type and amount of information in feedback, however, have shown inconsistent results (see Kulhavy, 1977, and Mory, 2004, for summaries of the range of results). Specific findings on the feedback complexity issue are described next.

No Effect of Feedback Complexity

Schimmel (1983) performed a meta-analysis on feedback as used in computer-based instruction (CBI) and programmed (scripted) instruction. He analyzed the results from 15 experimental studies and found that the amount of information (i.e., feedback complexity) was *not* significantly related to feedback effects. He also found that feedback effects were significantly larger in computer-based than in programmed instruction.

Sleeman, Kelly, Martinak, Ward, and Moore (1989) examined conflicting findings in the literature concerning the diagnosis and remediation of students' errors. They noted that few studies have systematically compared the effects of different styles of error-based feedback, and of those that have, the results are inconclusive. For instance, Swan (1983) found that a conflict approach (pointing out errors made by students and demonstrating their consequences, classified in Table 1 as "bugs/misconceptions") was more effective than reteaching (classified in Table 1

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

TABLE 1
Feedback types arrayed loosely by complexity

Feedback type	Description
No feedback	Refers to conditions where the learner is presented a question and is required to respond, but there is no indication as to the correctness of the learner's response.
Verification	Also called "knowledge of results" or "knowledge of outcome." It informs the learners about the correctness of their responses (e.g., right–wrong, or overall percentage correct).
Correct response	Also known as "knowledge of correct response." Informs the learner of the correct answer to a specific problem, with no additional information.
Try again	Also known as "repeat-until-correct" feedback. It informs the learner about an incorrect response and allows the learner one or more attempts to answer it.
Error flagging	Also known as "location of mistakes." Error flagging highlights errors in a solution, without giving correct answer.
Elaborated	General term relating to the provision of an explanation about why a specific response was correct or not and may allow the learner to review part of the instruction. It may or may not present the correct answer (see below for six types of elaborated feedback).
Attribute isolation	Elaborated feedback that presents information addressing central attributes of the target concept or skill being studied.
Topic contingent	Elaborated feedback providing the learner with information relating to the target topic currently being studied. May entail simply reteaching material.
Response contingent	Elaborated feedback that focuses on the learner's specific response. It may describe why the incorrect answer is wrong and why the correct answer is correct. This does not use formal error analysis.
Hints/cues/prompts	Elaborated feedback guiding the learner in the right direction, e.g., strategic hint on what to do next or a worked example or demonstration. Avoids explicitly presenting the correct answer.
Bugs/misconceptions	Elaborated feedback requiring error analysis and diagnosis. It provides information about the learner's specific errors or misconceptions (e.g., what is wrong and why).
Informative tutoring	The most elaborated feedback (from Narciss & Huth, 2004), this presents verification feedback, error flagging, and strategic hints on how to proceed. The correct answer is not usually provided.

as "topic contingent" feedback), but Bunderson and Olsen (1983) found no difference between these two feedback approaches.

To untangle these conflicting findings, Sleeman et al. (1989) conducted three studies that explicitly compared error-specific or model-based remediation (MBR;

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

bugs/misconceptions) with simply reteaching the algebra content (topic-contingent feedback). MBR bases its feedback on a model of student errors, whereas reteaching simply shows students a correct procedure and answer without addressing specific errors. Their results showed that MBR (more complex approach) and reteaching (simpler approach) are both more effective than no tutoring; however, MBR was *not* more effective than reteaching. The results are discussed in terms of stability of errors and their relevance to educational practice and to intelligent tutoring systems. Although the studies were carried out using human tutors, the results suggest that for the purpose of feedback in the algebra domain, when taught procedurally, feedback based on just reteaching content was found to be as effective as feedback based on more expensive error analyses.

Negative Effects of Feedback Complexity

Kulhavy, White, Topp, Chan, and Adams (1985) similarly examined the feedback complexity issue. They tested a group of college undergraduates who read a 2,400-word passage, responded to 16 multiple-choice questions about it, and received one of four types of feedback, increasing in complexity, following their responses. Feedback complexity was systematically varied. The lowest level was simply *correct answer* feedback, and the most complex feedback included a combination of verification, correct answer, and an explanation about why the incorrect answer was wrong with a pointer to the relevant part of the text passage where the answer resided. The main finding was that complexity of feedback was *inversely* related to both ability to correct errors and learning efficiency (i.e., the ratio of feedback study time to posttest score). Specifically, Kulhavy et al. showed that more complex versions of feedback had a small effect on students' ability to correct their own errors, and the least complex feedback (i.e., correct answer) demonstrated greater learner benefits in terms of efficiency and outcome than complex feedback.

In summary, the inconclusive findings on feedback complexity suggest that there may be other mediating factors involved in the relationship between formative feedback and learning. For instance, instead of feedback complexity, a more salient facet of feedback may be the nature and quality of the content, such as providing information about learning goals and how to attain them.

Goal-Directed Feedback and Motivation

Goal-directed feedback provides learners with information about their progress toward a desired goal (or set of goals) rather than providing feedback on discrete responses (i.e., responses to individual tasks). Research has shown that for a learner to remain motivated and engaged depends on a close match between a learner's goals and his or her expectations that these goals can be met (Fisher & Ford, 1998; Ford, Smith, Weissbein, Gully, & Salas, 1998). If goals are set so high that they are unattainable, the learner will likely experience failure and become discouraged. When goals are set so low that their attainment is certain, success loses its power to promote further effort (Birney, Burdick, & Teevan, 1969).

According to Malone (1981), there are certain features that goals must have to make them challenging for the learner. For example, goals must be personally meaningful and easily generated, and the learner must receive performance feedback about whether the goals are being attained. Hoska (1993) classified goals as being of two types: *acquisition* (i.e., to help the learner acquire something desirable)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

and *avoidance* (i.e., to help the learner avoid something undesirable). Moreover, acquisition and avoidance goals can be either external or internal.

Motivation has been shown to be an important mediating factor in learners' performance (Covington & Omelich, 1984), and feedback can be a powerful motivator when delivered in response to goal-driven efforts. Some researchers suggest that the learner's goal orientation should be considered when designing instruction, particularly when feedback can encourage or discourage a learner's effort (Dempsey et al. 1993). Goal orientation describes the manner in which people are motivated to work toward different kinds of goals. The idea is that individuals hold either a learning or a performance orientation toward tasks (e.g., Dweck, 1986). A *learning orientation* is characterized by a desire to increase one's competence by developing new skills and mastering new situations with the belief that intelligence is malleable. In contrast, *performance orientation* reflects a desire to demonstrate one's competence to others and to be positively evaluated by others, with the belief that intelligence is innate (Farr, Hofmann, & Ringenbach, 1993).

Research has shown that the two types of goal orientation differentially influence how individuals respond to task difficulty and failure (Dweck & Leggett, 1988). That is, learning orientation is characterized by persistence in the face of failure, the use of more complex learning strategies, and the pursuit of challenging material and tasks. Performance orientation is characterized by a tendency to withdraw from tasks (especially in the face of failure), less interest in difficult tasks, and the tendency to seek less challenging material and tasks on which success is likely. Consistent with these labels, research has generally shown that learning orientation is associated with more positive outcomes and performance orientation is related to either equivocal or negative outcomes (e.g., Button, Mathieu, & Zajac, 1996; Fisher & Ford, 1998; VandeWalle, Brown, Cron, & Slocum, 1999).

One way to influence a learner's goal orientation (e.g., to shift from a focus on performing to an emphasis on *learning*) is via formative feedback. Hoska (1993) showed how goal-orientation feedback can modify a learner's view of intelligence by helping a learner see that (a) ability and skill can be developed through practice, (b) effort is critical to increasing this skill, and (c) mistakes are part of the skill-acquisition process. Feedback can also serve as a cognitive support mechanism, described next.

Formative Feedback as Scaffolding

Like training wheels, scaffolding enables learners to do more advanced activities and to engage in more advanced thinking and problem solving than they could without such help. Eventually, high-level functions are gradually turned over to the students as the teacher (or computer system) removes the scaffolding and fades away (see Collins, Brown, & Newman, 1989; Graesser, McNamara, & VanLehn, 2005). For instance, Graesser et al. (2005) described a theoretically based approach to facilitating explanation-centered learning via scaffolding, including (a) pedagogical agents that scaffold strategies, metacognition, and explanation construction; (b) computer coaches that facilitate answer generation to questions that require explanations by using mixed-initiative dialogue; and (c) modeling and coaching students in constructing self-explanations. Their systems (i.e., Point&Query, AutoTutor, and iSTART) built with these components have shown promising results in tests of learning gains and improved learning strategies.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

In their book *How People Learn*, Bransford, Brown, and Cocking (2000) describe how psychological theories and insights can be translated into actions and practices. In relation to feedback, they suggest a goal-directed approach to learning using scaffolding (or scaffolded feedback) that (a) motivates the learner's interest related to the task, (b) simplifies the task to make it more manageable and achievable, (c) provides some direction to help the learner focus on achieving the goal, (d) clearly indicates the differences between the learner's work and the standard or desired solution, (e) reduces frustration and risk, and (f) models and clearly defines the expectations (goals) of the activity to be performed.

Conventional wisdom suggests that facilitative feedback (providing guidance and cues, as illustrated in the research cited previously) would enhance learning more than directive feedback (providing corrective information), yet this is not necessarily the case. In fact, some research has shown that directive feedback may actually be more helpful than facilitative—particularly for learners who are just learning a topic or content area (e.g., Knoblauch & Brannon, 1981; Moreno, 2004). Because scaffolding relates to the explicit support of learners during the learning process, in an educational setting, scaffolded feedback may include models, cues, prompts, hints, partial solutions, and direct instruction (Hartman, 2002). Scaffolding is gradually removed as students gain their cognitive footing; thus, directive feedback may be most helpful during the early stages of learning. Facilitative feedback may be more helpful later, and the question is: When? According to Vygotsky (1987), external scaffolds can be removed when the learner develops more sophisticated cognitive systems, where the system of knowledge itself becomes part of the scaffold for new learning. The issue of feedback timing is now discussed in more detail.

Timing

> It was my teacher's genius, her quick sympathy, her loving tact which made the first years of my education so beautiful. It was because she seized the right moment to impart knowledge that made it so pleasant and acceptable to me.
>
> —Helen Keller

Similar to the previously mentioned feedback variables (e.g., complexity and specificity), there are also conflicting results in the literature relating to the timing of feedback and the effects on learning outcome and efficiency. Researchers have been examining the effects of immediate versus delayed feedback on learning for decades (e.g., Clariana, 1999; Jurma & Froelich, 1984; Pound & Bailey, 1975; Prather & Berry, 1973; Reddy, 1969). The timing of feedback literature concerns whether feedback should be delivered immediately or delayed. "Immediately" may be defined as right after a student has responded to an item or problem or, in the case of summative feedback, right after a quiz or test has been completed. "Delayed" is usually defined relative to immediate, and such feedback may occur minutes, hours, weeks, or longer after the completion of some task or test.

Regardless of the unit of time, the effects of the feedback timing variable are mixed. Again, although there appears to be no consistent main effect of timing, there are interactions involving the timing of feedback and learning. Some researchers have argued for immediate feedback as a means to prevent errors being encoded into memory, whereas others have argued that delayed feedback reduces

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

proactive interference, thus allowing the initial error to be forgotten and the correct information to be encoded with no interference (for more on this debate, see Kulhavy & Anderson, 1972).

Support for Delayed Feedback

Researchers who support using delayed feedback generally adhere to what is called the *interference-perseveration hypothesis* proposed by Kulhavy and Anderson (1972). This asserts that initial errors do not compete with to-be-learned correct responses if corrective information is delayed. This is because errors are likely to be forgotten and thus cannot interfere with retention.

The superiority of delayed feedback, referred to as the delay-retention effect (DRE), was supported in a series of experiments by Anderson and colleagues (e.g., Kulhavy & Anderson, 1972; Surber & Anderson, 1975), comparing the accuracy of responses on a retention test with the accuracy of responses on an initial test. Although many studies in the literature do not support the DRE (e.g., Kippel, 1974; Newman, Williams, & Hiller, 1974; Phye & Baller, 1970), delayed feedback has often been shown to be as effective as immediate feedback.

Schroth (1992) presented the results from an experiment that investigated the effects of delayed feedback and type of verbal feedback on transfer using a concept-formation task. The four conditions of delayed feedback were: 0 s, 10 s, 20 s, and 30 s. The verbal feedback conditions were (a) correct–incorrect (*verification* feedback), (b) correct–nothing (i.e., where "nothing" means that no feedback was presented if the student solved an item incorrectly), and (c) nothing–incorrect (i.e., no feedback was presented if the student answered correctly). All participants were tested 7 days after an initial learning trial. The finding relevant to this article is that although delayed feedback slowed the rate of initial learning, it *facilitated transfer* after the delay.

Support for Immediate Feedback

Supporters of immediate feedback theorize that the earlier corrective information is provided, the more likely it is that efficient retention will result (Phye & Andre, 1989). The superiority of immediate over delayed feedback has been demonstrated for the acquisition of verbal materials, procedural skills, and some motor skills (Anderson, Magill, & Sekiya, 2001; Brosvic & Cohen, 1988; Corbett & Anderson, 1989, 2001; Dihoff, Brosvic, Epstein, & Cook, 2003).

Corbett and Anderson (2001) have been using immediate feedback successfully in their programming and mathematics tutors for almost two decades (see Anderson, Corbett, Koedinger, & Pelletier, 1995). For instance, they used their ACT Programming Tutor to examine differential timing effects on students' learning. The study involved four feedback conditions, the first three of which offered the student different levels of control over error feedback and correction: (a) immediate feedback and immediate error correction (i.e., the tutor intervened as soon as students made errors and forced them to correct the error before moving on), (b) immediate error flagging and student control of error correction, (c) feedback on demand and student control of error correction, and (d) no-tutor condition and no step-by-step problem-solving support (the control condition). *The immediate feedback group with greatest tutor control of problem solving yielded the most efficient learning* (i.e., the first condition). These students completed the tutor problems

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

fastest, and their performance on criterion tests was equivalent to that of the other groups (excluding the control group). Furthermore, questionnaires showed no significant differences in terms of preference among the tutor conditions. This study demonstrated that immediate error feedback helped with immediate learning.

Azevedo and Bernard (1995) conducted a meta-analysis on the literature concerning the effects of feedback on learning from CBI. They noted that despite the widespread acceptance of feedback in computerized instruction, empirical support for particular types of feedback information has been inconsistent and contradictory. Effect size calculations were performed on 22 CBI studies comparing feedback versus no feedback relating to *immediate* outcomes. This resulted in a mean weighted effect size of 0.80. The results from 9 studies employing *delayed* outcome conditions resulted in a mean weighted effect size of just 0.35. This provides support for the strength of feedback in relation to immediate outcome administrations, at least in CBI.

Conjoining Feedback Timing Findings

A preliminary conclusion derived from both the Schroth (1992) and Corbett and Anderson (2001) findings is that *delayed feedback* may be superior for promoting transfer of learning, especially in relation to concept-formation tasks, whereas *immediate feedback* may be more efficient, particularly in the short run and for procedural skills (i.e., programming and mathematics). This proposition has some support. For instance, Schmidt, Young, Swinnen, and Shapiro (1989) conducted an experiment that provided *verification* feedback following a set of trials relating to a relatively simple ballistic-timing task. Feedback timing consisted of one of four lengths: 1 (*verification after every trial*), 5 (*verification after 5 trials*), 10, and 15 trials. During the acquisition phase when feedback was present, all groups showed general improvements in performance across practice, although those in the longer length conditions showed worse performance relative to the shorter length conditions. In a delayed test, they found an *inverse* relation between the timing variable (1, 5, 10, 15 trials between feedback) and error rates. That is, longer delays between feedback episodes resulted in relatively poorer performance during acquisition but better retention compared with shorter delay conditions.

Mathan and Koedinger (2002) reviewed various studies on the timing of feedback and concluded that the effectiveness of feedback depends not on the main effect of timing but on the nature of the task and the capability of the learner. They called for further exploration on possible interactions involving timing effects and optimal ways to match feedback (type and timing) to learning tasks and students' individual needs or characteristics (e.g., Schimmel, 1988; Smith & Ragan, 1999). One such interaction reported in the literature concerns feedback timing and task difficulty. That is, if the task is difficult, then immediate feedback is beneficial, but if the task is easy, then delayed feedback may be preferable (Clariana, 1999). This is similar to the ideas presented earlier in the Formative Feedback as Scaffolding subsection.

Summary of Feedback Timing Results

Research investigating the relationship of feedback timing to learning and performance reveals inconsistent findings. One interesting observation is that many *field* studies demonstrate the value of immediate feedback (see Kulik & Kulik,

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

1988), whereas many *laboratory* studies show positive effects of delayed feedback (see Schmidt & Bjork, 1992; Schmidt et al. 1989). One way to resolve the inconsistency is by considering that immediate feedback may activate both positive *and* negative learning effects. For instance, the positive effects of immediate feedback can be seen as facilitating the decision or motivation to practice and providing the explicit association of outcomes to causes. The negative effects of immediate feedback may facilitate reliance on information that is not available during transfer and promote less careful or mindful behavior. If this supposition is true, the positive and negative effects of immediate feedback could cancel each other out. Alternatively, either the positive or negative effects may come to the fore, depending on the experimental context. A similar argument could be made for delayed feedback effects on learning. For example, on the positive side, delayed feedback may encourage learners' engagement in active cognitive and metacognitive processing, thus engendering a sense of autonomy (and perhaps improved self-efficacy). But on the negative side, delaying feedback for struggling and less motivated learners may prove to be frustrating and detrimental to their knowledge and skill acquisition.

Feedback and Other Variables

So far, formative feedback types and timing have been discussed in relation to their effects on learning. This section examines other variables that may interact with feedback features, such as learner ability level, response certitude, goal orientation, and normative feedback.

Learner Level

As alluded to in the Timing subsection of this review, some research has suggested that low-achieving students may benefit from immediate feedback, whereas high-achieving students may prefer or benefit from delayed feedback (Gaynor, 1981; Roper, 1977). Furthermore, when testing different types of feedback, Clariana (1990) has argued that low-ability students benefit from receipt of *correct response* feedback more than from *try again* feedback. Hanna (1976) also examined student performance in relation to different feedback conditions: *verification*, *elaboration*, and *no feedback*. The verification feedback condition produced the highest scores for high-ability students and elaborated feedback produced the highest scores for low-ability students. There were no significant differences between verification and elaborated feedback for middle-ability students, but both of these types of feedback were superior to no feedback. These findings support the research and suppositions presented earlier in the Scaffolding subsection.

Response Certitude

Kulhavy and Stock (1989) examined feedback and response certitude issues from an information-processing perspective. That is, they had students provide confidence judgments ("response certitude" ratings) following each response to various tasks. They hypothesized that when students are certain their answer is correct, they will spend little time analyzing feedback, and when students are certain their answer is incorrect, they will spend more time reviewing feedback. The implications of this are straightforward; that is, provide more elaborated feedback for students who are more certain that their answer is wrong and deliver more constrained feedback for those with high certitude of correct answers. Although their

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

own research supported their hypotheses, other studies did not replicate the findings. For instance, Mory (1994) tried to replicate the response certitude findings and found that although there were differences in the amount of feedback study time, there was no significant learning effect for feedback tailored to response certitude and correctness.

Goal Orientation

Davis, Carson, Ammeter, and Treadway (2005) reported the results of a study testing the relationship between goal orientation and feedback specificity on performance using a management decision-making task. In short, they found that feedback specificity (low, moderate, and high levels) had a significant influence on performance for individuals who were low on learning orientation (i.e., high feedback specificity was better for learners with low learning orientation). They also reported a significant influence of feedback specificity on performance for persons high in performance orientation (i.e., this group also benefited from more specific feedback). The findings support the general positive effects of feedback on performance and suggest the use of more specific feedback for learners with either high-performance or low-learning goal orientations.

Normative Feedback

According to research cited in Kluger and DeNisi (1996), when feedback is provided to students in a norm-referenced manner that compares the individual's performance with that of others, people who perform poorly tend to attribute their failures to lack of ability, expect to perform poorly in the future, and demonstrate decreased motivation on subsequent tasks (i.e., similar to learners with a performance orientation, described earlier). McColskey and Leary (1985) examined the hypothesis that the harmful effects of failure might be lessened when failure is expressed in self-referenced terms—that is, relative to the learner's known level of ability as assessed by other measures. In their study, learners received feedback indicating that they did well or poorly on an anagram test, and this feedback was described as either norm-referenced (comparing the individual's performance with that of others) or as self-referenced (comparing performance with other measures of the individual's ability). They found that, compared to norm-referenced feedback, self-referenced feedback resulted in higher expectancies regarding future performance and increased attributions to *effort* (e.g., "I succeeded because I worked really hard"). Attributions to *ability* (e.g., "I succeeded because I'm smart") were not affected. The main implication is that low-achieving students should not receive normative feedback but should instead receive self-referenced feedback—focusing their attention on their own progress.

This review has presented research findings covering the gamut of formative feedback variables. As with earlier reviews, this one has unearthed mixed findings regarding learning effects—whether examining feedback specificity, timing of feedback, and so on. The next section presents four influential feedback research studies that have attempted to integrate disparate findings into preliminary theories (or models) through large literature reviews, meta-analyses, or both. The articles summarized are Kluger and DeNisi (1996), Bangert-Drowns et al. (1991), Narciss and Huth (2004), and Mason and Bruning (2001).

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Toward a Framework of Formative Feedback

To understand the world, one must not be worrying about one's self.

—Albert Einstein

Kluger and DeNisi (1996)

Kluger and DeNisi (1996) examined and reported on the effects of feedback interventions (FIs) on performance from multiple perspectives and spanning decades of research—back to Thorndike's classic research in the early 1900s. Kluger and DeNisi conducted an extensive review of the literature, performed a meta-analysis on reported experimental findings, and constructed a preliminary theory based on a number of variables, or moderators. Their preliminary feedback intervention theory (FIT) offers a broad approach to investigating FI effects, including feedback moderators such as praise, written or verbal feedback, task novelty and complexity, time constraints, and types of tasks such as physical, memory, knowledge, and vigilance tasks. The basic premise underlying FIT is that *FIs change the locus of a learner's attention* among three levels of control: (a) task learning, (b) task motivation, and (c) metatask processes (see Figure 1).

The general pattern of results from Kluger and DeNisi's (1996) large meta-analysis of FI studies was consistent with the argument that all else being equal, FI cues affect performance by changing the locus of attention. *The lower in the hierarchy the FI-induced locus of attention is, the stronger is the benefit of an FI for performance*. In other words, formative feedback that focuses the learner on aspects of the task (i.e., the lower part of Figure 1) promotes learning and achievement compared to FIs that draw attention to the self (i.e., the upper box in Figure 1), which can impede learning. This phenomenon is described in the Normative Feedback section in this article.

FIT consists of five basic arguments: (a) behavior is regulated by comparisons of feedback to goals or standards, (b) goals or standards are organized hierarchically, (c) attention is limited and therefore only feedback–standard gaps (i.e., discrepancies between actual and desired performance) that receive attention actively participate in behavior regulation, (d) attention is normally directed to a moderate level of the hierarchy; and (e) FIs change the locus of attention and therefore affect behavior. These arguments are interdependent, and each consecutive argument is built on the preceding argument.

Specific results from Kluger and DeNisi's (1996) meta-analysis showed that four moderators (feedback variables) demonstrated significant relationships with d (effect size) at $p < .01$: (a) discouraging FIs *reduce* FI effects, (b) velocity FIs (i.e., "self-referenced" feedback that addresses a change from the learner's prior performance), (c) correct response FIs *increase* effects; and (d) FI effects on performance of physical tasks are lower than FI effects on cognitive tasks.

Six more moderators became significant after excluding biased studies from the meta-analysis. Of those six, three of them were shown to reduce FI effects: (a) praise, (b) FIs threatening self-esteem, and (c) orally delivered FIs (from the instructor). FIs that provide frequent messages enhance FI effects, and FI effects

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

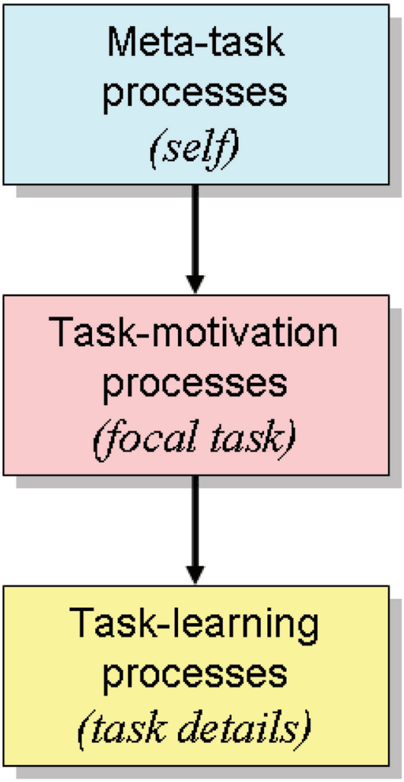

FIGURE 1. *Abstract hierarchy of processing*.

are stronger for memory tasks and weaker for more procedural tasks. Finally, other variables showing significance at $p < .05$ include the following: (a) computerized FIs yield stronger effects than noncomputerized FIs, (b) FIs in the context of complex tasks yield weaker effects than for simpler tasks, and (c) FIs are more effective with a goal-setting intervention than in the absence of goal setting. Figure 2 summarizes the main findings. This figure represents my interpretation (and categorization) based on data presented in the Kluger and DeNisi (1996) article.

One important finding from these results concerns the *attenuating effect of praise on learning and performance*, although this has been described elsewhere in the literature in terms of a model of self-attention (Baumeister, Hutton, & Cairns, 1990), attributions of effort (Butler, 1987), and control theory (Waldersee & Luthans, 1994). Also, Balcazar, Hopkins, and Suarez (1985) reported that praise was not as widely effective a reinforcer as previously believed.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

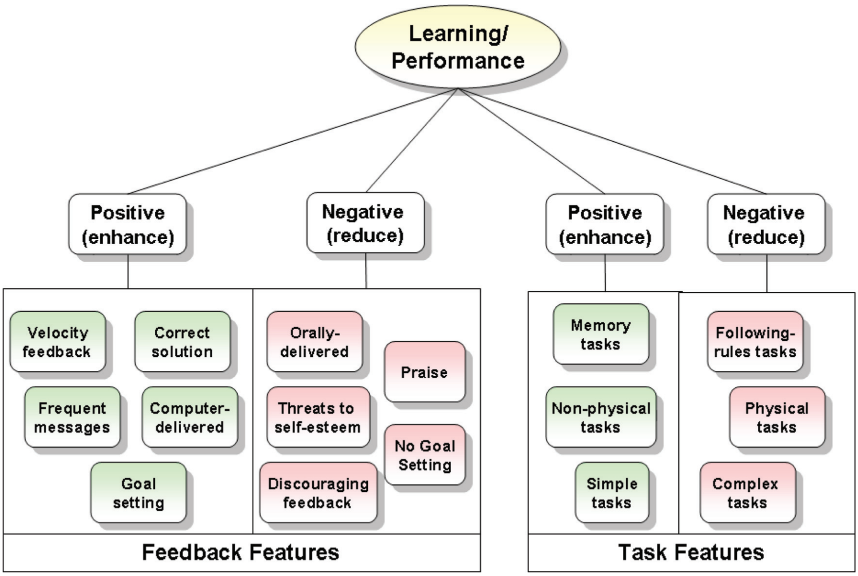

FIGURE 2. *Feedback intervention moderators and their relationships to learning and performance.*

Perhaps the most surprising finding that emerged from the Kluger and DeNisi (1996) meta-analysis is that *in more than one third of the 607 cases (effect sizes), FIs reduced performance.* Furthermore, most of the observed variability cannot be explained by sampling or other errors.

In conclusion, and as the authors observe in a later paper on the topic (Kluger & DeNisi, 1998), FIs may be viewed as double-edged swords, cutting both ways. Care should be taken to know which interventions increase performance and under which conditions.

Bangert-Drowns et al. (1991)

Bangert-Drowns et al. (1991) examined 40 research studies on feedback using meta-analysis techniques. They examined such variables as type of feedback, timing of feedback, and error rates in terms of their respective effect sizes. This widely cited article describes both behavioral and cognitive operations that occur in learning. The basic idea is that to direct behavior, a learner needs to be able to monitor physical changes brought about by the behavior. That is, learners change cognitive operations and thus activity by adapting it to new information and matching it with their own expectations about performance. They emphasize that

> any theory that depicts learning as a process of mutual influence between learners and their environments must involve feedback implicitly or explicitly because, without feedback, mutual influence is by definition impossible. Hence, the feedback construct appears often as an essential element of theories of learning and instruction. (p. 214)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

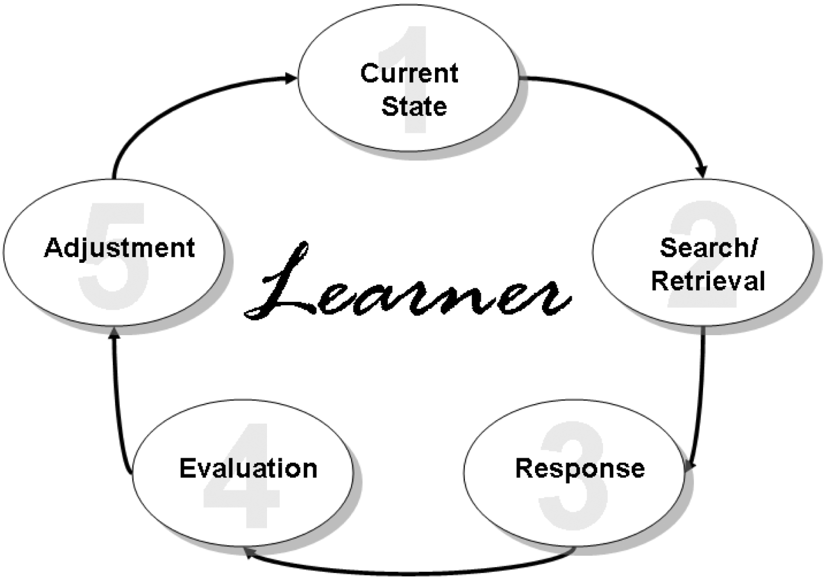

FIGURE 3. *Five-stage model of the learner during a feedback cycle.*

To make this point more concrete, imagine trying to learn something new in the absence of any feedback (explicit or implicit).

Most of the variables Bangert-Drowns et al. (1991) analyzed comprised text-based feedback, which they organized into a five-stage model. This model describes the state of learners as they move through a feedback cycle and emphasizes the construct of *mindfulness* (Salomon & Globerson, 1987). Mindfulness is "a reflective process in which the learner explores situational cues and underlying meanings relevant to the task involved" (Dempsey et al., 1993, p. 38).

The five stages are depicted in Figure 3 and are similar to other learning cycles (e.g., Gibbs, 1988; Kolb, 1984), particularly in relation to the importance of reflection.

As described by Bangert-Drowns et al. (1991, p. 217), the five states of the learner receiving feedback include:

1. The initial or *current state* of the learner. This is characterized by the degree of interest, goal orientation, degree of self-efficacy, and prior relevant knowledge.
2. *Search and retrieval strategies.* These cognitive mechanisms are activated by a question. Information stored in the context of elaborations would be easier to locate in memory because of more pathways providing access to the information.
3. The learner makes a *response* to the question. In addition, the learner feels some degree of certainty about the response and thus has some expectation about what the feedback will indicate.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

4. The learner *evaluates* the response in light of information from the feedback. The nature of the evaluation depends on the learner's expectations about feedback. For instance, if the learner was sure of his or her response and the feedback confirmed its correctness, the retrieval pathway may be strengthened or unaltered. If the learner was sure of the response and feedback indicated its incorrectness, the learner may seek to understand the incongruity. Uncertainty about a response with feedback confirmation or disconfirmation is less likely to simulate deep reflection unless the learner was interested in acquiring the instructional content.
5. *Adjustments* are made to relevant knowledge, self-efficacy, interests, and goals as a result of the response evaluation. These adjusted states, with subsequent experiences, determine the next "current" state.

Overall, Bangert-Drowns et al.'s (1991) meta-analysis found generally weak effects of feedback on achievement. More specifically (but not surprisingly), the authors found that *verification* feedback (correct–incorrect) resulted in lower effect sizes compared to *correct response* feedback (i.e., providing the correct answer). Also, using a pretest within a study significantly lowered effect sizes, as did uncontrolled presearch availability of answers (i.e., ability to locate an answer before responding to a question). These last two findings may be because pretests and presearch availability may be seen as "advance organizers" that may support short-term retention but undermine overall feedback effects in studies that employ them.

The main conclusion from Bangert-Drowns et al.'s (1991) meta-analysis and subsequent five-cycle model is that *feedback can promote learning if it is received mindfully.* Conversely, feedback can inhibit learning if it encourages mindlessness, as when the answers are made available before learners begin their memory search, or if the feedback message does not match students' cognitive needs (e.g., too easy, too complex, too vague).

Narciss and Huth (2004)

Narciss and Huth (2004) outlined a conceptual framework for the design of formative feedback. This framework is based on the body of research relating to elaborated feedback types. Cognitive task and error analyses served as the basis for the design of the framework. The impact of the feedback on learning and motivation was ultimately examined in two computer-based learning experiments. The results of these studies showed that *systematically designed formative feedback has positive effects on achievement and motivation.*

In general, Narciss and Huth (2004) asserted that designing and developing effective formative feedback needs to take into consideration instructional context as well as characteristics of the learner to provide effective feedback for complex learning tasks. The conceptual framework for the design of formative feedback is depicted in Figure 4 (modified from the original).

Each of the three factors is examined in more in the following:

1. *Instruction.* The instructional factor or context consists of three main elements: (a) the instructional *objectives* (e.g., learning goals or standards

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

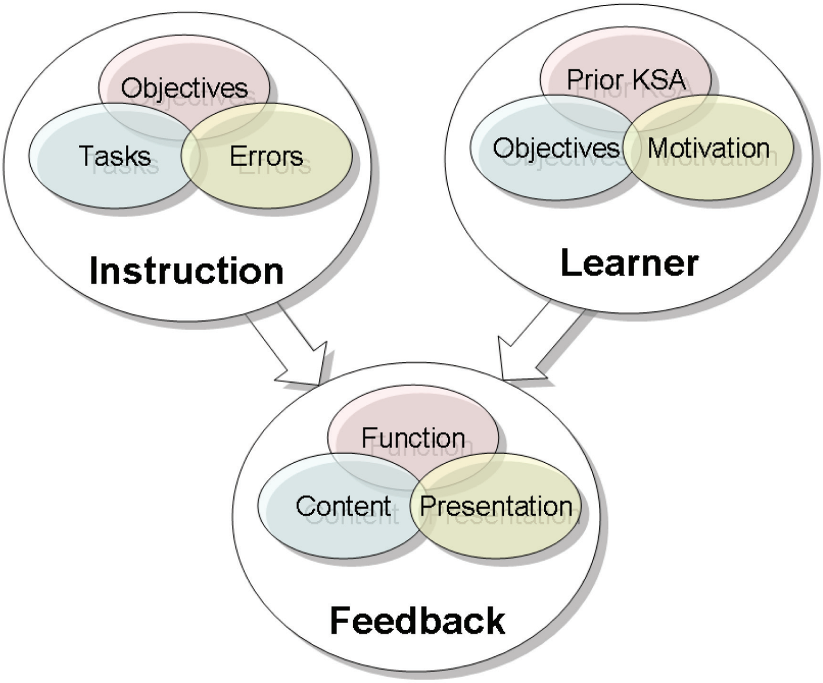

FIGURE 4. *Factors interacting with feedback to influence learning.*

relating to some curriculum), (b) the learning *tasks* (e.g., knowledge items, cognitive operations, metacognitive skills), and (c) *errors* and obstacles (e.g., typical errors, incorrect strategies, sources of errors).

2. *Learner*. Information concerning the learner that is relevant to feedback design includes (a) learning *objectives* and goals; (b) prior *knowledge, skills,* and *abilities* (e.g., domain dependent, such as content knowledge, and domain independent, such as metacognitive skills); and (c) academic *motivation* (e.g., one's need for academic achievement, academic self-efficacy, and metamotivational skills).
3. *Feedback*. The feedback factor consists of three main elements: (a) the *content* of the feedback (i.e., evaluative aspects, such as verification, and informative aspects, such as hints, cues, analogies, explanations, and worked-out examples), (b) the *function* of the feedback (i.e., cognitive, metacognitive, and motivational), and (c) the *presentation* of the feedback components (i.e., timing, schedule, and perhaps adaptivity considerations).

Narciss and Huth (2004) contend that adapting the content, function, and presentation format of the feedback message should be driven by considerations of the instructional goals and learner characteristics to maximize the informative value of the feedback. Specific steps for generating effective formative feedback include

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

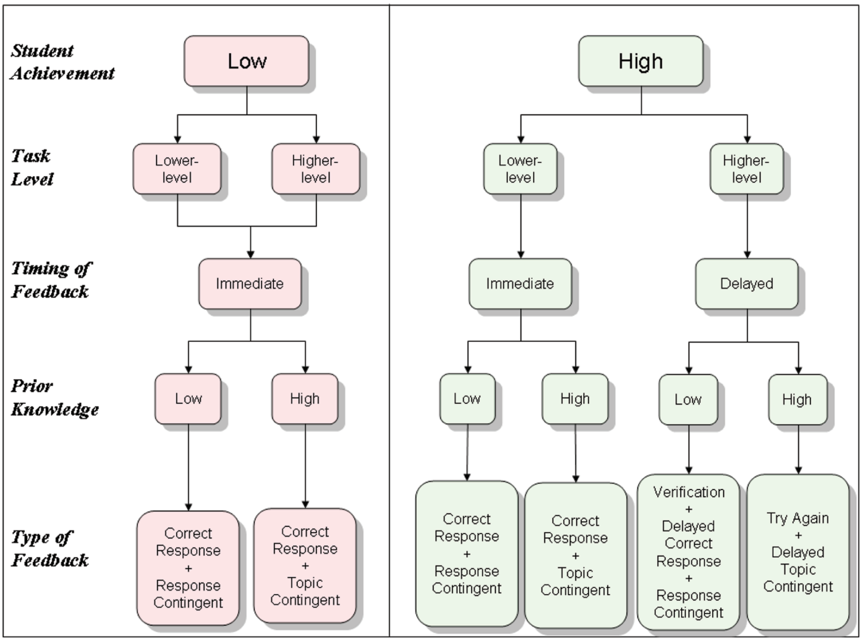

FIGURE 5. *Feedback variables for decision making in computer-based instruction. Adapted from "Providing Feedback in Computer-Based Instruction: What the Research Tells Us" by B. J. Mason and R. Bruning, 2001, Center for Instructional Innovation, University of Nebraska–Lincoln. Copyright 2001 by B. J. Mason and R. Bruning. Reprinted with permission.*

selecting and specifying learning objectives (concrete learning outcomes), identifying learning tasks, matching to learning outcomes, and after conducting cognitive task and error analyses, specifying information (i.e., formative feedback) that addresses specific, systematic errors or obstacles.

Mason and Bruning (2001)

Mason and Bruning (2001) reviewed the literature on feedback that is delivered via CBI systems and presented a theoretical framework intended to help designers, developers, and instructors build their own CBI tools. Mason and Bruning's theoretical framework, depicted in Figure 5, is based on research that has examined type of feedback and level of elaboration in relation to student achievement level, task complexity, timing of feedback, and prior knowledge. The general recommendation they have drawn from the framework is that immediate feedback for students with low achievement levels in the context of either simple (lower level) or complex (higher level) tasks is superior to delayed feedback, whereas delayed feedback is suggested for students with high achievement levels, especially for complex tasks.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

The following research supports Mason and Bruning's (2001) framework. First, significant learning gains often show up in response to various types of elaboration feedback (e.g., Clariana, 1990; Morrison, Ross, Gopalakrishnan, & Casey, 1995; Pridemore & Klein, 1991, 1995; Roper, 1977; Waldrop, Justen, & Adams, 1986). Second, research conducted in classroom settings seems to suggest that response-contingent feedback enhances student achievement more than other types of feedback (e.g., Whyte, Karolick, Neilsen, Elder, & Hawley, 1995). Third, Mason and Bruning reported that the level of feedback *complexity* has been shown to both influence and not influence learning, and this lack of effect may be due to interactions involving other variables, such as the nature of the topic and the type of skill measured (e.g., Hodes, 1985; Park & Gittelman, 1992). In cases where the level of feedback complexity has been shown to affect learning, more elaborative information tends to produce increased understanding (Gilman, 1969; Pridemore & Klein, 1991; Roper, 1977; Waldrop et al., 1986; Whyte et al., 1995). For instance, although verification feedback did not improve learning, correct response, response contingent, and a combination of the other levels of feedback have been shown to significantly improve student learning (e.g., Gilman, 1969). This may be due to the extra information available in elaboration feedback that allows students to correct their own errors or misconceptions. Information on the correctness of an answer (i.e., verification feedback) does not have much utility for learning.

Summary and Discussion

In general, formative feedback should address the accuracy of a learner's response to a problem or task and may touch on particular errors and misconceptions (Azevedo & Bernard, 1995; Birenbaum & Tatsuoka, 1987; Cheng, Lin, Chen, & Heh, 2005; Cohen, 1985; Kulhavy, 1977; Sales, 1993; Sleeman et al., 1989), the latter representing more specific or elaborated types of feedback. Formative feedback should also permit the comparison of actual performance with some established standard of performance (Johnson & Johnson, 1993).

In technology-assisted instruction, similar to classroom settings, formative feedback comprises information—whether a message, display, and so on—presented to the learner following his or her input (or on request, if applicable) with the purpose of shaping the perception, cognition, or action of the learner (e.g., Moreno, 2004; Schimmel, 1983; Wager & Wager, 1985). The main goal of formative feedback—whether delivered by a teacher or computer, in the classroom or elsewhere—is to enhance learning, performance, or both, engendering the formation of accurate, targeted conceptualizations and skills. Such feedback may be used in conjunction with low- or medium-stakes assessments, include diagnostic components, and even be personalized for the learner (Albertson, 1986; Azevedo & Bernard, 1995; Narciss & Huth, 2004; VanLehn, 1982).

Formative feedback might be likened to "a good murder" in that effective and useful feedback depends on three things: (a) *motive* (the student needs it), (b) *opportunity* (the student receives it in time to use it), and (c) *means* (the student is able and willing to use it). However, even with motive, opportunity, and means, there is still large variability of feedback effects on performance and learning, including negative findings that have historically been ignored in the literature (see Kluger & DeNisi, 1996).

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Despite this variability, several meta-analyses found that feedback generally improves learning, ranging from about .40 *SD* (Guzzo, Jette, & Katzell, 1985) to .80 *SD* and higher (Azevedo & Bernard, 1995; Kluger & DeNisi, 1996) compared to control conditions. But there remain major gaps in the feedback literature, particularly in relation to interactions among task characteristics, instructional contexts, and student characteristics that potentially mediate feedback effects. Therefore, although there is no simple answer to the "what feedback works" query, there are some preliminary guidelines that can be formulated based on the findings reported in this review.

Recommendations and Guidelines for Formative Feedback

Tables 2, 3, 4, and 5 present suggestions or prescriptions based on the current review of the formative feedback literature. These are intended to provide a point of departure for more comprehensive and systematic prescriptions in the future. Equivocal findings are not presented, and the references are not exhaustive, but representative. The tables differ in terms of formative feedback guidelines for (a) things to do (Table 2), (b) things to avoid (Table 3), (c) timing issues (Table 4), and (d) learner characteristics (Table 5).

Future Research

One reason studies examining formative feedback effects are so inconsistent may be a function of individual differences among motivational prerequisites (e.g., intrinsic motivation, beliefs, need for academic achievement, academic self-efficacy, and metacognitive skills). In fact, Vygotsky (1987) noted that the study of psychology had been damaged by the separation of the intellectual from the motivational and emotional (or affective) aspects of thinking. Crafting and delivering formative feedback may help bridge these "aspects of thinking" and enhance learning. This seems to be supported by a growing number of researchers (e.g., Goleman, 1995; Mayer & Salovey, 1993, 1997; Picard et al., 2004) who have argued that emotional upsets can interfere with mental activities (e.g., anxious, angry, or depressed students do not learn). Thus, one intriguing area of future research is to systematically examine the relationship(s) between *affective components in feedback and outcome performance*. And although there have been inroads in the area, according to Picard et al. (2004), extending cognitive theory to explain and exploit the role of affect in learning is still in its infancy.

In general, and as suggested by Schwartz and White (2000) cited earlier, we need to continue taking a *multidimensional view of feedback* where situational and individual characteristics of the instructional context and learner are considered along with the nature and quality of a feedback message. Narciss and Huth (2004) noted, and I strongly agree, that function, content, and mode of feedback presentation are important facets and should be considered separately as well as interactively with learner characteristics and instructional variables. Cognitive task and error analyses may be used to match formative feedback components to (a) learning objectives, (b) skills needed for the mastery of the task, and (c) typical errors or incorrect strategies. However such expensive analyses and methods may not, in fact, be necessary to promote learning (e.g., see the No Effect of Feedback Complexity subsection in this article, specifically the Sleeman et al., 1989, findings).

(text continues on page 181)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

TABLE 2
Formative feedback guidelines to enhance learning (things to do)

Prescription	Description and references
Focus feedback on the task, not the learner.	Feedback to the learner should address specific features of his or her work in relation to the task, with suggestions on how to improve (e.g., Butler, 1987; Corbett & Anderson, 2001; Kluger & DeNisi, 1996; Narciss & Huth, 2004).
Provide elaborated feedback to enhance learning.	Feedback should describe the what, how, and why of a given problem. This type of cognitive feedback is typically more effective than verification of results (e.g., Bangert-Drowns et al., 1991; Gilman, 1969; Mason & Bruning, 2001; Narciss & Huth, 2004).
Present elaborated feedback in manageable units.	Provide elaborated feedback in small enough pieces so that it is not overwhelming and discarded (Bransford et al., 2000; Sweller et al., 1998). Presenting too much information may not only result in superficial learning but may also invoke cognitive overload (e.g., Mayer & Moreno, 2002; Phye & Bender, 1989). A stepwise presentation of feedback offers the possibility to control for mistakes and gives learners sufficient information to correct errors on their own.
Be specific and clear with feedback message.	If feedback is not specific or clear, it can impede learning and can frustrate learners (e.g., Moreno, 2004; Williams, 1997). If possible, try to link feedback clearly and specifically to goals and performance (Hoska, 1993; Song & Keller, 2001).
Keep feedback as simple as possible but no simpler (based on learner needs and instructional constraints).	Simple feedback is generally based on one cue (e.g., verification or hint) and complex feedback on multiple cues (e.g., verification, correct response, error analysis). Keep feedback as simple and focused as possible. Generate only enough information to help students and not more. Kulhavy et al. (1985) found that feedback that was too complex did not promote learning compared to simpler feedback.
Reduce uncertainty between performance and goals.	Formative feedback should clarify goals and seek to reduce or remove uncertainty in relation to how well learners are performing on a task, and what needs to be accomplished to attain the goal(s) (e.g., Ashford et al., 2003; Bangert-Drowns et al., 1991).
Give unbiased, objective feedback, written or via computer.	Feedback from a trustworthy source will be considered more seriously than other feedback, which may be disregarded. This may explain why computer-based feedback is often better than human-delivered in some experiments in that perceived biases are eliminated (see Kluger & DeNisi, 1996).
Promote a "learning" goal orientation via feedback.	Formative feedback can be used to alter goal orientation—from a focus on performance to a focus on learning (Hoska, 1993). This can be facilitated by crafting feedback emphasizing that effort yields increased learning and performance, and mistakes are an important part of the learning process (Dweck, 1986).

(continued)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

TABLE 2 (*continued*)

Prescription	Description and references
Provide feedback after learners have attempted a solution.	Do not let learners see answers before trying to solve a problem on their own (i.e., presearch availability). Several studies that have controlled presearch availability show a benefit of feedback, whereas studies without such control show inconsistent results (Bangert-Drowns et al., 1991).

TABLE 3
Formative feedback guidelines to enhance learning (things to avoid)

Prescription	Description and references
Do not give normative comparisons.	Feedback should avoid comparisons with other students—directly or indirectly (e.g., "grading on the curve"). In general, do not draw attention to "self" during learning (Kluger & DeNisi, 1996; Wiliam, 2007).
Be cautious about providing overall grades.	Feedback should note areas of strength and provide information on how to improve, as warranted and without overall grading. Wiliam (2007) summarized the following findings: (a) students receiving just grades showed no learning gains, (b) those getting just comments showed large gains, and (c) those with grades and comments showed no gains (likely due to focusing on the grade and ignoring comments). Effective feedback relates to the content of the comments (Butler, 1987; McColskey & Leary, 1985).
Do not present feedback that discourages the learner or threatens the learner's self-esteem.	This prescription is based not only on common sense but also on research reported in Kluger and DeNisi (1996) citing a list of feedback interventions that undermine learning as it draws focus to the "self" and away from the task at hand. In addition, do not provide feedback that is either too controlling or critical of the learner (Baron, 1993; Fedor et al., 2001).
Use "praise" sparingly, if at all.	Kluger & DeNisi (1996), Butler (1987), and others have noted that use of praise as feedback directs the learner's attention to "self," which distracts from the task and consequently from learning.
Try to avoid delivering feedback orally.	This also was addressed in Kluger & DeNisi (1991). When feedback is delivered in a more neutral manner (e.g., written or computer delivered), it is construed as less biased.
Do not interrupt learner with feedback if the learner is actively engaged.	Interrupting a student who is immersed in a task—trying to solve a problem or task on his or her own—can be disruptive to the student and impede learning (Corno & Snow, 1986).

(continued)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

TABLE 3 (*continued*)

Prescription	*Description and references*
Avoid using progressive hints that always terminate with the correct answer.	Although hints can be facilitative, they can also be abused, so if they are employed to scaffold learners, provisions to prevent their abuse should be made (e.g., Aleven & Koedinger, 2000; Shute, Woltz, & Regian, 1989). Consider using prompts and cues (i.e., more specific kinds of hints).
Do not limit the mode of feedback presentation to text.	Exploit the potential of multimedia to avoid cognitive overload due to modality effects (e.g., Mayer & Moreno, 2002) and do not default to presenting feedback messages as text. Instead, consider alternative modes of presentation (e.g., acoustic, visual).
Minimize use of extensive error analyses and diagnosis.	In line with findings by Sleeman et al. (1989) and VanLehn et al. (2005), the cost of conducting extensive error analyses and cognitive diagnosis may not provide sufficient benefit to learning. Furthermore, error analyses are rarely complete and not always accurate, thus only helpful in a subset of circumstances.

TABLE 4
Formative feedback guidelines in relation to timing issues

Prescription	Description and references
Design timing of feedback to align with desired outcome.	Feedback can be delivered (or obtained) either immediately or delayed. Immediate feedback can help fix errors in real time, producing greater immediate gains and more efficient learning (Corbett & Anderson, 2001; Mason & Bruning, 2001), but delayed feedback has been associated with better transfer of learning (e.g., Schroth, 1992).
For difficult tasks, use immediate feedback.	When a student is learning a difficult new task (where "difficult" is relative to the learner's capabilities), it is better to use immediate feedback, at least initially (Clariana, 1990). This provides a helpful safety net for the learner so she does not get bogged down and frustrated (Knoblauch & Brannon, 1981).
For relatively simple tasks, use delayed feedback.	When a student is learning a relatively simple task (again, relative to capabilities), it is better to delay feedback to prevent feelings of feedback intrusion and possibly annoyance (Clariana, 1990; Corno, & Snow, 1986).
For retention of procedural or conceptual knowledge, use immediate feedback.	In general, there is wide support for use of immediate feedback to promote learning and performance on verbal, procedural, and even tasks requiring motor skills (Anderson et al., 2001; Azevedo & Bernard, 1995; Corbett & Anderson, 1989, 2001; Dihoff et al., 2003; Phye & Andre, 1989).

(continued)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

TABLE 4 (*continued*)

Prescription	Description and references
To promote transfer of learning, consider using delayed feedback.	According to some researchers (e.g., Kulhavy et al., 1985; Schroth, 1992), delayed may be better than immediate feedback for transfer task performance, although initial learning time may be depressed. This needs more research.

TABLE 5
Formative feedback guidelines in relation to learner characteristics

Prescription	Description and references
For high-achieving learners, consider using delayed feedback.	Similar to the Clariana (1990) findings cited in Table 4, high-achieving students may construe a moderate or difficult task as relatively easy and hence benefit by delayed feedback (see also Gaynor, 1981; Roper, 1977).
For low-achieving learners, use immediate feedback.	The argument for low-achieving students is similar to the one above; however, these students need the support of immediate feedback in learning new tasks they may find difficult (see Gaynor, 1981; Mason & Bruning, 2001; Roper, 1977).
For low-achieving learners, use directive (or corrective) feedback.	Novices or struggling students need support and explicit guidance during the learning process (Knoblauch & Brannon, 1981; Moreno, 2004); thus, hints may not be as helpful as more explicit, directive feedback.
For high-achieving learners, use facilitative feedback.	Similar to the above, high-achieving or more motivated students benefit from feedback that challenges them, such as hints, cues, and prompts (Vygotsky, 1987).
For low-achieving learners, use scaffolding.	Provide early support and structure for low-achieving students (or those with low self-efficacy) to improve learning and performance (e.g., Collins et al., 1989; Graesser et al., 2005).
For high-achieving learners, verification feedback may be sufficient.	Hanna (1976) presented findings that suggest that high-achieving students learn more efficiently if permitted to proceed at their own pace. Verification feedback provides the level of information most helpful in this endeavor.

(continued)

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

TABLE 5 (*continued*)

Prescription	Description and references
For low-achieving learners, use correct response and some kind of elaboration feedback.	Using the same rationale as with supplying scaffolding to low-achieving students, the prescription here is to ensure low-achieving students receive a concrete, directive form of feedback support (e.g., Clariana, 1990; Hanna, 1976).
For learners with low learning orientation (or high performance orientation), give specific feedback.	As described in the study by Davis et al. (2005), if students are oriented more toward performance (trying to please others) and less toward learning (trying to achieve an academic goal), provide feedback that is specific and goal directed. Also, keep the learner's eye on the learning goal (Hoska, 1993).

In line with the question concerning the value added of error analyses and more diagnostic types of formative feedback, controlled evaluations are needed, systematically testing the effects of feedback conditions (as listed in Table 1) on learning combined with a cost–benefit analysis. Some obvious costs include development time for specifying the feedback types and reading time for feedback by the student. Benefits relate to improvements in learning outcome and efficiency, as well as possible self-regulatory skills and affective variables. Information about the learner would be collected to examine possible interactions. The hypotheses are that (a) more complex formative feedback types (e.g., involving extensive and expensive error analyses) do not yield proportionately greater learning gains and (b) feedback can be made more effective if it can adapt to the needs of learners—cognitive and noncognitive characteristics—as well as to different types of knowledge and skills. The general question is: *What level of feedback complexity yields the most bang for the buck?*

Table 5 provides guidelines for linking a few learner characteristics to different feedback types. Future research may examine (a) additional learner characteristics and (b) links between different types of knowledge and feedback types. For instance, feedback to support fact learning (declarative knowledge) could reiterate definitions or provide the learner with a handy mnemonic technique; feedback to support conceptual knowledge could provide examples, counterexamples, and big pictures; and feedback to improve procedural knowledge could involve demonstrations, solution paths (complete or partial), and so forth. Ultimately, information about the learner, combined with information about desired outcomes, may inform the development of *adaptive* formative feedback. Various feedback types could be generated and incorporated into a program (or generated on the fly based on formative feedback models) and then accessed and delivered according to the

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

characteristics of the learner in conjunction with the nature of the task and instructional goals.

In closing, the goal of this review is to summarize research findings relating to formative feedback to serve as the foundation for a variety of future educational products and services. As evidenced throughout, there is no "best" type of formative feedback for all learners and learning outcomes. However, formative feedback has been shown in numerous studies to improve students' learning and enhance teachers' teaching to the extent that the learners are receptive and the feedback is on target (valid), objective, focused, and clear.

References

Albertson, L. M. (1986). Personalized feedback and cognitive achievement in computer assisted instruction. *Journal of Instructional Psychology, 13*(2), 55–57.

Aleven, V., & Koedinger, K. R. (2000). Limitations of student control: Do students know when they need help? In G. Gauthier, C. Frasson, & K. VanLehn (Eds.), *Proceedings of the 5th International Conference on Intelligent Tutoring Systems, ITS 2000* (pp. 292–303). Berlin: Springer-Verlag.

Anderson, J. R., Corbett, A. T., Koedinger, K. R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *Journal of the Learning Sciences, 4*, 167–207.

Ashford, S. J. (1986). Feedback-seeking in individual adaptation: A resource perspective. *Academy of Management Journal, 29*, 465–487.

Ashford, S. J., Blatt, R., & VandeWalle, D. (2003). Reflections on the looking glass: A review of research on feedback-seeking behavior in organizations. *Journal of Management, 29*, 773–799.

Azevedo, R., & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research, 13*(2), 111–127.

Balcazar, F. E., Hopkins, B. L., & Suarez, Y. (1985). A critical, objective review of performance feedback. *Journal of Organizational Behavior Management, 7*(3-4), 65–89.

Bandura, A. (1991). Social theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50,* 248–287.

Bandura, A., & Cervone, D. (1983). Self-evaluation and self-efficacy mechanisms governing the motivational effects of goal systems. *Journal of Personality and Social Psychology*, 45, 1017–1028.

Bangert-Drowns, R. L., Kulik, C. C., Kulik, J. A., & Morgan, M. T. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research, 61*, 213–238.

Baron, R. A. (1988). Negative effects of destructive criticism: Impact on conflict, self-efficacy, and task performance. *Journal of Applied Psychology, 73,* 199–207.

Baron, R. A. (1993). Criticism (informal negative feedback) as a source of perceived unfairness in organizations: Effects, mechanisms, and countermeasures. In R. Cropanzano (Ed.), *Justice in the workplace: Approaching fairness in human resource management* (pp. 155–170). Hillsdale, NJ: Lawrence Erlbaum.

Baumeister, R. F., Hutton, D. G., & Cairns, K. J. (1990). Negative effects of praise on skilled performance. *Basic & Applied Social Psychology, 11*(2), 131–149.

Birenbaum, M., & Tatsuoka, K. K. (1987). Effects of "on-line" test feedback on the seriousness of subsequent errors. *Journal of Educational Measurement, 24*(2), 145–155.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Birney, R. C., Burdick, H., & Teevan, R. C. (1969). *Fear of failure.* New York: Van Nostrand-Reinhold.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice, 5*(1), 7–74.

Bordia, P., Hobman, E., Jones, E., Gallois, C., & Callan, V. J. (2004). Uncertainty during organizational change: Types, consequences, and management strategies. *Journal of Business and Psychology, 18*, 507–532.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school* (Rev. ed.). Washington, DC: National Academies Press.

Brophy, J. E. (1981). Teacher praise: A functional analysis. *Review of Educational Research, 51*, 5–32.

Brosvic, G. M., & Cohen, B. D. (1988). The horizontal vertical illusion and knowledge of results. *Perceptual and Motor Skills, 67*(2), 463–469.

Bunderson, V. C., & Olson, J. B. (1983). *Mental errors in arithmetic skills: Their diagnosis in precollege students* (Report No. NSF SED 80-12500). Provo, UT: WICAT Education Institute.

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: Effects of different feedback conditions on motivational perceptions, interest, and performance. *Journal of Educational Psychology, 79*(4), 474–482.

Button, S. B., Mathieu, J. E., & Zajac, D. M. (1996). Goal orientation in organizational research: A conceptual and empirical foundation. *Organizational Behavior and Human Decision Processes, 67*, 26–48.

Cheng, S. Y., Lin, C. S., Chen, H. S., & Heh, J. S. (2005). Learning and diagnosis of individual and class conceptual perspectives: An intelligent systems approach using clustering techniques. *Computers & Education, 44*(3), 257–283.

Clariana, R. B. (1990). A comparison of answer-until-correct feedback and knowledge-of-correct-response feedback under two conditions of contextualization. *Journal of Computer-Based Instruction, 17*(4), 125–129.

Clariana, R. B. (1999, February). *Differential memory effects for immediate and delayed feedback: A delta rule explanation of feedback timing effects*. Paper presented at the Association of Educational Communications and Technology annual convention, Houston, TX.

Cohen, V. B. (1985). A reexamination of feedback in computer-based instruction: Implications for instructional design. *Educational Technology, 25*(1), 33–37.

Collins, C., Brown, J., & Newman, S. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Hillsdale, NJ: Lawrence Erlbaum.

Corbett, A. T., & Anderson, J. R. (1989). Feedback timing and student control in the LISP intelligent tutoring system. In D. Bierman, J. Brueker, & J. Sandberg (Eds.), *Proceedings of the Fourth International Conference on Artificial Intelligence and Education* (pp. 64–72). Amsterdam, Netherlands: IOS Press.

Corbett, A. T., & Anderson, J. R. (2001). Locus of feedback control in computer-based tutoring: Impact on learning rate, achievement and attitudes. In *Proceedings of ACM CHI 2001 Conference on Human Factors in Computing Systems* (pp. 245-252). New York: Association for Computing Machinery Press.

Corno, L., & Snow, R. E. (1986). Adapting teaching to individual differences among learners. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 605–629). New York: Macmillan.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Covington, M. V., & Omelich, C. L. (1984). Task-oriented versus competitive learning structures: Motivational and performance consequences. *Journal of Educational Psychology, 76*, 1038–1050.

Davis, W. D., Carson, C. M., Ammeter, A. P., & Treadway, D. C. (2005). The interactive effects of goal orientation and feedback specificity on task performance. *Human Performance, 18*, 409–426.

Dempsey, J., Driscoll, M., & Swindell, L. (1993). Text-based feedback. In J. Dempsey & G. Sales (Eds.), *Interactive instruction and feedback* (pp. 21–54). Englewood Cliffs, NJ: Educational Technology Publications.

Dihoff, R. E., Brosvic, G. M., Epstein, M. L., & Cook, M. J. (2003). The role of feedback during academic testing: The delay retention test revisited. *The Psychological Record, 53*, 533–548.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist, 41*, 1040–1048.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95*, 256–273.

Epstein, M. L., Lazarus, A. D., Calvano, T. B., Matthews, K. A., Hendel, R. A., Epstein, B. B., et al. (2002). Immediate feedback assessment technique promotes learning and corrects inaccurate first responses. *The Psychological Record, 52,* 187–201.

Farr, J. L., Hofmann, D. A., & Ringenbach, K. L. (1993). Goal orientation and action control theory: Implications for industrial and organizational psychology. In C. L. Cooper & I. T. Robertson (Eds.), *International review of industrial and organizational psychology* (pp. 193–232). New York: John Wiley.

Fedor, D. B. (1991). Recipient responses to performance feedback: A proposed model and its implications. *Research in Personnel and Human Resources Management, 9,* 73–120.

Fedor, D. B., Davis, W. D., Maslyn, J. M., & Mathieson, K. (2001). Performance improvement efforts in response to negative feedback: The roles of source power and recipient self-esteem. *Journal of Management, 27*(1), 79–97.

Fisher, S. L., & Ford, J. K (1998). Differential effects of learner effort and goal orientation on two learning outcomes. *Personnel Psychology, 51*, 397–420.

Ford, J. K., Smith, E. M., Weissbein, D. A., Gully, S. M., & Salas, E. (1998). Relationships of goal orientation, metacognitive activity, and practice strategies with learning outcomes and transfer. *Journal of Applied Psychology, 83*, 218–233.

Gaynor, P. (1981). The effect of feedback delay on retention of computer-based mathematical material. *Journal of Computer-Based Instruction, 8*(2), 28–34.

Gibbs, G. (1988). *Learning by doing: A guide to teaching and learning methods.* London: Further Education Unit.

Gilman, D. A. (1969). Comparison of several feedback methods for correcting errors by computer-assisted instruction. *Journal of Educational Psychology, 60*(6), 503–508.

Goldstein, I. L., Emanuel, J. T., & Howell, W. C. (1968). Effect of percentage and specificity of feedback on choice behavior in a probabilistic information-processing task. *Journal of Applied Psychology, 52*, 163–168.

Goleman, D. (1995). *Emotional intelligence*. New York: Bantam.

Goodman, J., Wood, R. E., & Hendrickx, M. (2004). Feedback specificity, exploration, and learning. *Journal of Applied Psychology, 89*, 248–262.

Graesser, A. C., McNamara, D., & VanLehn, K. (2005). Scaffolding deep comprehension strategies through AutoTutor and iSTART. *Educational Psychologist, 40*, 225–234.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Guzzo, R. A., Jette, R. D., & Katzell, R. A. (1985). The effects of psychologically based intervention programs on worker productivity: A meta-analysis. *Personnel Psychology, 38*, 275–291.

Hanna, G. S. (1976). Effects of total and partial feedback in multiple-choice testing upon learning. *Journal of Educational Research, 69*(5), 202–205.

Hartman, H. (2002). Scaffolding and cooperative learning. In *Human learning and instruction* (pp. 23–69). New York: City College, University of New York.

Hodes, C. L. (1985). Relative effectiveness of corrective and noncorrective feedback in computer assisted instruction on learning and achievement. *Journal of Educational Technology Systems, 13*(4), 249–254.

Hoska, D. M. (1993). Motivating learners through CBI feedback: Developing a positive learner perspective. In V. Dempsey & G. C. Sales (Eds.), *Interactive instruction and feedback* (pp. 105–132). Englewood Cliffs, NJ: Educational Technology Publications.

Ilgen, D. R., Fisher, C. D., & Taylor, M. S. (1979). Consequences of individual feedback on behavior in organizations. *Journal of Applied Psychology, 64,* 349–371.

Johnson, D., & Johnson, R. (1993). Cooperative learning and feedback in technology-based instruction. In J. Dempsey & G. Sales (Eds.), *Interactive instruction and feedback* (pp. 133–157). Englewood Cliffs, NJ: Educational Technology Publications.

Jurma, W. E., & Froelich, D. L. (1984). Effects of immediate instructor feedback on group discussion participants. *Central States Speech Journal, 35*(3), 178–186.

Kanfer, R., & Ackerman, P. L. (1989). Motivation and cognitive abilities: An integrative/aptitude-treatment interaction approach to skill acquisition. *Journal of Applied Psychology, 74*, 657–690.

Kippel, G. M. (1974). Information feedback schedules, interpolated activities, and retention. *Journal of Psychology, 87,* 245–251.

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin, 119*(2), 254–284.

Kluger, A. N., & DeNisi, A. (1998). Feedback interventions: Toward the understanding of a double-edged sword. *Current Directions in Psychological Science, 7,* 67–72.

Knoblauch, C. H., & Brannon, L. (1981). Teacher commentary on student writing: The state of the art. *Freshman English News, 10*(2), 1–4.

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

Kulhavy, R. W. (1977). Feedback in written instruction. *Review of Educational Research, 47*, 211–232.

Kulhavy, R. W., & Anderson, R. C. (1972). Delay-retention effect with multiple-choice tests. *Journal of Educational Psychology, 63*(5), 505–512.

Kulhavy, R. W., & Stock, W. (1989). Feedback in written instruction: The place of response certitude. *Educational Psychology Review, 1*(4), 279–308.

Kulhavy, R. W., & Wager, W. (1993). Feedback in programmed instruction: Historical context and implications for practice. In J. Dempsey & G. Ales (Eds.), *Interactive instruction and feedback* (pp. 3–20). Englewood Cliffs, NJ: Educational Technology Publications.

Kulhavy, R. W., White, M. T., Topp, B. W., Chan, A. L., & Adams, J. (1985). Feedback complexity and corrective efficiency. *Contemporary Educational Psychology, 10*(3), 285–291.

Kulik, J. A., & Kulik, C. C. (1988). Timing of feedback and verbal learning. *Review of Educational Research, 58*(1), 79–97.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Lepper, M. R., & Chabay, R. W. (1985). Intrinsic motivation and instruction: Conflicting views on the role of motivational processes in computer-based education. *Educational Psychologist, 20*(4), 217–230.

Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting & task performance.* Englewood Cliffs, NJ: Prentice Hall.

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science, 5*(4), 333–370.

Mason, B. J., & Bruning, R. (2001). *Providing feedback in computer-based instruction: What the research tells us.* Center for Instructional Innovation, University of Nebraska–Lincoln: 14. Retrieved June 1, 2006, from http://dwb.unl.edu/Edit/MB/MasonBruning.html

Mathan, S. A., & Koedinger, K. R. (2002). An empirical assessment of comprehension fostering features in an intelligent tutoring system. In S. A. Cerri, G. Gouarderes, & F. Paraguacu (Eds.), *Intelligent Tutoring Systems, 6th International Conference, ITS 2002* (Vol. 2363, pp. 330–343). New York: Springer-Verlag.

Mayer, J. D., & Salovey, P. (1993). The intelligence of emotional intelligence. *Intelligence, 17*(4), 433–442.

Mayer, J. D., & Salovey, P. (1997). What is emotional intelligence? In P. Salovey & D. Sluyter (Eds.), *Emotional development and emotional intelligence: Implications for educators* (pp. 3–31). New York: Basic Books.

Mayer, R. E., & Moreno, R. (2002). Aids to computer-based multimedia learning. *Learning and Instruction, 12*(1), 107–119.

McColskey, W., & Leary, M. R. (1985). Differential effects of norm-referenced and self-referenced feedback on performance expectancies, attribution, and motivation. *Contemporary Educational Psychology, 10*, 275–284.

Moreno, R. (2004). Decreasing cognitive load for novice students: Effects of explanatory versus corrective feedback in discovery-based multimedia. *Instructional Science, 32*, 99–113.

Morrison, G. R., Ross, S. M., Gopalakrishnan, M., & Casey, J. (1995). The effects of feedback and incentives on achievement in computer-based instruction. *Contemporary Educational Psychology, 20*(1), 32–50.

Mory, E. H. (1994). Adaptive feedback in computer-based instruction: Effects of response certitude on performance, feedback-study time, and efficiency. *Journal of Educational Computing Research, 11*(3), 263–290.

Mory, E. H. (2004). Feedback research review. In D. Jonassen (Ed.), *Handbook of research on educational communications and technology* (pp. 745–783). Mahwah, NJ: Lawrence Erlbaum.

Narciss, S., & Huth, K. (2004). How to design informative tutoring feedback for multimedia learning. In H. M. Niegemann, D. Leutner, & R. Brunken (Ed.), *Instructional design for multimedia learning* (pp. 181–195). Munster, NY: Waxmann.

Newman, M. I., Williams, R. G., & Hiller, J. H. (1974). Delay of information feedback in an applied setting: Effects on initially learned and unlearned items. *Journal of Experimental Education, 42*(4), 55–59.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist, 38*, 1–4.

Park, O., & Gittelman, S. S. (1992). Selective use of animation and feedback in computer-based instruction. *Educational Technology Research and Development, 40*(4), 27–38.

Phye, G. D., & Andre, T. (1989). Delayed retention effect: Attention, perseveration, or both? *Contemporary Educational Psychology, 14*(2), 173–185.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Phye, G. D., & Baller, W. (1970). Verbal retention as a function of the informativeness and delay of informative feedback: A replication. *Journal of Educational Psychology, 61*(5), 380–381.

Phye, G. D., & Bender, T. (1989). Feedback complexity and practice: Response pattern analysis in retention and transfer. *Contemporary Educational Psychology, 14*(2), 97–110.

Phye, G. D., & Sanders, C. E. (1994). Advice and feedback: Elements of practice for problem solving. *Contemporary Educational Psychology, 19*(3), 286–301.

Picard, R. W., Papert, S., Bender, W., Blumberg, B., Breazeal, C., Cavallo, D., et al. (2004). Affective learning—A manifesto. *BT Technology Journal, 22*(4), 253–269.

Pound, L. D., & Bailey, G. D. (1975). Immediate feedback less effective than delayed feedback for contextual learning? *Reading Improvement, 12*(4), 222–224.

Prather, D. C., & Berry, G. A. (1973). Delayed versus immediate information feedback on a verbal learning task controlled for distribution of practice. *Education, 93*(3), 230–232.

Pridemore, D. R., & Klein, J. D. (1991). Control of feedback in computer-assisted instruction. *Educational Technology Research and Development, 39*(4), 27–32.

Pridemore, D. R., & Klein, J. D. (1995). Control of practice and level of feedback in computer-based instruction. *Contemporary Educational Psychology, 20*, 444–450.

Reddy, W. B. (1969). Effects of immediate and delayed feedback on the learning of empathy. *Journal of Counseling Psychology, 16*(1), 59–62.

Roper, W. J. (1977). Feedback in computer assisted instruction. *Programmed Learning and Educational Technology, 14*(1), 43–49.

Sales, G. C. (1993). Adapted and adaptive feedback in technology-based instruction. In J. V. Dempsey & G. C. Sales (Eds.), *Interpretive instruction and feedback* (pp. 159–175). Englewood Cliffs, NJ: Educational Technology Publications.

Salomon, G., & Globerson, T. (1987). Skill may not be enough: The role of mindfulness in learning and transfer. *International Journal of Educational Research, 11*(6), 623–637.

Schimmel, B. J. (1983, April). *A meta-analysis of feedback to learners in computerized and programmed instruction.* Paper presented at the annual meeting of the American Educational Research Association, Montréal. (ERIC Document Reproduction Service No. 233708).

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

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.

Schmidt, R. A., Young, D. E., Swinnen, S., & Shapiro, D. C. (1989). Summary knowledge of results for skill acquisition: Support for the guidance hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(2), 352–359.

Schroth, M. L. (1992). The effects of delay of feedback on a delayed concept formation transfer task. *Contemporary Educational Psychology, 17*(1), 78–82.

Schwartz, F., & White, K. (2000). Making sense of it all: Giving and getting online course feedback. In K. W. White & B. H. Weight (Eds.), *The online teaching guide: A handbook of attitudes, strategies, and techniques for the virtual classroom* (pp. 57–72). Boston: Allyn & Bacon.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

Shute, V. J., Hansen, E. G., & Almond, R. G. (2007). *An assessment for learning system called ACED: Designing for learning effectiveness and accessibility.* ETS Research Report No. RR-07-26, Princeton, NJ.

Shute, V. J., Woltz, D. J., & Regian, J. W. (1989, May). *An investigation of learner differences in an ITS environment: There's no such thing as a free lunch.* Paper presented at the 4th International Conference on Artificial Intelligence and Education–AI-ED '89, Amsterdam, Holland.

Sleeman, D. H., Kelly, A. E., Martinak, R., Ward, R. D., & Moore, J. L. (1989). Studies of diagnosis and remediation with high school algebra students, *Cognitive Science, 13,* 551–568.

Smith, P. L., & Ragan, T. J. (1999). *Instructional design* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Song, S. H., & Keller, J. M. (2001). Effectiveness of motivationally adaptive computer-assisted instruction on the dynamic aspects of motivation. *Educational Technology Research and Development, 49*(2), 5–22.

Surber, J. R., & Anderson, R. C. (1975). Delay-retention effect in natural classroom settings. *Journal of Educational Psychology, 67*(2), 170–173.

Swan, M. B. (1983). *Teaching decimal place value. A comparative study of conflict and positively-only approaches.* Research Report No. 31, University of Nottingham, Sheel Center for Mathematical Education.

Sweller, J., Van Merriënboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10,* 251–296.

VandeWalle, D., Brown, S. P., Cron, W. L., & Slocum, L. W. (1999). The influence of goal orientation and self-regulation tactics on sales performance: A longitudinal field test. *Journal of Applied Psychology, 84,* 249–259.

VanLehn, K. (1982). Bugs are not enough: Empirical studies of bugs, impasses and repairs in procedural skills. *Journal of Mathematical Behavior, 3*(2), 3–71.

VanLehn, K., Lynch, C., Schulze, K., Shapiro, J. A., Shelby, R., Taylor, L., et al. (2005). The Andes physics tutoring system: Lessons learned, *International Journal of Artificial Intelligence in Education*, *15*(3). Retrieved May 22, 2006 from http://www.andes.pitt.edu/Pages/AndesLessonsLearnedForWeb.pdf

Vygotsky, L. S. (1987). *The collected works of L.S. Vygotsky.* New York: Plenum.

Wager, W., & Wager, S. (1985). Presenting questions, processing responses, and providing feedback in CAI. *Journal of Instructional Development, 8*(4), 2–8.

Waldersee, R., & Luthans, F. (1994). The impact of positive and corrective feedback on customer service performance. *Journal of Organizational Behavior, 15*(1), 83–95.

Waldrop, P. B., Justen, J. E., & Adams, T. M. (1986). A comparison of three types of feedback in a computer-assisted instruction task. *Educational Technology*, *26*(11), 43–45.

Whyte, M. M., Karolick, D. M., Neilsen, M. C., Elder, G. D., & Hawley, W. T. (1995). Cognitive styles and feedback in computer-assisted instruction. *Journal of Educational Computing Research, 12*(2), 195–203.

Wiliam, D. (2007). Keeping learning on track: Classroom assessment and the regulation of learning. In F. K. Lester Jr. (Ed.), *Second handbook of mathematics teaching and learning* (pp. 1053-1098). Greenwich, CT: Information Age Publishing.

Williams, S. E. (1997, March). Teachers' written comments and students' responses: A socially constructed interaction. *Proceedings of the annual meeting of the Conference on College Composition and Communication,* Phoenix, AZ. Retrieved

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010

December 24, 2007, from http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/16/a8/1e.pdf

Author

VALERIE J. SHUTE is currently an associate professor in the Educational Psychology and Learning Systems Department at Florida State University, Tallahassee, FL 32306; e-mail *vshute@fsu.edu.* She joined Florida State University in 2007 and teaches graduate students in the Instructional Systems program. Her research interests relate to cognitive modeling/diagnosis, instructional system design, formative/stealth assessment to support learning, and innovative evaluation methodologies, typically using the structure and power of Bayes net technology to support the various efforts.

Downloaded from http://rer.aera.net at FLORIDA STATE UNIV LIBRARY on May 7, 2010