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FEEDBACK RESEARCH REVISITED

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29.1 INTRODUCTION

In a previous examination of feedback research (Mory, 1996), the use of feedback in the facilitation of learning was examined extensively according to various historical and paradigmatic views of the past feedback literature. Most of the research presented in that volume in the area of feedback was completed with specific assumptions as to what purpose feedback serves. This still holds true, and even more so, because our theories and paradigms have expanded, and the field of instructional design has undergone and will continue to undergo rapid changes in technologies that will afford new advances to take place in both the delivery and the context of using feedback in instruction. It is not surprising that feedback may have various functions according to the particular learning environment in which it is examined and the particular learning paradigm under which it is viewed. In fact, feedback is incorporated in many paradigms of learning, from the early views of behaviorism (Skinner, 1958), to cognitivism (Gagné, 1985; Kulhavy & Wager 1993) through more recent models of constructivism (Jonassen, 1991, 1999; Mayer, 1999; Willis, 2000), settings such as open learning environments (Hannafin, Land, & Oliver, 1999), and views that support multiple approaches to understanding (Gardner, 1999), to name just a few. While feedback has been an essential element of theories of learning and instruction in the past (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991), it still pervades the literature and instructional models as an important aspect of instruction (Collis, De Boer, & Slotman, 2001; Dick, Carey, & Carey, 2001).

29.2 DEFINITION OF FEEDBACK

The basic meaning of feedback has remained the same in *Webster's New World Dictionary* from the 1984 edition to the current one. *Webster's* (2001) continues to define feedback as "a process in which the factors that produce a result are themselves modified, corrected, strengthened, etc. by that result" and "a response, as one that sets such a process in motion" (p. 520). Whereas this definition could fit a host of situations or systems, most educational researchers consider the term "feedback" in the context of instruction. Feedback has been widely perceived as an important component of general systems operations and may be viewed under a variety of settings (Kowitz & Smith, 1985, 1987). In the purely instructional sense, feedback can be said to describe any communication or procedure given to inform a learner of the accuracy of a response, usually to an instructional question (Carter, 1984; Cohen, 1985; Kulhavy, 1977; Sales, 1993). This type of feedback acts as one of the events of instruction described by Gagné (1985) and usually follows some type of practice task. More broadly, feedback allows the comparison of actual performance with some set standard of performance (Johnson & Johnson, 1993). In technology-assisted instruction, it is information presented to the learner after any input with the purpose of shaping the perceptions of the learner (Sales, 1993). Information presented via feedback in instruction might include not only answer correctness, but other information such as precision, timeliness, learning guidance, motivational messages, lesson sequence advisement, critical comparisons, and learning focus (Hoska, 1993; Sales, 1993). In fact, Wager and Wager (1985) refer to feedback in computer-based instruction as being *any* message or display that the computer presents to the learner after a response.

Most studies that have examined feedback use contrived experimental learning situations where feedback is given from an external source after a learner responds to a question during instruction. The main purpose of this feedback is to confirm or change a student's knowledge as represented by answers to practice or test questions. However, some researchers (Butler & Winne, 1995) have suggested that viewing feedback in such a unilateral context fails to take into account variances in behavior that might be the result of self-regulation and student engagement. Further, feedback can also be viewed in even less traditional settings, such as its role in program evaluation. When used in situations that are not necessarily instructional, the best definition of feedback is information presented that allows comparison between an actual outcome and a desired outcome. Tucker (1993) points out that feedback is particularly important when evaluating dynamic instructional programs because its presence or absence can "dramatically affect the accuracy required of human judgment and decision making" (p. 303).

New learning environments have erupted into a wide range of potential uses of feedback that were not utilized or considered before, as the ability to provide rapid information from and to learners is facilitated through a myriad of new technologies and simulations. There is quite a difference between Skinner's programmed instruction of the 1960s, which presented a linear series of steps, to that of interactive microworlds, gaming environments, open learning environments, and rapid transfer of information through advanced technologies such as the World Wide Web.

To illustrate some of the purposes of feedback, the next section presents the evolution of feedback research in instruction from its early beginnings through the present. The principal feedback variables that have interested researchers are then discussed.

29.3 A HISTORY OF FEEDBACK RESEARCH

Many of us may assume that the most recent studies of feedback are the result of several current trends and accepted paradigms—for example, the information processing model and newer theories of motivation. However, three definitions of feedback dating back to the early 1900s are surprisingly similar to the ones we use today. Kulhavy and Wager (1993) refer to these as the "feedback triad" (p. 5) and point out that these definitions still prevail in the views of feedback we currently hold. First, feedback served as a motivator or incentive for increasing response rate and/or accuracy. Second, feedback acted to provide a reinforcing message that would automatically connect responses to prior stimuli—the focus being on correct responses. Finally, feedback provided information that learners could use to validate or change a previous response—the focus falling on error responses.

29.3.1 The Law of Effect

The earliest studies of feedback date back to E. L. Thorndike's Law of Effect, which postulated that feedback would act as a "connector" between responses and preceding stimuli (see Kulhavy & Wager, 1993). Researchers such as Thorndike were examining the use of postresponse information as early as 1911 (cited in Kulhavy & Wager, 1993). Thorndike's work showed that a response followed by a "satisfying state of affairs" is likely to be repeated and increases the likelihood of learning. The view of feedback as information emphasized the role that the learner had in learning, with the ability to adapt his or her response according to information in the feedback and thus correct his or her errors. The first researcher to emphasize error correction was Sidney Pressey (1926). However, a later study using his "teaching machine" emphasized both the error-correcting function of feedback and its acting as a punishment for errors—a Thorndike viewpoint that supports the notion of feedback as a reinforcer (Pressey, 1927). Thus we see that the confusion in the feedback research began quite early and that, given the early "feedback triad," the research has not evolved as much as one might expect.

29.3.2 Programmed Instruction

Thorndike's pioneering work paved the way for the next avenue of research on feedback, B. F. Skinner's (1958) study of programmed instruction. Using principles from the Law of Effect and the application of reinforcement on learners, Skinner proposed that a solution to instructional problems lied in the use of strategically designed classroom materials that would take learners through information in a step-by-step fashion, shaping behavior and strengthening desired responses. By the year 1960, the programmed instruction movement was well under way, purporting that feedback in programmed instruction served as both a reinforcer and a motivator, perpetuating a confusion between learning and incentive. During this period, instructional errors were either ignored or considered "aversive consequences" to be avoided (Skinner, 1968). The fact that errors were deemed as aversive implies an emotional element from which the early motivational view of feedback was derived. The viewpoint that incorrect responses cause distress and influence self-concept is used even today (Fischer & Mandl, 1988). Kulhavy and Wager (1993) suggest that such motivational variables should be separated from the feedback message, keeping them extrinsic to the lesson content itself. Certainly this would help remove the confusion between the instructional content of feedback and other factors that might affect performance.

29.3.3 Feedback as Reinforcement

Programmed instruction emphasized an operant approach to learning—one that had the concept of reinforcement at its heart. Programs were designed to shape a student's responses using a small lock-step approach with a high level of redundancy. Operant psychologists of the time argued that learning tasks should be analyzed and broken down into small enough steps that the probability of a successful response was ensured (Cohen, 1985). By telling a student that an answer is correct, the student is "reinforced" to answer correctly again on a later test (Kulhavy, 1977).

Around 1970, most researchers began to doubt the feedback-as-reinforcement view. In fact, 10 years of research under this paradigm showed no systematic effects for feedback (see Kulhavy & Wager, 1993). Studies provided little evidence that feedback following positive responses acts in a reinforcing manner (Anderson, Kulhavy, & Andre, 1972; Bardwell, 1981; Barringer & Gholson, 1979; Kulhavy, 1977; Roper, 1977). Researchers then had to look at the basic functions of feedback to discover what was actually occurring. A series of studies by R. C. Anderson and his colleagues found that students will not use feedback as the researcher intends unless this use is controlled (Anderson, Kulhavy, & Andre, 1971, 1972). For instance, students will simply copy answers from feedback if allowed to do so, with little or no processing or learning of information. Kulhavy (1977) coined the term *presearch availability* to describe the ease with which learners can find a correct answer without reading the lesson material. If presearch availability is high, then students will usually copy the answer itself, bypassing the instruction and yielding little learning (Anderson & Faust, 1967). In programmed material, feedback significantly facilitates learning only if students must respond *before* seeing the feedback.

29.3.4 Feedback as Information

The data collected by Anderson and his colleagues (1971, 1972) not only provided insight into the importance of the learner's processing of the lesson material before his or her response to a question, but also, and perhaps more importantly, provided indication that feedback functions primarily to correct errors, not merely to "reinforce" correct answers. Numerous studies during this time supported feedback's ability to correct inaccurate information (Anderson et al., 1971, 1972; Bardwell, 1981; Barringer & Gholson, 1979; Kulhavy, 1977; Kulhavy & Anderson, 1972; Roper, 1977; Tait, Hartley, & Anderson, 1973). Concurrent shifts toward cognitive psychology led researchers to focus on how feedback influenced primary cognitive and metacognitive processes within a learner (Briggs & Hamilton, 1964; Kulhavy, 1977).

Examining feedback from an information-processing perspective, the learner participates in the system to correct his or her errors. Kulhavy and Stock (1989) use the concept of servo-control theory, contrasting the two feedback systems (feedback as reinforcement vs. feedback as information) as open-loop versus closed-loop. Feedback acting as reinforcement is an example of an open-loop system, in which errors are ignored because the system is not affected by input information. The operant approach does not provide error-correcting mechanisms. In contrast, the feedback-as-information position acts as a closed-loop system. Because this type of system has ways of correcting errors, errors are of primary importance. Studies indeed emerged that made the correction and analysis of errors a major goal (Anderson et al., 1971; Birenbaum & Tasuoka, 1987; Elley, 1966; Gilman, 1969; Kulhavy & Parsons, 1972), with a predominant focus on all the metacognitive processes involved in this type of error correction.

It is from the information processing perspective that most research of the past 20 years has been conducted. In a later section of this chapter, the prevailing concerns of researchers from that period to the present are discussed in detail. But first, it is helpful to present two current models of feedback as a framework for what follows.

29.4 MAJOR MODELS OF FEEDBACK

29.4.1 A Connectionist Model of Feedback Effects

Perhaps the most recent reference to any type of feedback model, per se, lies in the work of Clariana (1999, 2000) in the area of using a connectionist model to explain feedback effects. "Connectionist models apply various mathematical rules within neural network computer simulations in an effort, among other things, to mimic and describe human memory associations and learning" (Clariana, 2000, p. 83). He describes the theory of connectionism as comprising several families of models, which include "simple feedforward networks, pattern associators, multilayer networks with backpropagation, competitive networks, and recurrent networks" (p. 83). These apparently differ little in how the nodes of the network are interconnected but are vastly different in terms of the type of processing that they are able to accomplish (McLeod, Plunkett, & Rolls, 1998). Neural networks have been used to determine pattern matching, pattern completion, and retrieval by content, recognition, prototype extraction, and classification (Haberlandt, 1997; as cited in Clariana, 2000).

The crux of the model lies in a view of learning as involving the interaction of information given by instruction with existing information that is already in the learner's memory (Ausubel, 1968; Bruner, 1990). When a learner "commits" to a lesson response, that response reflects the learner's immediate understanding of a particular instructional instance. Clariana terms this the initial lesson response (ILR) and uses it to provide a measure of a learner's existing information. He then relates this to what happens to the learner's memory traces of ILRs that are error responses, to determine if these initial errors interfere with attaining correct responses. He views this as one key to our understanding of how feedback works and has researched this approach using the *delta rule* to predict posttest memory activation levels of ILR errors and of correct responses for immediate and delayed feedback (Clariana, 1999).

The delta rule apparently is one of the simplest and most common of connectionist rules that implies the effect of feedback on learning (Shanks, 1995; Widrow & Hoff, 1960). It describes the change in association weight between an input unit and an output unit at each learning trial. Application of the delta rule in this setting assumes that lesson average item difficulty values are reasonable estimates of the association weights of correct responses.

Use of the delta rule involves the use of delta equations and assigned values for learner responses, so that the association weight increases with correct responses and decreases with incorrect responses. Or in simpler terms, when feedback is provided as part of the responding instance, correct responses are strengthened and incorrect responses weakened. The amount of this increase or decrease can be determined by the delta rule

(Clariana, 2000). When given the lesson item difficulty (the initial response), the delta rule should be able to predict posttest item difficulties after feedback has been presented.

Clariana postulates that this has implications for the effectiveness of immediate versus delayed feedback. He suggests several ways in which this would occur. For correct lesson responses, memory of ILRs and of correct responses would be strengthened in general for both immediate and delayed feedback, as the application of the delta equation result would be positive. For lesson errors, the ILR association with the item stem would be weakened for immediate feedback, as the equation produces a negative result, but would not be for delayed feedback.

For delayed feedback, the connectionist model predicts that ILR errors would actually be strengthened. Typically in associated learning within living systems, there is a small portion of time during the specific input pattern activation when associations can be strengthened or weakened. Clariana suggests that immediate feedback provides the necessary feedback information within this time frame, whereas delayed feedback does not.

Based on a previous study (Clariana, 1999), three hypotheses were postulated in the Clariana (2000) study:

1. Retention test memory of ILRs will be considerably greater for delayed feedback than for immediate feedback at all item difficulty levels.
2. Both types of feedback will obtain the across the range of possible lesson to posttest gain with difficult lesson items.
3. Retention test memory of correct responses will vary across the range of possible lesson item difficulty values for the delayed and immediate forms, with immediate feedback slightly better than delayed feedback with more difficult lesson items and delayed feedback slightly better than immediate feedback with easier lesson items. (p. 85)

Clariana (2000) also tried to separate any effects observed from immediacy versus multiple exposures by including multiple-try feedback. The study utilized two levels of questions, verbatim versus inferential, depending on their relationship either directly to one or to multiple propositions in the text. The three alternate feedback treatments were delayed feedback, single-try immediate feedback, and multiple-try immediate feedback.

Results confirmed that retention of initial lesson responses is greater for delayed feedback compared to immediate feedback across all item difficulties, but particularly with difficult lesson items. The essential value in this result is that it can help instructional designers use initial question responses to broaden understanding, particularly when answers are not absolutely "right" or "wrong" but function as learning transitions to broaden students' understanding. Feedback was also suggested to have its greatest effect with difficult lesson items, thus suggesting that future feedback studies should consider and control lesson item difficulty so as not to confound results. However, feedback timing did not interact with lesson item difficulty as predicted. Clariana suspects that the lesson items were not difficult enough in the study to produce the hypothesized interaction.

In terms of feedback effects, multiple-try feedback was much more like single-try feedback in retention test memory of ILRs, suggesting that feedback's immediacy does indeed serve to reduce memory of ILR errors—what Clariana (2000) terms a "retroactive interference effect" (p. 89). The multiple-try feedback group fell midway between the single-try feedback (immediate) and the delayed feedback (multiple-item exposure) groups. He suggests that this indicates that both feedback timing and number of exposures combine or interact to impact retention test memory, particularly for memory of correct responses. A similar study (Clariana, Wagner, & Murphy, 2000) also supports the use of a connectionist model for explaining instructional feedback effects

29.4.2 A Certitude Model of Feedback

Kulhavy and Stock (1989) have proposed a model of feedback in written instruction that attempts to clarify and explain previous findings in the literature. Their model also goes beyond these basic explanations to make testable predictions under girded by theoretical rationales. The model has been scrutinized (Bangert-Drowns et al., 1991; Dempsey, Driscoll, & Swindell, 1993; Mory, 1991, 1992, 1994) and tested by current researchers (Kulhavy & Stock, 1989; Kulhavy, Stock, Hancock, Swindell, & Hammrich, 1990; Kulhavy, Stock, Thornton, Winston, & Behrens, 1990; Mory, 1991, 1994; Swindell, 1991, 1992; Swindell, Peterson, & Greenway, 1992). It is cited as the most comprehensive treatment of feedback in facilitating learning from written instruction (Dempsey, Driscoll, & Swindell, 1993), as it integrates the factors of learner confidence, feedback complexity, and error correction and has been investigated under different modes of presentation and timing. (Note that each of these components is discussed individually and in depth later.)

Kulhavy and Stock (1989) assert that much of the prior research on feedback is conceptually flawed. For one thing, researchers always treated responses as being absolutely right or wrong—a dichotomy that virtually ignored the complexity of learning behavior. Consider that a correct answer may be just a lucky guess or that a wrong answer may be anything from a careless mistake to a total miscomprehension of the material. Even more puzzling were studies that resulted in initial correct answers being *changed* to *wrong* responses on a posttest and instances in which initial errors were never corrected, despite what was included in the feedback (Lhyle & Kulhavy, 1987; Peeck, van den Bosch, & Kreupeling, 1985).

The model proposes that the feedback process is made of three cycles that constitute each instructional episode. In Cycle I, the learner is presented with a task to which he or she needs to respond. In Cycle II, feedback is presented based upon the input from the learner in Cycle I. In Cycle III, the original task is presented again as a test item to which the learner responds. Within each cycle, a common series of steps ensues. Put succinctly, each cycle involves an input from the task at hand to the learner, a comparison of the input to some sort of reference standard that then results in an output. The degree of mismatch between the perceived stimulus and the reference standard results in a measure of error. The discrepancy between these two entities causes the system to exert effort to reduce the discrepancy. Dempsey, Driscoll, and Swindell (1993) have

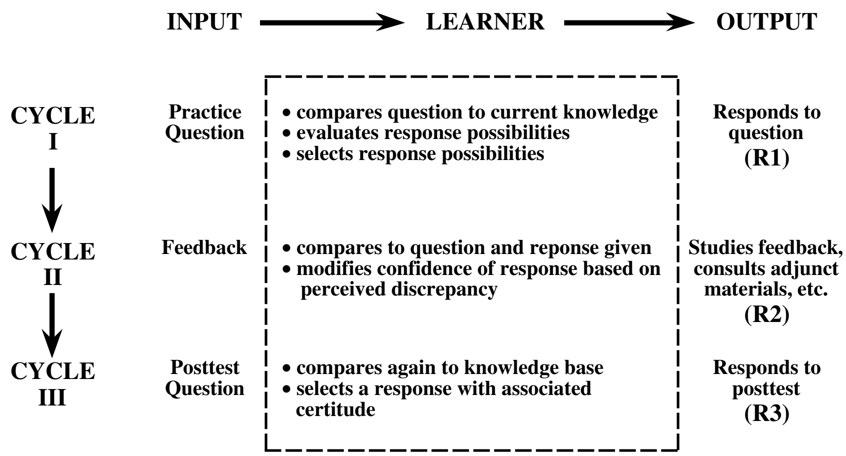

FIGURE 29.1. Representation of Kulhavy and Stock's (1989) certitude model of text-based feedback (from Dempsey, Driscoll, & Swindell, 1993). From *Interactive Instruction and Feedback* (p. 42), by J. V. Dempsey and G. C. Sales (Eds.), 1993, Englewood Cliffs, NJ: Educational Technology. Copyright 1993 by Educational Technology Publications. Reprinted with permission.

graphically represented the Kulhavy and Stock model as shown in Fig. 29.1.

During each cycle, the learner engages in mental activity aimed at processing the input and preparing an appropriate response. The model emphasizes the learner's level of certainty (termed *response certitude*) between the demands of the instructional task in Cycle I and his or her prior knowledge and current understanding of that task. If this perceived match is good, the learner will select a response with a high level of certainty or confidence. The worse the match, the lower the learner's confidence level will be. In Cycle II, when the learner receives feedback on his or her response, the feedback acts as verification to allow the learner to compare the response to the information contained in the feedback. When this verification is combined with the learner's initial response confidence level, a discrepancy value results. If learners receive verification of a correct answer when they are certain they were correct, there is no discrepancy. Conversely, learners who are informed that their answer was wrong when they were confident that their answer was correct will produce a high level of discrepancy.

Kulhavy has represented this discrepancy value in the equation

$$f_v \cdot c = d,$$

where f_v is the verification component, c is the initial certitude level, and d is the discrepancy. The verification component f_v is set to equal $(-1)^m$, where $m = 0$ for initial error responses and $m = 1$ for initial corrects. This is explained as having the effect of assigning an algebraic sign to d, where $[(-1)^0 = +1]$ for errors and $[(-1)^{-1} = -1]$ for correct responses. The response certitude variable, c, usually employing a 5-point Likert-type scale, results in a discrepancy (d) from (-5) to $(+5)$ (Kulhavy & Stock, 1989; Kulhavy, Stock, Hancock et al., 1990).

In this model, it is predicted that the level of discrepancy is a major factor influencing how much time and effort a student will naturally expend in error correction. In the case of a high-certitude correct answer (low discrepancy), students have little need for extensive or elaborated feedback. But when students think an answer is correct that is in reality an incorrect response (high discrepancy), they will exert much effort to find out what was remiss in their thinking. In the case of low-certitude responses, regardless of whether students' answer is correct or wrong, they likely do not understand the information and would benefit from feedback that acts as new instruction. Even in Kulhavy's (1977) prior research we see that high-confidence correct answers yield the shortest feedback study times, high-confidence errors yield the longest time, and low-confidence responses fall somewhere in between (Kulhavy, White, Topp, Chan, & Adams, 1985; Kulhavy, Yekovich, & Dyer, 1976, 1979). Obviously, discrepancy must mediate effects of different types of feedback in terms of their complexity or elaboration. Further, according to the model, prescriptions can be made as to how much and what type of information to include in feedback for the varying levels of discrepancy.

Kulhavy and Stock's (1989) predictions have been shown to prevail in a number of conditions, thus suggesting its robustness. In testing the model, they performed three studies relating to discrepancy and feedback times and the durability of correct answers under low discrepancy. As predicted by the model, learners who thought they answered correctly when in fact they were in error (high discrepancy) spent more time studying feedback. To test this finding further, students in a second study (Kulhavy & Stock, 1989) were told that an answer was wrong when it was in fact correct, and vice versa. Because the students *thought* their answer was wrong when they had assumed they were correct (even though in actuality the answer *was* correct), they indeed spent more time studying the feedback. Again, these results support the model. And in their third study, Kulhavy and Stock (1989) demonstrated that the probability of a correct posttest response increased with the initial response certainty level, particularly when practice responses were also correct. In this way, feedback served to increase the durability of initially correct responses.

Several other studies have also supported the model. Kulhavy and his associates (Kulhavy, Stock, Hancock et al., 1990) found that in the absence of feedback, response confidence and the probability of a correct posttest response are positively related. The model suggests that feedback elaboration should be useful in correcting particularly high-certitude errors, a prediction that a study by Swindell (1991) supports. One problem in the Swindell study, however, is that feedback elaboration consisted of presenting the stem and all of the alternatives listed, with the correct alternative designated by an asterisk. As discussed later, feedback elaborations usually provide more information than was operationalized in the Swindell (1991) study, usually informing the learner of why an answer is incorrect or re-presenting a portion of the original instruction.

The prediction that there is a direct relationship between increases in discrepancy and increased study effort is supported by another study by Swindell (1992). In that study, she also constrained the time that students were allowed to study feedback, expecting that as the feedback reading time became increasingly constrained, the probability of a correct posttest response would decrease. This was generally true, but for groups receiving feedback at both slow and average presentations speeds, high certitudes resulted in lower probabilities of correct responses and lower certitudes resulted in higher probabilities. Swindell explained this through interference theory, suggesting that in the case of errors, certitude may reflect response competition that results in an inaccurate perception of comprehension. Her study was not able to support the durability hypothesis that high-certitude response alternatives would be better remembered and carry over to a posttest and that low-certitude judgments are more likely to be forgotten over time and are less likely to be chosen again on a posttest. No systematic relationship could be determined from her study.

Swindell, Peterson, and Greenway (1992) have also attempted to extend the model to younger learners, as the original model was developed from a research base of adult learners. Certainly the developmental stage of children will determine whether or not they are able to assess their own learning confidence accurately. The results of the study suggest that fifth graders demonstrated the pattern that high-confidence errors (maximum discrepancy) were more likely to be corrected on a posttest than were low-confidence errors. However, third graders in the study demonstrated the opposite pattern: High-confidence errors were less likely to be corrected than those of low confidence. Further, fifth graders were more likely to correct high-confidence errors than were third graders.

Dempsey, Driscoll, and Swindell (1993) point out that the Kulhavy and Stock (1989) model also provides a useful framework for past research results. The durability hypothesis explaining why initially correct responses are better remembered than errors, assuming that learners are more likely to make higher-confidence judgments for correct responses than for incorrect responses, is supported by Peeck and Tilleman (1979) and Peeck et al. (1985). Measures of response certitude and durability should be positively related because high confidence should represent better comprehension and will therefore be better remembered. Further, the model supports the finding that learners not only were more likely to recall initially correct responses, but also were more likely to correct initial errors if they could recall their initial response. And a recent study (Swindell, Kulhavy, & Stock, 1992) found similar response patterns for durability as well.

Although the Kulhavy and Stock (1989) model of feedback is the most comprehensive to date, it does have some problematic aspects. For one thing, response certitude is a self-report measure. Whereas response certitude judgments do provide some useful information about the cognitive status of the learner (Kulhavy et al., 1976; Metcalfe, 1986; Nelson, Leonesio, Landwehr, & Narens, 1986), the nature of determining certitude has some underlying problems. The idea behind response certainty lies in the learner's metacognitive process of predicting his or her criterion performance on a task. This process can be related to "feeling of knowing" research (Butterfield, Nelson, & Peck, 1988; Metcalfe, 1986; Nelson, 1988; Nelson et al., 1986). Feeling of knowing has been shown to be accurately predicted for memory recognition tasks and has been found to exist over all age groups, and the reliability of feeling of knowing has been found to be generally excellent. However, the stability of an individual's feeling of knowing accuracy has been found to fluctuate significantly (Nelson, 1988). In Nelson's (1988) findings, when a subject gives a higher feeling-of-knowing rating to one item over another, there is perfect retest reliability in that the same outcome occurs if the person subsequently makes feeling-of-knowing responses on those same items (Nelson et al., 1986). Conversely, individuals having a relatively high level of feeling-of-knowing accuracy at one time do not also have a relatively high level of feeling-of-knowing accuracy at another time (see Nelson, 1988). Since individual differences of feeling-of-knowing accuracy may be inconsistent, it raises the question of whether or not a response certitude estimate is valid for prescribing feedback, if certitude statements may not be a stable measure of an individual's true knowledge. Perhaps if a variable or variables could be identified that influence these changes, researchers would have more insight into the process. For example, learners' general level of self-esteem or motivation might be influencing their perceptions of certainty.

Further inconsistency predominates when comparing the levels of tasks involved in feeling-of-knowing research. Learners were able to predict their feeling of knowing in memory tasks accurately but overestimated their likelihood of success on problem-solving tasks or problems requiring insight (Metcalfe, 1986). Other researchers (Driscoll, 1990) have found a contrary finding, that students learning concepts tended to underestimate their feelings of answer correctness. These cases of over- and underestimation show that students generally possess an inaccurate perception of their own knowledge. Of further concern, most feedback studies using response certitude have employed verbal information tasks only; in fact, the model itself was built upon a vast well of studies that involved rote memorization of verbal information. As researchers are discovering (Dempsey & Driscoll, 1994; Mory, 1991, 1994), tasks of learning intellectual skills may produce different results, especially in light of the prior findings suggesting that subjects tend to estimate their feeling of knowing incorrectly during studies using higher-level tasks. Indeed, this was the case in a recent study (Mory, 1994) that used response certitude estimates as part of the feedback cycle for both verbal information and concept learning tasks. Students tended to have a high level of certitude for concept questions, regardless of actual answer correctness. Thus, low-certitude feedback designed to give the most information was not encountered when it was truly needed. Learners simply were not able to give accurate assessments of their own abilities to classify a particular concept.

Another issue that regards the application of response certitude estimates within an instructional situation is that of efficiency. Corrective efficiency results from taking the total number of correct answers on a posttest and dividing it by the amount of time spent during an instructional task. Kulhavy and his associates (1985) examined efficiency using two separate measures. One measure isolated the amount of time spent reading the instruction, thus accounting for the efficiency of only the instruction or "text" portion of the lesson. When this measure was tested across varying feedback groups, there were no significant differences found. The second measure used was the amount of time spent just in studying the feedback, as less complex forms of feedback are usually more time efficient in terms of what Kulhavy and his colleagues (1985) call "posttest yield per unit of study time invested" (p. 289). The amount of time a learner spends on feedback is affected by two things: (a) the amount of information included in the feedback message (load) and (b) the response certitude levels. Results from the study confirmed that the less complex forms of feedback were more time efficient and, also, that efficiency rose as a function of increases in confidence values. Considering that high-confidence responses should reflect an understanding of subject matter and content, the learner would be more likely to make efficient use of the feedback presented (Kulhavy et al., 1985).

One should note that the Kulhavy study (Kulhavy et al., 1985) examined efficiency in terms of the feedback portion of a lesson only. But the process of giving a response confidence rating for each question could possibly add considerable time and interference to the overall lesson for the student. Mory (1991, 1994) investigated adaptive feedback that was based on levels of discrepancy and prescriptions of the model. The study supported that feedback efficiency can be increased by varying the amount of feedback information according to levels of discrepancy, however, the added time for response certitude evaluations resulted in lower overall lesson efficiency. Further, when a typical nonadaptive feedback sequence was compared with an adaptive one that employed response certitude as part of the cycle, adaptive feedback was significantly less efficient than traditional feedback in terms of overall lesson efficiency (Mory, 1994).

And finally, one might question the generality of a model that was built around experimental testing environments and usually limited to the use of multiple-choice questions (see Kulik & Kulik, 1988). Many of the studies present brief paragraphs of text information, followed by multiple-choice questions based on the preceding paragraph (Chanond, 1988; Kulhavy et al., 1976, 1979; Lhyle & Kulhavy, 1987). Many of these studies used generic topics with limited relevance to current topics being studies by learners within the experimental groups. And to confound matters further, in several studies students were not given instruction at all, but questions and feedback alone served as "instruction" (Anderson et al., 1971, 1972; Kulhavy & Anderson, 1972; Kulhavy & Stock, 1989; Swindell, 1991). In fact, recent findings (Clariana, Ross, & Morrison, 1991) support the notion that feedback effects tend to be stronger in conditions where materials involve no text but use questions and feedback only than in conditions in which text was used before questions and feedback. This leads to the question of whether or not the model will be supported in "real world" instructional environments. Researchers (Chanond, 1988; Dempsey, Driscoll, & Litchfield, 1993; Mory, 1991, 1992, 1994; Peterson & Swindell, 1991) are beginning to recommend that the model be examined under more typical classroom learning situations.

Researchers interested in exploring the Kulhavy and Stock (1989) model further should consider some of the aforementioned issues, both supportive and problematic. Dempsey, Driscoll, and Swindell (1993) point out that the model has made more precise predictions for high-confidence responses than for low-confidence responses and that midrange levels of confidence have no such predictions. This means that the entire range of metacognitive judgments should be examined. Further, if response confidence could be linked to a variable other than self-report, the adaptation of feedback might more readily fit the needs of the learner. For example, Dempsey and others (Dempsey, 1988; Dempsey, Driscoll, & Litchfield, 1993) used levels of fine and gross discrimination error during a concept learning task to adapt feedback to the needs of learners.

29.4.3 A Five-Stage Model of Mindfulness

Bangert-Drowns and his associates (1991) organize the findings of previous researchers' investigations of text-based feedback into a five-stage model, describing the state of the learner as he or she is going through a feedback cycle. The model emphasizes the construct of mindfulness (Salomon & Globerson, 1987), described as "a reflective process in which the learner explores situational cues and underlying meanings relevant to the task involved" (Dempsey, Driscoll, & Swindell, 1993, p. 38). They describe both behavioral and cognitive operations that occur in learning. To direct behavior, a learner needs to be able to monitor physical changes brought about by the behavior. Learners change cognitive operations and, consequently, activity by adapting it to new information and matching it with their own expectations about performance (Bangert-Drowns et al., 1991). These researchers 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)

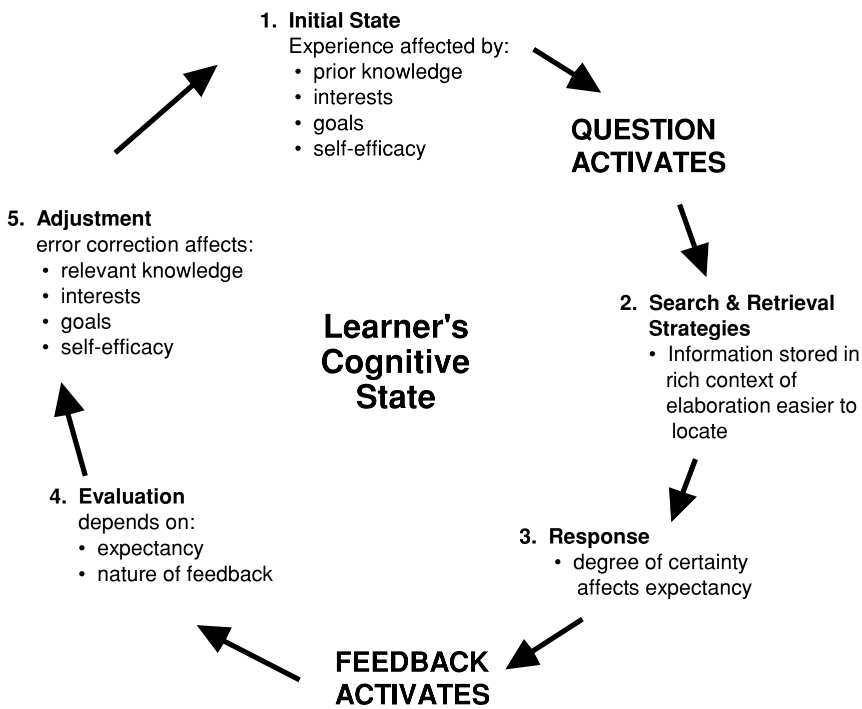

FIGURE 29.2. The state of the learner receiving feedback based on Bangert-Drowns et al. (1991; from Dempsey, Driscoll, & Swindell, 1993). From *Interactive Instruction and Feedback* (p. 40), by J. V. Dempsey and G. C. Sales (Eds.), 1993, Englewood Cliffs, NJ: Educational Technology. Copyright 1993 by Educational Technology Publications. Reprinted with permission.

The five stages are (1) the learner's initial state, (2) what search and retrieval strategies are activated, (3) the learner's response, (4) the learner's evaluation of the response, and (5) adjustments the learner makes. A graphic representation of the model by Dempsey, Driscoll, and Swindell (1993) is shown in Fig. 29.2.

This model emphasizes the construct of mindfulness, in which activities are exactly the opposite of automatic, overlearned responses. Feedback can promote learning if it is received mindfully. However, it also can inhibit learning if it encourages mindlessness, as when the feedback message is made available before learners begin their memory search or if the instruction is too easy or redundant. The inhibition of learning effect relates to research conducted on processes that "kill" learning (Clark, Aster, & Hession, 1987) and presearch availability (Anderson et al., 1971, 1972; Kulhavy, 1977).

Bangert-Drowns et al. (1991) examined 40 studies using metanalytic procedures looking at such variables as type of feedback, timing of feedback, and error rates in terms of their various effect sizes. They reported generally weak effects of feedback on achievement. Also, feedback indicating only whether an answer was correct or wrong resulted in lower effect sizes than feedback containing the correct answer. Further, using a pretest within a study significantly lowered effect sizes, as did uncontrolled presearch availability of answers.

Dempsey, Driscoll, and Swindell (1993) pointed out that the emphasis on mindfulness is an important framework for future research involving text-based feedback. Whereas the studies examined by the Bangert-Drowns et al. (1991) metanalysis "may be too simple or specific" (p. 234), it leads us to believe that future studies should examine feedback in more complex environments that involve higher-learning outcomes.

29.5 FEEDBACK RESEARCH VARIABLES OF INTEREST

Several common areas have prevailed in the research literature on feedback. These include type of information content, amount of information (load), complexity of feedback, timing of feedback (immediate versus delayed), type and analysis of errors, type of learning outcomes being studied, and various motivational functions that feedback might provide.

29.5.1 Information Content and Load

29.5.1.1 Complexity. Feedback complexity refers to how much and what information should be included in the feedback messages. There is an abundance of literature concerning feedback complexity. Dempsey, Driscoll, and Swindell (1993) have organized the major variables of interest in most corrective feedback studies as follows.

1. *No feedback* means the learner is presented a question and is required to respond, but no indication is provided as to the correctness of the learner's response.
2. *Simple verification feedback or knowledge of results (KR)* informs the learner of a correct or incorrect response.
3. *Correct response feedback or knowledge or correct response (KCR)* informs the learner what the correct response should be.
4. *Elaborated feedback* provides an explanation for why the learner's response is correct or incorrect or allows the learner to review part of the instruction.
5. *Try-again feedback* informs the learner when an incorrect response and allows the learner to one or more additional attempts to try again. (p. 25)

If feedback is to serve a corrective function, even in its most simple form feedback should verify whether the student's answer is right or wrong. This verification is usually combined with an elaboration component to provide more information to the learner. Studies that have examined the type and amount of information in feedback have not yielded very consistent results (Kulhavy, 1977; Schimmel, 1988).

What types of elaborative information have been used along with the verification component in the feedback message? In a review of the feedback literature, Kulhavy and Stock (1989) suggest that there are basically three possible elaboration types to employ during feedback. They categorize them as (a) *task specific,* which is drawn from the initial task demand or initial question (e.g., restatement of the correct answer), (b) *instruction based,* which contains information derived from the specific lesson material but not directly from the actual question completed before the feedback (e.g., explanation of why an answer is correct, based on the original instruction, or a display of the original instructional text that contains the correct answer), and (c) *extrainstructional,* which is the addition of information from outside the immediate lesson environment (e.g., new information to clarify meaning). The majority of elaboration studies fall within the task-specific and instruction-based types.

First, consider task-specific types of feedback, where the feedback is a restatement of the correct answer. Usually studies that contain this type of feedback have examined changes in the amount of information, sometimes referred to as *load*. A study by Phye (1979) examined three types of feedback for multiple-choice questions. One contained the question stem and only the correct alternative; another contained the stem and designated correct answer, with incorrect alternatives from the question; and a third contained the stem and designated correct answer, with the two incorrect alternatives from the question plus two previously unseen incorrect alternatives. No differential effect was produced by type of feedback on the posttest. However, in the second experiment in the study, immediate feedback in the form of only the correct answer plus an answer sheet from the practice was superior to other forms of feedback. Thus, the type of feedback thought to provide the least information produced the greatest improvement on the posttest. Phye suggests a threshold hypothesis to account for this unexpected finding, positing that when more than sufficient information needed to correct or confirm an answer is provided to students, it does not have a facilitative effect on their ability to use the feedback.

Some studies that have added increases of task information to feedback have actually produced lower scores on a posttest. Phye, Gugliamella, and Sola (1976) used feedback very similar to that used in the Phye (1979) study, adding either the correct answer only, the initial item plus all original distracters, or the correct alternative and three extralist distracters. Feedback in the form of correct answer only was superior to the other types that contained more information. This would imply that the feedback with more load contained considerable distracting information in the form of incorrect alternatives.

Another similar finding was provided by Sassenrath and Yonge (1969) in providing two types of feedback cues: with or without the stem of the question and with or without correct plus wrong alternative answers. Students who received information feedback without the stem of the question performed better than those who received information feedback with the question stem. This goes against the results of a previous study they completed (Sassenrath & Yonge, 1968) in which students receiving the stem of the question and the alternatives performed better on a retention test than those receiving only the alternatives. The researchers explain this discrepancy by the fact that the earlier (1968) study gave feedback after the students had responded to the entire list of questions, so that the question stem conveyed valuable information in addition to the alternatives. But in the second study (1969), feedback was presented after each item response, and it is suggested that the stem was distracting when used in feedback given within such a short time lapse after a response.

Wentling (1973) compared the effects of (a) partial feedback that contained knowledge of results to (b) total feedback that contained knowledge of correct answer and required a reresponse or (c) no feedback at all. The partial feedback treatment exceeded the other two treatments on immediate achievement scores, and surprisingly, the total feedback treatment was least effective in terms of immediate achievement.

Another study (Hanna, 1976) comparing partial feedback, total feedback, and no feedback found that partial feedback produced highest scores for high-ability students, and total feedback produced the highest scores for lower-ability students. There were no differential effects between partial and total feedback for middle-ability students, but both of these types of feedback were superior to no feedback.

Three studies do show positive results for task-specific item elaborations. Roper (1977) provided students with either no feedback, yes–no verification, or an opportunity to restudy the correct answer. Scores on the posttest increased as more information was added to the feedback. There was also evidence that the correction of errors and not just reinforcement of responses was the major effect of feedback. Also, Winston and Kulhavy (cited in Kulhavy & Stock, 1989) found that using feedback consisting of a multiple-choice item stem plus the correct response and all of the original distracter alternatives was more effective at correcting errors than using feedback containing the stem plus only the correct alternative. And finally, an early study (Travers, van Wagenen, Haygood, & McCormick, 1964) gave an interesting variation of task-specific feedback for corrects and wrongs. One group received verification for both corrects and wrongs, a second group received verification only for wrongs and nothing for corrects, a third group received verification only for corrects and verification plus the correct answer for wrongs, and a fourth group received nothing for corrects and verification plus the correct answer for wrongs. A relationship between information content of the feedback condition and extent of learning was found to exist. Highest criterion test performance occurred under the latter two feedback conditions—the ones that were the most information laden. The second feedback condition, merely saying "That's wrong," was significantly inferior to all the other conditions studied.

An even more inconsistent pattern of results is found in studies that have used instruction-based elaborations, in which information in the feedback is taken from the instruction itself. The information used in this type of feedback has been quite diverse, including explaining of the correct answer (Gilman, 1969), supplying solution rules (Birenbaum & Tatsuoka, 1987; Lee, 1985; J. Merrill, 1987), and re-presenting original instruction (Peeck, 1979).

Gilman (1969) employed "additive" feedback, comparing (1) no feedback to (2) feedback of "correct" or "wrong," (3) feedback of correct response choice, (4) feedback appropriate to the student's response, or (5) a combination of 2, 3, and 4. The means of the groups that had guidance toward the correct answer (groups 3–5) performed better than the groups that had to search for the correct answer. Gilman points out that providing learners with a statement of which response was correct or with a statement of why the correct response is correct may be of more value than merely telling the learner "correct" or "wrong." In terms of error correction, knowledge-of-results feedback resulted in the lowest number of corrected errors. In terms of retention rates, Gilman suggests that extensive information in feedback messages show advantages in retention rates.

Merrill employed both corrective feedback and attribute isolation feedback in his 1987 study of feedback to aid concept acquisition. Corrective feedback informed the learners of the correctness or incorrectness of their answers and also provided the full text of the correct answer when a student's answer was wrong. The full text consisted of a single word, phrase, or short paragraph. Attribution isolation feedback also informed the learners of the correctness of their responses, but then included the attributes of the concepts being studied. Attribution isolation is used to help focus attention on the variable attributes of a concept (M. Merrill & Tennyson, 1977). No main effects for feedback form were found, possibly due to the attribute isolation feedback being presented after two incorrect responses and, consequently, not being encountered enough times in the lesson to make a difference.

Another study (Lee, 1985) that provided solution rules in its feedback used either (1) "right/wrong" feedback only, (2) "right/wrong" plus the correct answer after an error, or (3) "right/wrong" plus the rule restated and the correct answer after an error. No significant main effects were found in the feedback treatments.

One unique approach using feedback solution rules was devised by Tatsuoka and her colleagues (cited in Kulhavy & Stock, 1989). The seriousness of instructional errors was analyzed from a pretest to assess the effect of additive feedback elaborations on a later criterion measure. Students received feedback as either (1) "OK/NO" verification, (2) the correct answer to the problem, or (3) a statement of correct and incorrect rules for solving the problem. They found that for nonserious errors, more feedback elaborations result in a greater probability of these errors being corrected. But for serious errors, correction was relatively unaffected by the amount of elaboration. This finding suggests that more complex errors or misunderstandings are not as likely to be corrected by typical feedback treatments.

Schloss, Sindelar, Cartwright, and Schloss (1987) presented either instructions to try again or a re-presentation of the instruction after student errors in computer-assisted instructional modules to test if error correction procedures would interact with question type such that higher cognitive questions with feedback loops and factual questions with re-presentation of questions would yield maximum results. They concluded that when factual questions are used in CAI modules, allowing a student to attempt a second answer after an error results in more learning than re-presenting the part of the instruction in which the answer appears.

Sassenrath and Garverick (1965) compared more traditional classroom types of feedback: looking up wrong answers in the textbook to having answers discussed by the instructor or checking over answers from correct ones written on the board. These three feedback groups did perform significantly better on a retention test than a no feedback control group. The discussion group also performed better than the groups that looked up answers in the textbook.

Students in a different study (Peeck, 1979) were either given feedback sheets identical to immediate test sheets, with the correct alternatives circled, or were given both the original text and the feedback sheets with correct alternatives circled. Also, to test if the effectiveness of different forms of feedback was influenced by the kind of test question presented, both fact and inference multiple-choice questions were used. There was little difference in scores between the two feedback conditions. More inference questions were answered correctly when subjects could refer to the original text during the feedback. But for fact questions, subjects were more successful on a delayed test when the text was absent during the feedback.

Similarly, two types of questions (factual and application) and two types of feedback (correct answer feedback, self-correction feedback, and no feedback control) were employed in a study by Andre and Thieman (1988). Both types of feedback facilitated performance on the same concept questions but did not facilitate the application to new examples. This suggests that such feedback may be helpful in tasks where the students memorize an answer, but be ineffective for tasks which require application to new cases.

Even large-scale additions to the feedback have failed to influence posttest performance, as was the case for Kulhavy and his colleagues (1985). Four types of feedback were developed additively. Four components could be used in the feedback:

(1) the test item stem and the correct alternative, (2) incorrect response alternatives, (3) four sentences, each explaining why one of the error choices was incorrect, and (4) the relevant section of the passage in which the correct answer was identified. One group received only component 1; a second group, components 1 and 2; a third group, components 1, 2, and 3; and a fourth group, all four components. The principle was that increases in the feedback complexity are closely tied to corresponding increases in the amount of information available to the learner. Results showed that more complex versions of feedback had a small effect on error correction, with the least complex feedback correcting a significantly greater portion of errors than the more complex third feedback group.

In a computer-assisted instruction (CAI) drill and practice program using a concept learning task, it was indicated that immediate extended feedback following both correct and incorrect responses is superior to minimal feedback (Waldrop, Justen, & Adams, 1986). In the first of three treatment conditions, subjects received only minimal feedback of "correct" or "incorrect." In a second treatment condition, subjects received minimal feedback ("that's correct") if a response was correct but received minimal feedback ("that's incorrect") for three trials if a response was wrong. After the third trial, if a response was still incorrect, students were provided extended feedback relating the example given to the definition of the type of consequence involved in that example. The third treatment condition provided a detailed explanation of the correct answer following both correct and incorrect responses. The results of this study agree with a suggestion made by Gilman (1969) that providing the student with a statement of which response was correct after errors and reasons for correctness of a correct response is essential.

Noonan (1984) examined the presence or position of knowledge of results, knowledge of correct response, elaborated, and try-again feedback. In this study, knowledge of results with an explanation and a second attempt was no less effective than giving knowledge of correct response and moving on or giving knowledge of correct response and another second attempt. In support of error analysis, Noonan suggests that explanations should depend more on the type of error made by the learner, and not merely on the correct answer.

Varying types and amounts of information in feedback given after specific combinations of answer correctness and response certitude in a CAI lesson were used by Chanond (1988). If a subject's answer was correct, and he or she was confident of the answer, the subject received knowledge of result feedback. If a subject's answer was correct, but he or she was not confident of the answer, the subject received knowledge of result feedback and a statement of why the response was correct. If a subject's answer was incorrect, but he or she was confident of the answer, the subject received knowledge of result, a statement of why the response was incorrect, knowledge of correct response, and a statement of why the correct answer was correct. If a subject's answer was incorrect, and he or she was not confident of the answer, the subject received knowledge of result, knowledge of correct response, and a statement of why the correct answer was correct.

Subjects were given both an immediate and a delayed posttest at the end of the lesson. Results indicated that for immediate retention of verbal information in terms of overall correct responses, the feedback had a significant effect. No significant effect was found for delayed retention, however. Further analyses indicated that, regardless of the level of confidence for the response, feedback following incorrect responses had a significant effect on both immediate and delayed retention.

The use of extrainstructional feedback types has been studied very little (Kulhavy & Stock, 1989). However, adaptive feedback that additively used all three feedback types, task specific, instruction based, and extrainstructional, was implemented by Mory (1991) and involved two levels of learning tasks: verbal information and concepts. Varying combinations of task-specific, instruction-based, and extrainstructional feedback were prescribed according to a combined assessment of answer correctness and response certitude level for an adaptive feedback group. Compared to nonadaptive feedback that utilized task-specific and instruction-based elaborations only, there were no significant differences in posttest performance for either verbal information or concept tasks.

To summarize the feedback elaboration literature, only half of the studies utilizing task-specific feedback produced any significant improvements in learning. An even greater inconsistency is found in studies using information-based feedback, perhaps due partially to the diverse types of information manipulations tried. Such variance has made it difficult to prescribe any set rule for the use of either type of elaboration (Kulhavy & Stock, 1989). Extrainstructional feedback types have not been researched enough to draw conclusions as to their effectiveness on learning.

29.5.2 Timing of Feedback

Recall from the early reports of feedback research that the idea of feedback as reinforcement—a Skinnerian view—would suggest that feedback should follow a response as closely in time as possible in order to be most effective. Skinner himself is quoted as saying, ". . . The lapse of only a few seconds between response and reinforcement destroys most of the effect" (cited in Kulhavy & Wager, 1993, p. 13). But when researchers began comparing the effects of immediate versus delayed feedback, discrepancies from such an operant approach were soon discovered. Kulhavy (1977) reported that studies showed repeatedly that delaying the presentation of feedback for a day or more results in significant increases in student retention on posttest scores (Sassenrath & Yonge, 1968, 1969; Sturges, 1969, 1972). This phenomenon was termed the delay-retention effect (DRE) (Brackbill, Bravos, & Starr, 1962; Brackbill & Kappy, 1962) and was found to occur predominantly in studies concerned with multiple-choice testing. The explanation for the DRE is thought to lie in the proactive interference from initial error responses on the acquisition of correct answers given via immediate feedback. That is, when a learner is presented immediate feedback showing the correct response after an error, his or her error response interferes with the correction of the response due to the immediacy of the feedback. Thus delayed feedback eliminates this type of interference, and the learner is better able to remember the correct response. Several studies support this hypothesis, e.g., the interference-perseveration hypothesis, explains the DRE through the assumption that initial errors tend to be forgotten over time (Bardwell, 1981; Kulhavy & Anderson, 1972; Kulik & Kulik, 1988; Sassenrath, 1975; Surber & Anderson, 1975). But others have found either that the delay did not make a difference (Peeck et al., 1985; Phye et al., 1976), that initial responses were not forgotten (Peeck & Tillema, 1979), or that the DRE was not present when subjects were required to re-respond (Phye & Andre, 1989).

In a 1988 metanalysis conducted by Kulik and Kulik, the issue of immediate versus delayed feedback was examined more thoroughly. In analyzing the available research on the timing of feedback, they found that studies using actual classroom quizzes and materials usually found that immediate feedback was more effective than delayed feedback. Apparently the studies that supported the effects of delayed feedback over immediate feedback for improving retention of material were conducted using contrived, experimental learning situations, such as list learning. These findings challenge both the use of delayed feedback in more practical learning environments and the explanations afforded by the interference-perseveration hypothesis in "real-world" learning situations.

Dempsey, Driscoll, and Swindell (1993) suggest that delaying feedback in many instructional contexts "is tantamount to withholding information from the learner that the learner can use" (p. 24). And a pragmatic suggestion postulated by Tosti (1978) and Keller (1983) is to present feedback containing pertinent information from the learner's prior performance right before the next learning trial, when the learner would be able to use the information to improve his or her subsequent learning. As Dempsey Driscoll, and Swindell (1993) point out, this amounts to providing feedback at what is commonly referred to as "the teachable moment" (p. 24). An interesting variation involving a delay of feedback was designed by Richards (1989) using a declarative knowledge task involving labels and facts. In this case, feedback was more effective when delayed temporarily and the learner was required to respond covertly a second time to the question—that is, a covert second try, *prior* to feedback.

In a 1989 study conducted to examine the timing of feedback with respect to the acquisition of motor skills, shorter feedback times improved acquisition and performance while feedback was present, but delayed feedback resulted in improved subsequent performance once feedback had been withdrawn (Schmidt, Young, Swinnen, and Shapiro, 1989). They explain these findings in terms of what is termed the guidance hypothesis. The guidance hypothesis suggests that during the initial stages of skill acquisition, immediate feedback guides the learner and results in superior initial performance. But this guidance can lead to dependence on the feedback and obscure the need to learn the secondary skills (such as detection and self-correction) necessary to perform the task without feedback (Schmidt et al., 1989).

The guidance hypothesis is supported by a previous study that examined the effects of immediate versus delayed feedback within the context of an adventure game on subsequent performance (Lewis & Anderson, 1985). Subjects that received immediate feedback were more likely to select appropriate operators, but those that received delayed feedback were better able to detect errors. But a differing trend was found by Anderson, Conrad, and Corbett (1989) when assessing the effects of immediate and delayed feedback within the context of the GRAPES LISP Tutor. Subjects receiving immediate feedback moved through the material more quickly than did those subjects receiving delayed feedback, but there was no significant difference in test performance. A more recent study by Schooler and Anderson (1990) found that when students were acquiring LISP skills, subjects receiving immediate feedback went through the training material in 40% less time than those receiving delayed feedback, yet with no detrimental effects on learning. In a second experiment during the same study, subjects used an improved LISP editor and less supportive testing conditions. During this trial, subjects in the immediate feedback group completed the problems 18% faster than those in the delayed feedback group, but they were slower on the test problems and made twice as many errors. The final experiment, a partial replication of the first two experiments, indicated that delayed feedback was an advantage in terms of errors, time on task, and percentage of errors that subjects self-corrected. They suggest that immediate feedback competes for working memory resources, forcing out necessary information for operator compilation—a finding that would support the interference-perseveration hypothesis mentioned above. In contrast, delayed feedback in the study fostered the development of secondary skills such as error detection and self-correction (Schooler & Anderson, 1990).

Regarding which to recommend, immediate or delayed feedback, several researchers concur (Dempsey, Driscoll, & Swindell, 1993; Kulhavy, 1977; Kulik & Kulik, 1988) that in most learning situations delayed feedback appears to function to hinder the acquisition of needed information. Only in under very special experimental situations has the use of delayed feedback helped learning. As Kulik and Kulik (1988) point out,

> The experimental paradigms that show superiority of delayed feedback are very similar to paradigms used for testing effects of massed versus distributed practice. When experiments deviate from this paradigm, they show results similar to those in applied studies. In such experiments, immediate feedback produces a better effect than delayed feedback does. (p. 94)

One only has to look at the myriad of definitions that past researchers have used in the areas of both immediate and delayed feedback to understand why this field of study has always been muddied. Dempsey and Wager (1988) have summarized the types of immediate and delayed feedback as reported in Table 29.1.

Some researchers suggest that as newer technologies offer more instructional delivery options and a wider variety of modalities through which to deliver feedback, these issues will become even more complex (Dempsey, Driscoll, & Swindell, 1993). Perhaps as delivery options increase, researchers will be better able to determine when delayed feedback might aid learners.

TABLE 29.1. Immediate and Delayed Feedback with Computer-Based Instruction: Definitions and Categories (from Dempsey & Wager, 1988)

Immediate feedback is informative corrective feedback given to a learner or examinee as quickly as the computer's hardware and software will allow during instruction or testing.

Types of immediate feedback

1. Item by item
2. Learner controlled
3. Logical content break
4. End of module (end of session)
5. Break by learner
6. Time controlled (end of session)

Delayed feedback is informative, corrective feedback given to a learner or examinee after a specified programming delay interval during instruction or testing.

Types of delayed feedback

1. Item by item
2. Logical content break
3. Less than 1 hr (end of session)
4. 1–24 hr (end of session)
5. 1–7 days (end of session)
6. Extended delay (end of session)
7. Before next session

29.5.3 Error Analyses

In the early 1930s, Thorndike demonstrated that errors made in rote learning tasks tend to persist. By the year 1958, Skinner argued that errors made within programmed instruction will tend to persist as well. Elley (1966) tested the hypothesis that errors play different roles in rote and meaningful learning tasks. Results supported the hypothesis, showing that fewer errors were associated with better retention in rote tasks but not in meaningful types of learning. Both experiments supported the hypothesis that errors are undesirable in rote learning and tend to be repeated even with immediate feedback. however, when learners were given meaningful problems, incidence of errors was unrelated to ultimate performance.

The current view considers an error to be a valuable opportunity to clarify misunderstanding in the learner. Thus errors play an important role in feedback studies today. The belief that feedback's main function lies in correcting errors makes error analyses more critical for gaining insight into the corrective process.

Kulhavy and Parsons (1972) examined errors that are never corrected, or that "perseverate" to a posttest. They suggest that error perseveration is a function of at least three factors: (a) the rated meaningfulness of the items used, (b) the amount of incorrect material available during learning, and (c) the response mode required of the learner. In their study, students were forced to respond incorrectly to see if these errors would be repeated on a posttest. But their analyses revealed that forcing a student to make an error does not automatically result in the transference of that error to the posttest.

Patterns of pretest–posttest responses were introduced in a limited way by Phye and his colleagues (1976). This work was later extended to include three error types (Peeck & Tillema, 1979; Phye, 1979). An error analysis model was developed independently by Peeck and Tillema (1979) and Phye (1979), and this model has been used by several researchers (Peeck, 1979; Phye & Andre, 1989; Phye & Bender, 1989). Their research has served to help understand further how feedback is being used by learners in most experimental settings.

Whenever informative feedback is used in a pretest–feedback–posttest design, five possible outcomes for pretest–posttest response sequences exist. First, when feedback has a *confirmatory* function, the feedback serves to confirm a correct answer at pretest (a combination sequence of correct–correct). Second, when feedback has a *corrective* function, it serves to correct an error made on the pretest (a sequence combination of wrong–correct). And finally, feedback can have *no* function, as in cases when errors result on the posttest (Phye & Bender, 1989).

The three error types where feedback is considered nonfunctional are described as follows. One type is a *same* error and is perseverative in nature. A same error occurs when an initial incorrect response reoccurs on the posttest, regardless of any correct answer feedback that was provided. The second type of error is a *different* error, in which an item is missed on both the pretest and the posttest but was not the same error across trials. That is, the posttest error was a different error than the pretest error. Perhaps insufficient information was encoded during feedback so that on the posttest the learner remembers that his or her initial response was wrong but does not remember information well enough to respond correctly. The final type of error is a *new* error, in which an item was initially correct on the pretest or practice but for some reason was changed to a wrong answer, or new error, on the posttest. Perhaps in this instance, the initial response was a lucky guess, feedback was basically ignored, and a new error resulted on the test.

Thus, the five possible combinations of pretest–posttest responses are (1) correct–correct, (2) wrong–correct, (3) wrong–same wrong, (4) wrong–different wrong, and (5) correct–new wrong (see Fig. 29.3).

When put into a response pattern profile in terms of percentage of occurrence, a more exhaustive account of test performance is facilitated (Peeck et al., 1985). Response pattern profiles have been used for multiple-choice formats (Peeck, 1979; Phye, 1979). Some researchers (Peeck et al., 1985) argue that to interpret the cognitive processes involved in such sequences, it is important to determine to what extent learners remember their initial responses after the pretest. Peeck et al. (1985) included "guess questions" that could not be answered from the text and "factual questions" that could be answered from the text. The most important finding was that learners remembered their initial responses in the wrong-changed-to-correct category. This indicates that retention of initial responses did not prevent subjects from learning the correct answer from feedback, casting serious doubt, incidentally, on the assumption that subjects tend to forget their responses on the initial task after a delay and that error tendencies interfere with learning the correct answers from feedback—an assumption that was a major component of the interference-perseveration interpretation of the delayed-retention effect studies (Kulhavy & Anderson, 1972).

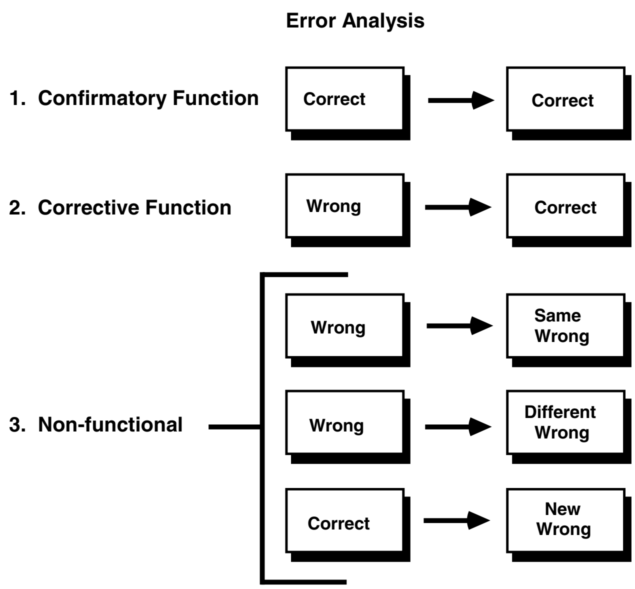

FIGURE 29.3. Five response pattern combinations based on Phye and Bender's (1989) response pattern analysis.

Data also indicated that when subjects changed their initial response after feedback (correct to a new wrong, wrong to correct, and wrong to a different wrong), the highest identification scores were obtained in the category of corrected errors (wrong to correct).

The construct validity of error analysis was addressed by Phye and Bender (1989) and demonstrated when Peeck et al. (1985) examined pooled data from four previous experiments. Proportional frequencies for the three error types when averaged across the four studies were 0.10 for same errors, 0.06 for different errors, and 0.05 for new errors. These averages were quite similar compared to results of Phye and Bender (1989) in which same errors equaled 0.08, different errors equaled 0.05, and new errors equaled 0.04. These data contribute to the construct validity of the error analysis model and suggest its value when combined with correct response and conditional probability data to assess feedback effectiveness.

Further research from an information processing perspective should address feedback effectiveness and efficiency by considering not only correct responses but also an analysis of processing errors (Phye & Bender, 1989). Error data, when used with correct response data and conditional probability data, "provides a multivariate account of feedback utilization by the learner in a learning situation involving practice" (p. 109).

Another way of analyzing errors is to classify them in some way that is related to the specific learning outcome involved. In rule using tasks, an example would be the classification of errors as "serious" or "nonserious" as was done in an analysis developed by Tatsuoka (see Birenbaum & Tatsuoka, 1987). The measure of seriousness of error types indicated to what extent a wrong rule deviates from the right rule. Using an "error vector" system to analyze signed-number problems, error codes were developed based on the absolute number operation and the sign operation involved in solving problems. Students' response patterns to test items were then classified into three categories: serious errors, nonserious errors, and correct answers.

In concept learning, errors are categorized according to three kinds of concept classification errors: overgeneralization, undergeneralization, and misconception (cited in Tennyson & Cocchiarella, 1986). When students are learning to classify a member of a concept class, they must make discriminations between examples and nonexamples of the concept. Certain nonexamples may be quite difficult to discriminate from a given concept example (termed a "close-in" nonexample), and others may be easy to discriminate from an example (termed a "far-out" nonexample) (Dempsey, 1988). When a learner is consistently making a particular overgeneralization error of accepting nonexamples, it is likely that he or she is having a problem with fine discrimination of the concept. Fine discrimination errors occur when close-in nonexamples are classified by the learner as an example of a concept. But if the student is regularly classifying a far-out nonexample as a true example, he or she may be undergeneralizing by rejecting the examples, resulting in an error of gross discrimination. In general, fine discrimination errors result from classification problems on close-in nonexamples, whereas gross discrimination errors result from a student's having classification problems on far-out nonexamples. Because close-in nonexamples are more difficult to discriminate from examples than are far-out nonexamples, more close-in errors (or fine discrimination errors) should be expected to occur. This indeed was the case in a study by Dempsey (1988). In the same study, it was found that learners who made fewer fine discrimination errors during instruction scored significantly higher on a retention test. In fact, 4 of 10 errors made during the instruction were those that were predetermined as fine discrimination errors. These findings encourage the analysis of close-in and far-out nonexamples associated with fine and gross discrimination errors when employing concepts learning tasks.

Finally, Meyer (1986) identified four errors reflected in a review of research on teachers' correction of students: (a) lack-of-information errors, (b) motor errors, (c) confusions, and (d) rule application errors. Lack-of-information errors result when a student's mistakes are caused by missing knowledge. Motor errors result when a student knows the information but cannot express it. Confusions occur when students fail to discriminate correctly between concepts and ideas. And rule application errors result when students apply rules incorrectly in problem-solving situations. Meyer asserts that feedback should be designed to fit each type of misunderstanding.

Because the correction of errors appears to be where feedback has its most promising effects, researchers should continue to examine ways in which to manipulate feedback to maximize this outcome. As Noonan (1984) pointed out, more sophisticated procedures that involve analysis of common errors or error patterns might be more useful than traditional correct answer feedback. Adaptive feedback information can easily be facilitated within a computer-based instruction environment, where the computer can record and analyze the types of errors being made and give appropriate feedback based upon error types.

29.5.4 Learning Outcomes

A detailed overview of suggested feedback for various learning outcomes has been offered by Smith and Ragan (1993). These researchers discuss their views of what information to include for each type of learning outcome according to Gagné's taxonomy. Instructional design theorists have proposed that different types of learning tasks require different strategies and instructional methods (Gagné, 1985; Merrill, 1983; Reigeluth & Stein, 1983). Very few researchers have attempted to investigate the differences in feedback needs for differing types of learning. Schimmel (1983) found differences in informative feedback given for declarative knowledge versus procedural knowledge. The studies that have been conducted are summarized below. In terms of testing current views of feedback, recall that results from the Mory (1991) study indicated that predictions from the Kulhavy and Stock (1989) model held for verbal information learning but not for concept acquisition. Swindell (1991) also reported a study attempting to examine the same model (Kulhavy & Stock, 1989) under the conditions of higher-level learning. Although results of the study claim to suggest the generalizability of the model to higher learning, questions required recall of verbal information only, with no guarantee that intellectual skill learning had occurred.

The vast majority of feedback studies have dealt with verbal information tasks (Schimmel, 1988). Consequently, it is not known if certain patterns or inconsistencies that have emerged from these studies would necessarily result when involving other types of learning. This question has been acknowledged by a few researchers, an example of which is clear in Andre and Thieman's (1988) statement, "Whether feedback on questions facilitates concept learning as well as factual learning is not known from available research" (p. 297). Indeed, Schimmel discovered differences in the value of informative feedback for declarative knowledge versus procedural learning in the results of a 1983 metaanalysis.

Smith and Ragan (1993) estimate feedback requirements for different learning outcomes based on the theoretical cognitive processing requirements of each outcome. Thus their suggestions are predominantly theory based, and the reader should note that each area is a source of much needed research to test these conjectures. The following sections address the feedback requirements suggested by either research, theory, or both.

29.5.4.1 Learning Outcome Comparisons. In an effort to bridge the gap between learning outcome differences, some researchers have compared declarative information tasks with higher cognitive tasks. Lee (1985) compared verbal information with rule using, hypothesizing that feedback for rule using tasks should be more complex than feedback for learning verbal information. Three levels of feedback were compared. Correct answer feedback was the same for all three levels (i.e., "right"). Differences in feedback occurred only if the student missed the question. For an error, students in the first level of feedback simply received the statement, "Wrong." Students in the second level were told, "Wrong. The answer is. . . . " for errors made. Errors for the students in the third level of feedback were presented with, "Wrong. The rule is. . . . The correct answer is. . . . " There were no significant differences between feedback levels, suggesting that more complex feedback did not prove more effective in either task. An additional finding was that there were no differences between feedback that was given immediately or feedback that was delayed.

Another study comparing verbal information with rule using was completed by Char (1978). Char refers to his intellectual skill task as "higher-order learning," which he describes as both identifying concepts and applying rules. The purpose was to examine the effects of both informative feedback versus no feedback and delayed versus immediate feedback on retention of verbal information and higher-order learning. As one might predict, informative feedback did significantly enhance retention of both verbal information and higher-order learning. There were no differences between immediate and delayed feedback. It is regrettable that Char did not categorize each higher-order question separately as being either a concept or a rule application, so as to delineate more clearly the specific kinds of learning being applied.

S. U. Wager (1983) also compared verbal information learning with a type of intellectual skill—specifically, defined concepts. She examined the effects of timing and type of feedback on retention of an instructional task involving verbal information and defined concepts learning. Both immediate and delayed feedback timing were used, and feedback was either simple or elaborated. Simple feedback presented a knowledge of results only, and elaborated feedback presented a combination of knowledge of results, knowledge of correct response, and response contingent feedback, which explained why a particular response choice was or was not correct. Results indicated that neither timing of feedback nor type of feedback made any significant differences between groups. These results were attributed partially to the fact the feedback may have assumed a lesser role when students were given tutorial instruction.

Gaynor (1981) also compared across verbal tasks and higher-level tasks. Rather than using Gagné's categorizations of "verbal information" and "intellectual skill," Gaynor classified her materials according to Bloom's taxonomy. She compared test items that fell into three levels of intellectual ability: knowledge, comprehension, and application. She concluded that when degree of original learning is equated, immediate feedback, end of session feedback, or even no feedback has little effect on short- or long-term retention of materials at Bloom's first three taxonomy levels.

Mory (1991, 1994) attempted to test the Kulhavy and Stock (1989) model of response certitude using two types of learning outcomes for her subjects to try to determine if the model would generalize to a concept learning task. The model was derived from studies that used predominantly verbal information and rote memorization of facts. In the Mory (1991, 1994) study, feedback was adaptive based on a combined assessment of answer correctness and level of certitude. The rationale was that by varying the type and amount of information contained in the feedback to fit the prescriptive state of learners under high- and low-certitude conditions and correct and error responses, learners would be given only the most "economic" form of feedback. Further, this type of adaptive feedback treatment was compared with a traditional form of nonadaptive feedback that essentially contained a verification component combined with knowledge of correct response. Whereas there were no significant differences in posttest performance between the adaptive and the nonadaptive groups, there was a significant increase in feedback efficiency for the adaptive group. Mory postulates that one reason that adaptive feedback did not seem to improve scores in the higher-level learning task of concept learning was that students did not accurately predict their answer correctness and thus were not able to receive the appropriate feedback for that condition. Data in the study revealed that certitude levels tended to be high throughout the adaptive program, regardless of actual answer correctness. This means that students did not receive low-certitude feedback when it was needed most. Learners simply could not give accurate assessments of their own abilities to classify a particular concept. As stated earlier, these findings are supported by previous studies involving "feeling of knowing" judgments (which are similar to response-certitude estimates) that proposed that when learning involved higher-level tasks, judgments tended to be overestimated by learners (Metcalfe, 1986). In contrast to this, some researchers have found that students learning concepts tended to underestimate their belief about their answer correctness (M. P. Driscoll, personal communication, August 30, 1990). Despite the opposing nature of these two separate results, it would appear that learners do not accurately predict their knowledge in higher cognitive tasks.

29.5.4.2 Declarative Knowledge. This type of knowledge is what is referred to as verbal information in Gagné's (1985) taxonomy and specifically by Smith and Ragan (1993) as including labels, facts, lists, and organized discourse. For labels and facts, feedback should give some evaluation of whether the learner's response is complete and whether the learner's associations are complete. Lists will possibly involve the elements of both completeness and sequence to be evaluated. They suggested that feedback might point out errors in incorrect combinations of associations and that simple correct or incorrect feedback may be sufficient. In Schimmel's work (1983), confirmation feedback was found to be more potent than correct answer feedback in verbal information tasks. Simpler feedback was more effective than complex feedback in a study by Siegel and Misselt (1984). Further, Kulhavy and his colleagues (1985) found that knowledge of correct response was more beneficial than more complex feedback.

In terms of organized discourse, Smith and Ragan (1993) asserted that feedback must act as an intelligent evaluator or provide model responses. This "intelligent" evaluation may be provided by a knowledgeable human being or by computerized intelligent tutors. In terms of a model response, feedback should be constructed with attention to modeling organization, links of information, and elaborations that would be considered essential for an appropriate answer.

29.5.4.3 Concept Learning. Four feedback studies were found that dealt specifically with concept learning tasks. Although already described with the feedback elaboration research, they are discussed in this section for their importance as involving concepts. But before discussing these studies, an overview of concepts is presented from the major tenets of concepts learning research.

Concepts are types of classifying rules (Gagné & Driscoll, 1988; Gagné et al., 1992) that are used to facilitate the classification of instances through acquiring definitions, attributes, and examples (Tessmer, Wilson, & Driscoll, 1990). The two categories of concepts are concrete concepts and defined concepts (Gagné & Driscoll, 1988). Concrete concepts represent categories determined on the basis of perceptual features, whereas defined concepts represent semantic categories that may or may not have a perceptual basis (Tessmer et al., 1990). Defined concepts must be identified through the use of a definition, rather than by actual sight.

Concepts have both declarative and procedural components that require instruction designed to convey both of these learning outcomes. Declarative strategies help make information about the concept meaningful to the learner, and procedural strategies produce accuracy and ease in performance of concept classification skills (Tessmer et al., 1990). Conceptual knowledge is more than just the storage of declarative (or verbal information) knowledge, embodying also an understanding of a concept's operational structure within itself and of structure between associated concepts (Park & Tennyson, 1986; Tennyson & Cocchiarella, 1986). Because conceptual knowledge is the storage and integration of information, and procedural knowledge is the retrieval of knowledge in the service of solving problems, instruction could typically include portions that focus on verbal information outcomes (the declarative component) and intellectual skill (concept) outcomes (the procedural component). Although testing how well a student has stored information in the form of verbal information outcomes is not a guarantee that the student also understands and can integrate the information, it still is an indicator of how much he or she can remember in order to apply it.

The primary method of teaching concepts usually involves presenting a definition or classification rule, followed by sets of examples and nonexamples. Examples and nonexamples are in the form of both (a) statement presentations to the student (expository instances) and (b) question presentations to the student (interrogatory instances) (Tennyson & Cocchiarella, 1986). Additionally, critical attributes of a concept may be presented. Critical attributes are what define a concept and must be present in any given case to be an example of the concept. The presence of these critical attributes constitutes both "necessary and sufficient conditions for judging the presence of the concept" (Wilson, 1986, p. 16). The test of whether a concept has been learned is to present the student with new instances of the concept not previously encountered to see if he or she can classify the instance correctly.

Further, a concept is a set of specific objects, symbols, or events that share common characteristics (critical attributes) and can be categorized by a particular name or symbol (Tennyson & Park, 1980). Most concepts do not exist in isolation but as part of a set of related concepts. The placement of a given concept in relation to other concepts having similar attributes implies that certain concepts would be subordinate, whereas others would be superordinate. Those concepts that are placed in the same general location in the content structure and are neither subordinate nor superordinate may be defined as coordinate concepts (M. Merrill & Tennyson, 1977; Tennyson & Park, 1980). Coordinate concepts fall at the same level of specificity, and the members of any coordinate class are not members of any other coordinate class (Klausmeier, 1976). For coordinate concept learning, the nonexamples of one concept are examples of other coordinate concepts. Usually a set of concepts is presented simultaneously, making it easy for the learner to confuse specific attributes of one concept with another one and resulting in an error of misclassification. But simultaneous presentation is helpful in enabling learners to compare and contrast similarities and differences between concepts and thus aid in clarification of individual concepts (Litchfield, 1987).

The first study to involve both feedback and concepts was by Waldrop, Justen, and Adams (1986). They approach feedback with an emphasis on feedback being effective only under *certain conditions,* relating the importance of this when using feedback in CAI. They compared three types of feedback during a drill- and- practice CAI program. The program presented a series of 20 examples of four types of consequences for behavior (positive reinforcement, negative reinforcement, punishment, and extinction). Although the classification of concepts was used in the practice, they did not test the learning of the concepts by giving them new instances on the posttest. Instead, the criterion measure consisted of the same 20 items used in the CAI modules, only presented in a random order and within a test booklet. At least in terms of retention of the original examples, immediate extended feedback following both correct and incorrect responses was superior to minimal feedback. It would have been of value if the researchers had tested the concepts in the manner typically in line with what theorists would say constitutes successful learning of the concept—that is, being able to classify previously unencountered examples—and not merely by a repetition of the same examples.

The second feedback study to employ the use of concepts was by J. Merrill (1987). High- and low-level questions were used in combination with corrective feedback and attribute isolation feedback to form four versions of a computer-based science lesson that taught Xenograde terminology concepts. J. Merrill chose attribute isolation feedback based on M. Merrill and Tennyson's (1977) proposition that the correct classification of newly encountered examples of a concept is more likely if attribution isolation is presented both in the instructional presentation of examples and in the feedback given after practice examples. The primary hypothesis of the study was that students who received high-level questions and attribute isolation feedback would perform better than the other groups. Although there was a question-level main effect of students in the high-level question treatments performing significantly better than those in low-level question treatments, there was an absence of a feedback form main effect. J. Merrill suggests that this absence may be due to the fact that potential benefits of either feedback form were not fully available to the students. The attribute isolation feedback was presented only after two wrong responses and, consequently, was not encountered very often. This is unfortunate considering results from previous studies (cited in J. Merrill, 1987) that yielded significant posttest results from the addition of attribute isolation to the concept learning task.

Andre and Thieman (1988) approached the concept issue by directly addressing the problem that feedback research has used tests that measure only factual learning and thus has stood "mute on the issue of concept/principle acquisition" (p. 297). Unlike the Waldrop et al. (1986) study, these researchers measured both retention of the presented examples and performance on new instances of the concept. They broke student scores into performance on four types of questions: (a) repeated factual, (b) repeated application, (c) new factual, and (d) new application. Performance on the new application questions was cited as the main variable of interest, as the major purpose of the study was to determine the effects of type of question and type of feedback on concept learning. Subjects were given either factual, application, or both types of adjunct questions immediately after reading an instructional passage. A day later, subjects were given either no feedback, correct answer feedback, or self-correction feedback, in which the students received a list of incorrect items without the correct answer, the instructional passage, and instructions to find the correct answers to the incorrect items.

One major finding of the study was that adjunct application questions significantly improved student performance on later use of concepts and that this improvement occurred without any loss of incidental factual learning. This beneficial effect was obtained only when application questions were used in isolation. When both factual and application adjunct questions were used in the practice, poor performance occurred on new application items. This suggests some sort of interference when the two types of questions are presented together.

A second major finding was that feedback did not influence concept learning (i.e., performance on new instances) but did influence performance on repeated examples of concepts. Thus, feedback did not facilitate the acquisition of a concept that could be applied to new examples. They suggested that more than one trial of feedback may have been insufficient to induce concept acquisition and cited Park and Tennyson's (1980) finding that students required approximately four examples to learn a particular concept.

Dempsey and his associates (Dempsey, 1988; Dempsey, Driscoll, & Litchfield, 1993) examined concepts in terms of achievement on a retention test, feedback study time, and type and numbers of discrimination errors. These studies examined the effects of four methods of immediate corrective feedback on retention, discrimination error, and feedback study time in computer-based instruction. Also, the studies explored the relationship between types of corrective feedback and types of errors made by learners. The four feedback conditions were (a) feedback that gave knowledge of correct response only, (b) feedback that informed students of the correct response and then required that they make that response, (c) feedback that gave knowledge of the correct response and also presented anticipated wrong answer feedback, and (d) feedback that gave knowledge of correct response and allowed a second try to answer the question. No significant differences in retention rates resulted for any feedback group, but the group receiving knowledge of correct response only used significantly less feedback study time and was more efficient than the other conditions. Type of feedback made no difference in the number of errors during instruction. Students making fewer fine discrimination errors during the instruction performed better on a retention test. More fine than gross discrimination errors were made on the retention test. Regarding feedback study times and discrimination error, almost twice as much feedback study time was consumed for fine discrimination errors. This finding may suggest a link between fine discrimination errors and high-certitude errors from Kulhavy's work, as in both cases, the longest feedback study times resulted.

29.5.4.4 Rule Learning. According to Smith and Ragan (1993), rules may be one of two types: relational rules and procedural rules. Relational rules involve relationships between two or more concepts, often being described in terms of "if–then" or "cause–effect" (p. 84). Relational rules have also been referred to as propositions, principles, laws, axioms, theorems, and postulates. These researchers (Smith & Ragan, 1993) describe suggested feedback for rule learning in terms of various practice stages for using the rule. When practicing verbalizing or visualizing the rule, feedback should provide information concerning the key concepts of the rule and their relationships. Note that this would basically qualify as verbal information, and not rule utilization itself.

When practice involves the recognition of situations in which the rule is applicable, feedback should identify (a) whether the rule is applicable and (b) what features of the situation make the rule applicable or not. Smith and Ragan (1993) suggest that the explanatory portion of the feedback be placed under learner control, as explanatory feedback has been shown to confuse some learners (Phye, 1979).

When learners begin actually applying the rule, feedback should provide the outcome of the application of the rule. Explanatory feedback might include a step-by-step solution of the problem, highlighting critical features that influence the application of the rule or illustrating in graphic form how a solution can be drawn. Such explanatory feedback was found to be significantly superior to simple correct/incorrect feedback on college students' ability to apply rules in computer programming (Lee, Smith, & Savenye, 1991).

When learners determine whether a rule has been correctly applied, feedback should include simple correct answer feedback. For situations in which the rule has been applied incorrectly, feedback should point out the specific error in application and give the correct way that rule should have been applied. Feedback might also serve to provide hints for modification of the learner's use of a rule or be adapted to correct specific misconceptions or error patterns that a learner is making (Smith & Ragan, 1993).

The second type of rules, procedural, involves learning a series of steps to reach a specific goal. Procedural rules may be simple, with only one set of steps to complete linearly, or they may be complex, with many decision points leading to different baths or branches. The first step in learning procedural rules involves determining if the procedure is required. Smith and Ragan (1993) recommend feedback that is confirmatory, informing the learner whether he or she has appropriately identified the situations that require the application of the procedure. Learners should also be given feedback as to the accuracy of their completion of each step in the procedure. During initial practice stages, feedback should be detailed and given during the practice of each step of the procedure. Then as the learner is able to perform the entire procedure, feedback would both determine whether each step was correctly completed and provide qualitative information concerning selection, criterion, and precision and efficiency. Smith and Ragan (1993) also recommend that feedback be given as to the remembrance of steps in the procedure and their correct sequence of completion. And, finally, feedback should be provided as to the appropriateness of a completed procedure in the form of correct answer feedback.

Departing from the usual fare of verbal learning studies in the feedback elaboration research, only a few experimenters have chosen to look at rule using alone. Birenbaum and Tatsuoka (1987) examined the seriousness of errors committed by eighth graders using rules to add signed numbers in a CAI task. For serious errors, it did not matter how much elaboration was in the feedback, correction was relatively unaffected by feedback. Feedback elaborations for nonserious errors did have an increasing probability of being corrected as more information was added to the feedback.

A second group of researchers (Tait et al., 1973) examined rule using in a CAI environment designed to help children multiply two- and three-digit numbers by one-digit numbers. Treatment conditions included (a) no feedback, (b) passive feedback, and (c) active feedback. The active feedback procedure required an overt response to be given for each step in the procedure for computing the answer. The passive procedure merely printed a message to the student and required no overt response. The active feedback was designed to alleviate the problem of children not attending to feedback messages that explained the procedure. Children seemed to be copying the answer presented at the end of the feedback and ignoring other information in the feedback. Active feedback required the student's active engagement with the feedback at each step in solving the problem. Additionally, active feedback contained more information than did passive feedback.

Even when using both active and passive feedback, there was still little improvement from pretest to posttest. The researchers concluded that with the active feedback, children were still able to copy answers without understanding the procedure behind them. Consequently, a second experiment was designed that required the pupils to repeat the question until it had been answered correctly. The correct answer was required in both passive and active feedback groups before the child was allowed to continue on to a new problem. Even under these conditions, active feedback was no more beneficial than passive feedback. However, pupils who had scored low on the pretest did perform much better on the posttest when given active feedback than similar pupils in the passive feedback group.

29.5.4.5 Problem Solving. In the domain of problem solving, a learner must select and combine multiple rules to reach a solution. This may require that learners use declarative knowledge and cognitive strategies within a content domain and combine previously learned relational and procedural rules to solve a previously unencountered problem (Gagné, 1985). According to Smith and Ragan (1993), the following stages often occur during a problem-solving task, and not necessarily in the same sequence:

1. Clarify the given state, including any obstacles or constraints.
2. Clarify the goal state, including criteria for knowing when the goal is reached.
3. Search for relevant prior knowledge of declarative, rule, or cognitive strategies that will aid in solution.
4. Decompose problem into subproblems with subgoals.
5. Determine a sequence for attacking subproblems.
6. Consider possible solution paths to each subproblem using related prior knowledge.
7. Select solution path and apply production knowledge (rules) in appropriate order.
8. Evaluate to determine if goal is achieved. If not revise by returning to (1) above. (p. 92)

Because this type of learning involves the use of several other types of learning, feedback during a problem-solving task must work to help the learner see where his or her strategies or information gaps are occurring. According to Smith and Ragan's (1993) suggestions, initial feedback may be in the form of hints or guiding questions. It may include data on which information has been used or misused, the appropriateness of selected solutions, whether individual phases of the solution have been correctly performed, and the efficiency of the solution process. As learners transition from novice to expert, their approaches to a problem should become more automatic. At this expert level, learners will need feedback on the efficiency or speed of their problem solving. The extent of this type of feedback will depend on the extent that genuine expertise is an expected part of the learning goal.

In simulations, feedback is often provided in terms of presenting learners with the consequences of their decisions. Open-ended response questions may be followed by feedback presenting a model of the solution process. And during the initial stages of practice, immediate feedback will be most helpful for intermediate stages, when responses can keep the learner from an eventual successful solution (cited in Smith & Ragan, 1993).

It should be noted that more recent views of problem solving are found in the literature on constructivism, presented later in this chapter. In particular, recent research in the areas of anchored instruction, situated cognition, situated learning, and generative learning have examined what might be thought to be "problem solving," but with very different philosophical assumptions about the way in which learning takes place (Cognition and Technology Group at Vanderbilt [CTGV], 1990, 1991a, 1991b, 1992a, 1992b, Young, 1993). It is from this broadened perspective that researchers will find the most need for research on types of feedback that can aid learners as they construct solutions to authentic problems.

29.5.4.6 Cognitive Strategies. Cognitive strategies are techniques that learners use to help them attend to, organize, elaborate, manipulate, and retrieve knowledge, thus controlling their own cognitive processes (see Gagné, 1985). Smith and Ragan (1993) relate the use of cognitive strategies with problem solving, as the selection, application, and evaluation of a cognitive strategy are similar to problem-solving techniques. Given that similarity, feedback will have some of the same functions as stated for problem solving—that of modeling appropriate decisions and stating explicitly whether the decisions and performance of the learner were adequate. Feedback should also contain explanations as to why the model is appropriate. Characteristics such as the learners' capabilities, requirements of the task, learner efficacy, and applications of various strategies should be considered as well. They (Smith & Ragan, 1993) suggest that for open-ended trials toward a solution, feedback should involve reviewing appropriateness of a particular strategy and the critical details of the strategy for a given problem or solution.

In a study by Ahmad (1988), college-age learners participating in a guided discovery lesson were taught strategies that were either compatible or incongruent with their prior cognitive strategies. When feedback on the effective or ineffective use of a particular strategy was provided, better performance resulted when the strategy was compatible with previously employed strategies. But when the strategy used by learners was incompatible with their prior strategy use, feedback containing only whether a solution was correct or incorrect proved to be more effective.

Because cognitive strategies can be very subject domain oriented, it would probably be fruitful to explore the uses of various cognitive strategies within specified subject areas and contexts. Also, as stated above, researchers should consider examining cognitive strategies in terms of their applications to a learner's construction of solutions of more authentic learning tasks. In fact, one of the important goals underlying the development of the Jasper series (CTGV, 1990, 1991a, 1992a, 1992b) was helping students learn to become independent thinkers, to identify and define issues and problems on their own (CTGV, 1992a). Cognitive strategies should begin to be viewed as "generative learning" (CTGV, 1990, 1992a), as the learners themselves generate the relevant subproblems and data necessary to satisfy subgoals that they have generated on their own.

29.5.4.7 Psychomotor Skills. Psychomotor learning involves skills that are physical in nature, often with coordinated muscular movements. Psychomotor skills require a cognitive component, particularly in the early stages of learning the skill. As the skill becomes more automatic, the cognitive awareness becomes an unconscious part of performing the skill. Two components of psychomotor skill are (a) executive subroutines to control decisions and supply subordinate hierarchical skills and (b) temporal patterning of skills to integrate the sequence of performance over time, involving pacing and anticipation (cited in Smith & Ragan, 1993). Further, psychomotor skills are sometimes classified on a continuum from "closed" to "open." Closed skills are predictable and do not require much adaptation to the environment, thus they are referred to as being "internally paced" (Singer, as cited in Smith & Ragan, 1993). Open skills, on the other hand, must be adapted to unpredictable aspects of a changing environment.

The function of feedback in the learning of psychomotor skills is to provide a surrogate for the learners' self-evaluation, at least until learners reach a skill level at which they can provide this role for themselves. However, as Smith and Ragan (1993) point out, this transfer is more pronounced than in other types of learning tasks. Learners are able, through their own seeing and hearing, to determine when a skill has been performed correctly, thus providing themselves a type of internal feedback.

Feedback may be given about (a) the product (the quality of the response outcome) or (b) the process (what causes the response outcome). During the beginning practice stages of motor skill, feedback serves the critical function of providing information about the process of executing the motor skill. Then, as learners advance in their ability to execute the skill, feedback can focus on the response outcome (product) itself. Ho and Shea (cited in Smith & Ragan, 1993) found that learners appeared to learn simple motor skills better when feedback was withdrawn or at least not given after every single response. Also, quantitative feedback (using a measurable criterion) appears to be superior to qualitative feedback (e.g., "too fast," "too low") (Smoll, as cited in Smith & Ragan, 1993). However, there is an optimal precision point to include in feedback, past which point the feedback can result in detrimental learning (Rogers, as cited in Smith & Ragan, 1993).

Graphic representations can be very beneficial to learners when included in feedback about the quality of a psychomotor response. Sometimes referred to as "kinematic" feedback, it can increase both the efficiency and the effectiveness of the learner during the acquisition of a psychomotor skill. Further, feedback that is interspersed throughout the learning of a motor task is more effective than massed feedback at the end of practice (cited in Smith & Ragan, 1993).

29.5.4.8 Attitude Learning. The final type of learning capability discussed in this section is attitude learning. The desired outcome of attitude learning is that a learner will choose to behave in a particular way. A person's attitude about something is reflected in the decisions or choices he or she makes. The goal of instruction for attitude learning would be to influence what a learner chooses to do after the instruction is completed (Gagné, 1985; Gagné et al., 1992). Obviously before a person can "choose" to do something, there are cognitive and behavioral components that have to be learned beforehand. The person has to cognitively "know how" to practice the attitude. Also, a person has to see the need to apply the attitude, behaviorally responding to opportunities to make decisions and make the particular choice. This can be accomplished through his or her own experience or vicariously through others' experiences. The affective side of attitude learning merely involves "knowing why."

Feedback for the cognitive and behavioral components can simply include information concerning whether learners have successfully employed the knowledge or skill that the attitude will require. Feedback can also include information about the congruency of their responses with the desired attitude. In terms of mediating attitudes through feedback, learners can be presented with information concerning the anticipated consequences of their choices, incorporating the affective component of why the behavior that reflects the attitude is important (Smith & Ragan, 1993).

29.5.5 Motivation

When one begins to speak of motivation in feedback, it is easy to bring to mind the reinforcement view of feedback, and indeed, theories of motivation have tended to focus on behavioral reinforcement and performance rather than on increasing motivation through instructional means (Jacobs & Dempsey, 1993). To understand ways in which feedback can be used to help the motivational level of students, whether from a behavioral or a cognitive view, it will be useful to examine briefly some of the basic theories of motivation that psychologists have constructed to explain motivation in the learning process.

29.5.5.1 Goals and Goal Discrepancy Feedback. Past research in the area of motivation (cited in Covington & Omelich, 1984) has shown that for a learner to remain motivated and involved depends on a close match between a learner's aspirations or goals and his or her expectations that these goals can be met. If these aspirations are set so high that they are unattainable, the learner will likely experience failure and discouragement. Conversely, when goals are set so low that their attainment is certain, success loses its potency in promoting further effort (Birney, Burdick, & Teevan, 1969). Covington and Omelich (1984) have suggested that setting performance goals beyond present capabilities, particularly in the case of low self-perception of success, can become a main source of gratification. Apparently the statement of a worthy goal is enough to boost self-regard irrespective of goal attainment. One might say that feedback is a means to allow a learner to study and "retest" information, actions that, according to some researchers, would encourage greater performance aspirations coupled with increased confidence to achieve these elevated goals. Findings suggest that motivation is a key mediating factor in the performance of learners (Covington & Omelich, 1984).

Feedback can be a powerful motivator when it is given 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, thus regulating sustained effort and future goal orientations (Dempsey, Driscoll, & Swindell, 1993). Other researchers claim that feedback enters into the actual goal-setting process, as a basis for evaluating assigned goals and in guiding the formation of a learner's personal goals (Erez & Zidon, 1984; Locke, Shaw, Saari, & Latham, 1981). Malone (1981) asserts that there are certain attributes that a goal must have to challenge the learner to attain them. First, they should be personally meaningful and easily generated by the learner. This is supported by Locke et al. (1981), who contend that goals may enhance performance only when the learner conscientiously accepts them. Indeed, Erez and Zidon (1984) found a linear decrease in performance after assigned goals were rejected.

Malone (1981) also suggests that learners need some type of performance feedback as to whether or not they are achieving their goals. This notion was explored in a study by Vance and Coella (1990) in which goal discrepancy feedback (GDF) and past-performance discrepancy feedback (PDF) were used to examine acceptance of assigned goals and personal goal levels of learners. GDF conveyed to what level learners were performing above or below the assigned goals. PDF indicated the learner's performance level from one trial to the next. Interestingly, assigned goals were designed to become increasingly difficult over given trials. This meant that, concurrently, the GDF became increasingly negative, and consequently, the learner's acceptance of the goals because less likely. Learners were found to switch over to PDF for evaluating assigned goals and for selecting new goals, what one would expect given the uncomfortable nature of the GDF over time.

Hoska (1993) refers to goals in terms of whether they help in acquiring something desirable or in avoiding something undesirable. These *acquisition* and *avoidance goals* can be external (in which the learner's focus is performing for others) or internal (in which the learner's focus is on learning for him- or herself). Several researchers (Dweck, 1986; Dweck & Legget, 1988; Nolen-Hoeksema, Seligman, & Girgus, 1986) have found that an individual's general goal orientation falls on a continuum from an ego-involved performing goal orientation to a task-involved learning goal orientation. Hoska further explains that learners who have performing goals want to demonstrate high ability and to avoid poor performance. They tend to view their success as a display of their abilities, which they measure in terms of the perceived abilities of others. To ego-involved learners, ability is their key to success, and effort is merely a means to achieve such external goals. In contrast, individuals who have learning goals pursue learning and extend effort to gain skills. They view their competence as improved mastery, attained through effort. To a task-involved learner, effort is perceived as being beneficial, as it helps the learner attain mastery.

When learners are successful, individual goal orientation is not a critical issue because success breeds the desire to extend effort, regardless of the goal. But when looking at instances of performance failure, the two goal orientations can produce very different results. If an individual with a learning goal orientation perceives an impending failure, it results in his or her exerting more effort on the task. To this task-focused individual, obstacles are a challenge to be overcome through effort. Task-involved learners believe that effort, not ability, is the key to success, and consequently, they will look for ways to overcome any difficulties that arise. Their satisfaction lies in effort, which has been shown to result in higher mastery scores and produces 50% more work than by other learners (Dweck, 1986).

In contrast, learners with a performance goal orientation will react quite differently to an impending failure. Obstacles become a threat to success and, therefore a threat to their self-worth. Even high ability learners in this group will set up defenses to protect themselves against the emotional threat. These self-defense reactions include such tactics as discounting (Kelley, 1973); avoiding the task, feigning boredom, or engaging in task-irrelevant actions to bolster their self-image (Dweck & Legget, 1988); and using inefficient strategies, resulting in learned helplessness (Seligman, Maier, & Geer, 1968).

According to Hoska (1993), if learners begin a task without a predisposition toward one of these two goal orientations, they will probably approach the task with the goals of both learning and performing. If learners do not receive cues favoring one type of goal over another, they will act according to their predisposition. But if a learning situation is structured to foster a particular type of goal, learners will respond. Thus a learner's goal orientations can be temporarily and, over time, permanently altered by intervention. This is where feedback can have a great effect on this aspect of motivation.

Providing lesson feedback can be used to influence learners' goal orientation by increasing their incentives to learn and minimize their incentives to perform. Hoska (1993) classifies these modifications into three approaches: (a) changing the learner's view of intelligence, (b) modifying the goal structure of the learning task, and (c) controlling the delivery of learning rewards. In terms of modifying a learner's view of intelligence, feedback can help learners view intelligence in a way that helps them see that ability and skill can be developed through practice, that effort is critical to increasing this skill, and that mistakes are part of the skill-developing process.

In terms of altering a learner's goal structure, one should consider the type of learning environment in which the lesson is taking place. Often goal structures are set within competitive, cooperative, and individualistic learning environments. Competitive goal structures emphasize performance success and failure and causes learners to become ego-involved. Cooperative goal structures teach a learner that the task is important, thus helping to foster learning goals (Johnson & Johnson, 1993). In individualized goal structures, although noncompetitive, learners will not necessarily be task-focused, but their orientation will be determined by the reward system of the learning experience.

Finally, the control of the delivery of learning awards usually involves providing external awards, offering praise and blame feedback, and offering unrequested help that can increase the learner's chance for success and comparison of the learner's performance to that of others.

Unfortunately, providing external rewards to learners can easily undermine any personal learning goals that they have. Researchers have found that learners will often select less difficult tasks to increase their probability of success (Deci, 1972; McCullers et al., 1987), and this effect increases under competitive conditions (Covington & Omelich, 1979). Further, learners often think that only difficult or boring tasks require reward (McCullers et al., 1987). Hoska (1993) offers the suggestion that feedback on the development of skills at various stages of a learning task can help redirect the learner to a focus on internal rewards.

Praise and blame feedback, once thought to provide positive and negative reinforcement, has been shown to be interpreted by learners as an estimate of their ability (Deci, 1972). While most learners associate praise and blame in terms of how much effort they expended, ego-involved learners and learners in competitive tasks often interpret praise and blame feedback as an indicator of both ability and success levels, sometimes even producing learned helplessness (Koestner, Zuckerman, & Koestner, 1987). Hoska (1993) summarizes the effects of praise and blame feedback in terms of whether or not the learner felt the comments were warranted, the difficulty of the task involved, and the goal structure of the learning environment. She points out that praise has the most potential for being misinterpreted by learners. When high praise occurs after successful completion of an easy task, it is interpreted to mean that the evaluator thinks the learner must have low ability. When minimal praise occurs after the successful completion of a difficult task, learners may believe that the evaluator thinks they have high ability, with success occurring due to this high ability rather than effort. And when praise or no feedback occurs after a failure, learners will tend to believe that this indicates low ability.

Blame feedback for incorrect responses can have more positive effects than praise feedback does for successes. Learners will tend to perceive blame as a result of their withheld effort. Hoska (1993) cautions that blame feedback must be used carefully because it also can be harmful in instances when a learner has invested a high degree of effort and has achieved at least some level of success. In such cases, the feedback can teach learners that small sustained improvements do not help them reach mastery—an undesirable outcome. In general, praise and blame feedback should focus on individual learner responses rather than overall success levels so as to associate the feedback with effort and not with ability.

It should be noted that having the option of being retested, in which a learner is given feedback and allowed to improve, also increases the number of failures experienced by a learner (Covington & Omelich, 1982). These failures have been shown to lead to decreases in self-estimates of ability, which in turn trigger hopelessness, shame, and anxiety (Covington, 1983; Covington & Omelich, 1981). But under a mastery format, positive perceptions of ability have been shown to be maintained even in the event of failure, as long as learners eventually reached their grade goals or showed improvement (Covington & Omelich, 1984). In the same study (Covington & Omelich, 1984), although isolated failures were temporarily demoralizing, they were shown to play little part in determining overall motivational reactions. When students do not have the opportunity to make good their failures, the result is greater demoralization even though they experience fewer failures. The study makes the point that task-oriented learning may be especially beneficial for slow learners, who may require several tries before mastering the subject matter.

Although the mastery learning approach is not new, nor is the idea of mastery being a desirable approach for slow learners, it is important to note here that the motivational element at work in such approaches should not be ignored. This line of motivation research suggests that students who are given the chance to improve through practice and feedback of some sort will have a positive perception of ability and will retain a high level of motivation overall. Thus the "retesting" effects of feedback have implications for improving and sustaining motivation, irrespective of the numbers of errors made.

29.5.5.2 Self-Efficacy and Expectancy. Self-efficacy and task expectancy have been said to be equally important in determining how a learner will respond to a learning task (Hoska, 1993). Self-efficacy is the learner's perception of how well he or she can perform the learning tasks to achieve his or her goals. It helps the learner select attainable goals and determine the amount of effort that will be involved for reaching success. Self-efficacy affects learning because it influences how much effort a learner will invest in a task. For example, low self-efficacy can cause learners to dwell on their deficiencies, resulting in inaccurate personal assessments of task difficulty and excessive attention devoted to the possibility of failure, resulting in a learning detriment (Bandura; cited in Hoska, 1993). On the other hand, high self-efficacy does not always result in maximum effort because the amount of effort extended by learners is said to depend on not only self-efficacy, but also goal incentives and the perceived demand or load of a task. Hoska (1993) points out that when learners are aware that a task is demanding, high self-efficacy will usually result in the effort needed for optimal performance. But when learners perceive tasks as being easy, high self-efficacy may cause them to feel that minimal effort is needed.

Bandura (1977) cites three information sources from which learners derive their general sense of self-efficacy. One is through vicarious experiences, in which self-efficacy is increased through viewing others' successes or decreased by viewing others' failures. Self-efficacy is also developed through the learner's own personal performance. The impact of a success or failure affects self-efficacy by how the learner interprets the outcome. Any success that is achieved through a minimal amount of effort is viewed to indicate high ability and can result in increased self-efficacy. Some learners view success that requires high effort to mean low ability, thus reducing their self-efficacy. The third area from which learners build their self-efficacy is verbal persuasion. Verbal persuasion comes in the form of opinions from parents, teachers, and peers concerning the learners' ability to perform various tasks and tend to affect learners' own perceptions about their abilities. Even learners with an initially high level of self-efficacy are said to have their own opinions of their ability affected by continual exposure to negative criticism (Hoska, 1993). Self-efficacy levels can also be temporarily affected by the learner's physiological state (Bandura, 1977), role assignment, familiarity with a task, or the presence of a highly confident person (Bandura, 1982).

Expectancy is determined by the amount of effort a learner deems as appropriate for a task, based on the learner's goal incentives. Hoska (1993) describes several elements of expectancy as follows:

- Belief that an outcome, or goal, is possible given the current situation. (Learner must feel that he or she has some control over goal attainment; this goal may or may not be task completion.)
- Belief that an outcome, which can be achieving either an acquisition or an avoidance goal, will have desired consequences. (The consequences of goal achievement must have some value to the learner.)
- Determination of the amount of effort appropriate for goal attainment. (The greater the goal incentive, the more effort the learner is willing to invest to achieve the goal.)
- Determination of whether or not the selected amount of effort will lead to goal attainment. (p. 119)

Keller and Suzuki (1986) assert that learners tend to evaluate outcomes against their own expectations. Recall that Kulhavy's

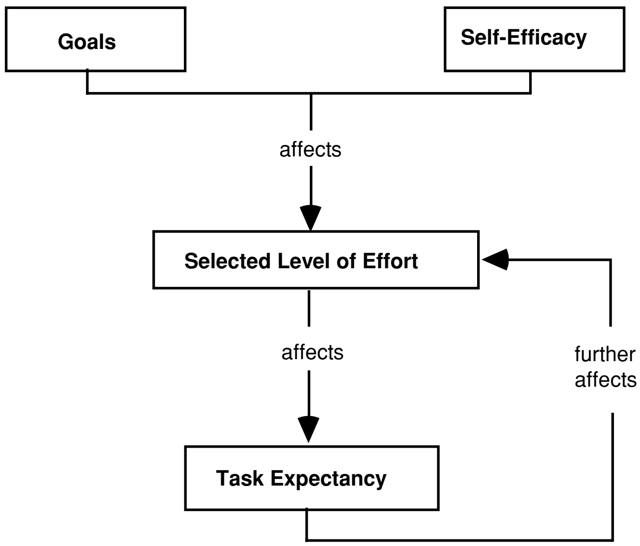

FIGURE 29.4. Relationship among a learner's goals, self-efficacy, selected level of effort, and task expectancy (from Hoska, 1993, p. 121). From *Interactive Instruction and Feedback* (p. 121), by J. V. Dempsey and G. C. Sales (Eds.), 1993, Englewood Cliffs, NJ: Educational Technology. Copyright 1993 by Educational Technology Publications. Reprinted with permission.

research in the area of response certitude supports the importance of the learner's expectancy level. Dempsey, Driscoll, and Swindell (1993) note that Kulhavy's work supports the hypothesis that "corrective feedback should be personally relevant to the learner and tailored to the learner's expectancy for success" (p. 28) and that this link has major implications for both motivational and instructional designs.

Hoska (1993) asserts that self-efficacy and expectancy levels can be modified. Figure 29.4 depicts the relationship between learners' goals and self-efficacy and their selected with level of effort and task expectancy.

As shown in the figure, a learner's self-efficacy and strength of task goals influence the level of effort that the learner will decide to invest in the task. This selected level of effort will then affect the learner's task expectancy, which will in turn influence further effort decisions. Learners' level of effort can be increased by providing them with experiences that are positive and internally satisfying, such as experiencing continually increasing levels of competence. Another method of increasing self-efficacy is by modifying the learner's attributes of success and failures (see the following section).

29.5.5.3 Attribution Theory. One classic approach to motivation emphasizes the importance of causal attributions in explaining the consequences of academic failure and success (Weiner, 1972, 1979, 1980). According to attribution theory, a learner's achievement, affective reactions, and expectations concerning future outcomes are determined in part by the learner's attributional conclusions. Following performance on a learning task, students will react in a generally positive or negative manner, formulate causes to explain their performance (causal attributions), and then experience affect and expectancy changes dependent on the nature of these attributions. Note how closely this last description matches what Kulhavy and his associates (Kulhavy, 1977; Kulhavy & Stock, 1989) described for a learner's processing of feedback and the comparison of his or her response to the feedback information. Recall that Kulhavy explained how a learner's level of response confidence combined with the actual correctness of response determined how feedback was used.

Forsyth and McMillan (1981) describe Weiner's proposed model of educational attributions and attempt to assess the relationship among the attributions, affect, and expectations of college students following a course exam. They cite previous research that suggests that when students attribute their success to factors such as ability or the nature of the task, their expectations for success increase, whereas students who attribute their success to luck or effort report less positive expectancies. Further, according to self-worth theory, "failure is more likely to lead to shame, depressed expectations, and lowered self-worth when it is ability linked rather than effort linked" (p. 394). Effort is something that is within the learner's control and has been found to have a strong relationship to affect. In the Forsyth and McMillan (1981) study, the affective reactions of students who felt that their performance was caused by factors they could control were more positive than the reactions of students who believed that they did not control the cause of their outcome. This supports studies of learned helplessness in that even students who did well on the test yet believed that they could not control their outcomes reported less positive affect.

Learned helplessness has been described by Seligman (1990) as "the giving-up reaction, the quitting response that follows from the belief that whatever you do doesn't matter" (p. 15). In his 25 years of research in this area, Seligman has isolated what he believes to be "the great modulator of learned helplessness," *explanatory style*. When events, whether good or bad, happen to a person, he or she has an habitual manner of explaining those events. These explanatory styles can either prevent helplessness or spread helplessness, depending on the person's explanations of events. Seligman further divides these explanations into the areas of *permanence, pervasiveness,* and *personalization*. He has found that if you can alter the way in which pessimistic people explain a success or failure—that is, alter the levels of permanence, pervasiveness, and personalization with which they surround their self-talk—you can change their outlook to one of optimism. Optimism, in turn, prevents people from remaining in a state of helplessness so that they can be more productive individuals.

Because students' "perceived noncontingency" (Forsyth & McMillan, 1981, p. 400) is associated with loss of achievement motivation, it seems reasonable to suggest that feedback could help students see a direct link between their level of effort and success and provide information concerning various factors that the learners have under control. This is elaborated on in the next section, in which strategies for modifying learners' motivational perspectives are examined.

TABLE 29.2. Motivating Learners Through Feedback (modified from Hoska, 1993, pp. 126–129)

Type of Feedback	Function of the Feedback	Technique	Cautions
Feedback to strengthen the incentive of learning goals	Help learner view his or her abilities as improvable.	In intro. To lesson or as feedback when learner has difficulty: • Suggest that abilities are skills that can be developed. • Identify the skills that the lesson is aimed at developing. • Indicate that effort is the main tool for increasing skills. • Treat mistakes as an important part of skill development.	Help learner view his or her abilities as improvable. If learners are working in pairs or small groups, set up a cooperative environment.
	Present a task-focused, noncompetitive learning environment.	When presenting feedback for both correct and incorrect responses: • Keep comments task focused. • Have the learner set goals related to completion of small-task stages. • Do not tie goals to accuracy rate or the time required for mastery. • Avoid comparisons. Do not rate the learner's progress against the progress of previous lesson users. • Do not offer rewards such as bonus points.	
Feedback to minimize the effect of difficulty level	In the case of CBI feedback, counteract learner s tendency to view the computer as solely an entertainment source.	As an introduction to the lesson and intermittently within feedback, reinforce the idea that the lesson is designed to help the learner develop skills. During feedback, occasionally stress the importance of paying close attention to presented information.	Do not suggest that the learner needs to work hard before he or she is presented with a learning task. This may cause him or her to overestimate task difficulty.
	Convince learner that difficulties and challenges are positive and do not reflect ability level.	Introduce the idea that the learner may easily complete some parts of the lesson, while having difficulty with others. Present the need for increasing levels of difficulty as a necessary part of skill development.	
Feedback to increase a learner s self-efficacy	Steadily increase the self-efficacy of learners.	To develop a sense of self-efficacy, use the following strategy throughout the lesson: 1. Use feedback that provides support during the early stages of learning a task. Either give the learner some type of advised control over help sequences or attempt to put some aspect of forced support under learner control. 2. As the learner progresses, slowly reduce the amount of available help, letting the learner know that he or she is starting to do well on his or her own. 3. As the learner gains skill, begin to give him or her increasing control over the lesson. Let learners know that they have earned the ability to direct their study. If track able factors are present, such as the speed at which the learner selects answers to questions, indicate that poor performance may be due to guessing; suggest to the learner that guessing is a waste of time, and lesson mastery is possible if he or she takes time and concentrates.	Do not offer high verbal praise for successes; a learner can easily misinterpret praise as a sign of low ability. Simple verification of a success is usually enough. Do not admonish learners every time they do poorly. If a learner with low self-efficacy is trying, blame may cause him or her to give up. Do not always force help on a learner. Provide help only when the learner really needs it.
Learner gains a sense of control over his or her learning	Help learner to attribute his or her success and failures to effort.	Provide feedback related to effort levels for both successes and failures. Track the learner s performance and: • If a learner responds incorrectly to several problems in a row, suggest that the difficulty does not mean failure. Encourage effort and suggest that if the learner tries hard, he or she will achieve success. Follow this advice with a slightly less-different problem. • If a learner has had difficulty and is now improving, point out the success and suggest that the cause is effort. Encourage continued effort. Follow this advice with a problem the learner has a fairly good chance of answering correctly. • If the learner is having difficulty, guide the learner to select a different, more-effective strategy. Relate the search for and use of strategies to effort.	Make certain that the learning environment is task focused and noncompetitive. Present the effort feedback after the learner responds to a problem. Offer effort-directed feedback only when the learner is working on problems of medium difficulty.

29.5.5.4 Modifying Learner's Perspectives Through Feedback. Hoska (1993) cites several steps that learners go through when they select and perform tasks, based on Weiner (1979).

Step 1. Learner selects a goal.
Step 2. Learner evaluates task difficulty.
Step 3. Learner evaluates his or her abilities and develops a level of self-efficacy.
Step 4. Learner selects an effort level and decides if that level will yield task success.
Step 5. Learner invests effort to complete the task and evaluates progress toward task completion.
Step 6. Learner determines and dimensions the cause of the success or failure.
Step 7. Learner modifies his or her learner perspective.

As learners go through these steps, Hoska suggests feedback according to its motivational function. This is summarized in Table 29.2.

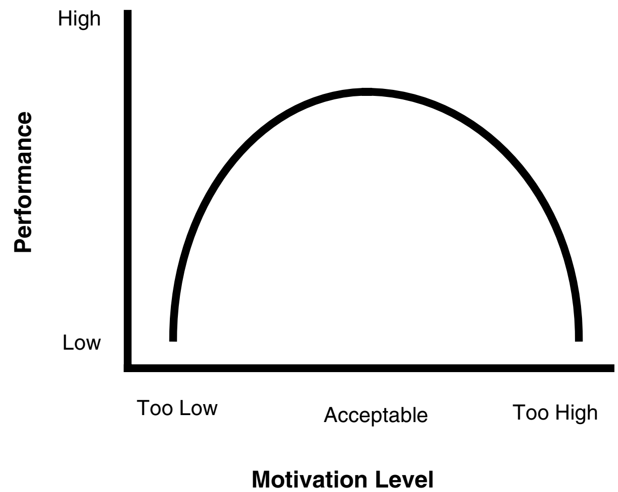

FIGURE 29.5. Inverted-U curve depiction of the relationship between motivation and performance (based on Keller, 1987).

29.5.5.5 ARCS Model of Motivation. Some researchers (Keller, 1983, 1987a, 1987b, 1987c; Keller & Kopp, 1987; Keller & Suzuki, 1987) have developed a model for increasing student motivation through instructional design, emphasizing instructional components that serve to motivate learners. The model grew from a macro theory, which motivation and instruction developed by Keller (1983). It is grounded in expectancy-value theory, which assumes that "people engage in an activity if it is perceived to be linked to the satisfaction of personal needs (the value aspect), and if there is a positive expectancy for success (the expectancy aspect)" (Keller, 1987a, pp. 2–3). The model came about by dividing the value components into the categories of *interest* and *relevance*. *Interest* refers to attentional factors in the environment, and *relevance* refers more to goal directed activities (p. 3). The expectancy component remained as a category, and a fourth category was added which was originally called *outcomes*. *Expectancy* refers to one's own expectation for being successful, and *outcomes* refers to the reinforcing value of instruction. Outcomes include reinforcement as described in operant conditioning theory but also include any environmental outcomes that help maintain intrinsic motivation (see Deci, 1972).

The ARCS model was created by generating a large list of motivational strategy statements, derived from research findings and from practices that have resulted in motivated learners. The four original categories of *interest, relevance, expectancy,* and *outcomes* were renamed to strengthen the central feature of each component and to generate a useful acronym (Keller, 1987a). The model now focuses on the four categories, attention, relevance, confidence, and satisfaction, and is hence referred to as the ARCS model. By using each of these four categories as a framework, instructional designers are able to incorporate strategies that relate to each.

When Keller (1987a) refers to *attention,* he is referring to the interest level of the learner—whether or not the learner's curiosity is aroused and is sustained over an appropriate period of time. Whether the learner perceives the instruction to satisfy personal needs or to help achieve personal goals is referred to by the *relevance* component of the model. *Confidence* refers to the learner's perceived likelihood of success (expectancy) and whether the learner perceives success as being under his or her control. Intrinsic and extrinsic motivation are referred to under the *satisfaction* component and focuses on the learner's intrinsic motivation and response to extrinsic awards.

Keller (1987c) notes that one of the challenges of motivation is that it is just as detrimental to learning and performance for learners to be overmotivated as it is for them to be undermotivated. Undermotivation results in low productivity levels, whereas overmotivation results in high error rates and poor efficiency due to stress and overconfidence (pp. 2–3). The typical graphical representation of this is the inverted-U curve, illustrating this result (see Fig. 29.5).

Keller (1987c) uses this inverted-U depiction when he completes audience analyses, plotting the levels of attention, relevance, confidence, and satisfaction on the curve. The rise and fall in performance in relationship to levels of motivation have implications for instruction. It appears that enhancing motivation for learning is an area that should be of concern to researchers: and, as we shall see momentarily, an area that feedback potentially may influence.

In Keller's (1983) original description of the motivational design of instruction, he lists several strategies to enhance motivation, some of which recommend the use of feedback to the learner. For our purposes of considering areas for future feedback research, these deserve closer inspection. They are as follows.

"Increase expectancy for success," which is now included in the model as *confidence,* "by using *attributional feedback* and other devices that help students *connect success* to personal effort and ability" (Keller, 1983, p. 420).

Attributional feedback is important when a student does not perceive a connection between his or her effort and its consequences. This is what was referred to earlier as *learned helplessness*. A person who has developed learned helplessness toward a task does not perceive any causal link between behavior (effort) and its consequences. This type of learner cannot see the connection between ability and persistence as the key to success. When working with this type of learner, a sequence of problems or assignments should be developed that is initially easy but becomes challenging. After each success, feedback should be given as encouragement to keep trying, and after success on more difficult problems, attributional feedback should be presented. Basically attributional feedback tells learners that their success occurred because they kept trying. Keller (1993) refers to this feedback as being given verbally by a teacher in a classroom situation, but it is easily conceivable that adaptive feedback in other forms that contains the same type of messages would be appropriate.

Enhancing the learner's perception of outcome, now referred to as *satisfaction,* involves both intrinsic and extrinsic motivation. Keller (1983) recommends the following.

1. To maintain intrinsic satisfaction with instruction, use *verbal praise* and *informative feedback* rather than threats, surveillance, or external performance evaluation.
2. To maintain quantity of performance, use *motivating feedback* following the response.
3. To improve the quality of performance, provide *formative* corrective) feedback when it will be immediately useful, usually just *before* the next opportunity to practice. (pp. 426–427)

The first strategy is concerned with the types of consequences that will enhance or suppress intrinsic motivation. Keller (1983) points out that intrinsic motivation is more likely to flourish in a context of positive but noncontrolling consequences than when excessive evaluation and aversive forms of control are used (p. 426). In terms of motivating feedback in the second strategy, the behavioral view of operant conditioning using positive reinforcement again surfaces. As Keller emphasizes, we are more likely to repeat behaviors that have pleasurable consequences than those that do not. When a learner receives positive reinforcement following a desired response, it affects the quantity of performance. One might contest this view of feedback in light of the evolution of feedback research from this type of behavioral view to that of cognition only. But it does make sense in terms of increasing and maintaining motivation or morale.

The third strategy refers to formative feedback, used to affect the quality of performance. It signals a gap between the given performance of the student and the desired performance, and it indicates the actions to take to close the gap. Again, it is easy to see that this is feedback with the purpose of correcting errors, as seen in the latest feedback studies that view feedback from a cognitive standpoint with a predominantly corrective function.

A prototype of motivationally adaptive CAI has been developed using the ARCS model (Song & Keller, 1999, 2001). One study (1999) focused on how three versions of motivationally adaptive CAI affected student achievement, perceived motivation, efficiency, and continuing motivation. The three types of adaptive motivational feedback were (a) motivationally adaptive, (b) motivationally saturated, and (c) motivationally minimized. The motivationally adaptive group showed higher levels of effectiveness, overall motivation, and attention than the other two groups.

In the ARCS model area of relevance, the motivationally adaptive group ranked higher than the motivationally saturated group, but not any higher than the motivationally-minimized group. In the areas of confidence and satisfaction, the motivationally adaptive CAI group did not prove to be more effective than the other two groups. In the case of efficiency, both the motivationally adaptive and the motivationally minimized groups were more efficient than the motivationally saturated CAI group; however, the efficiency of the motivationally adaptive group was identified as the area that offers practical importance to future design. In terms of continuing motivation, the groups were not significantly different, however, a significant correlation was found between students' overall motivation and their continuing motivation across the three groups. This study does support the notion that motivationally adaptive CAI can be an effective, efficient, and motivating form of instruction and that it also may enhance students' continuing motivation (Song & Keller, 1999).

Song and Keller (2001) also examined the prototype of motivationally adaptive CAI on the dynamic aspects of motivation—that is, changes in learner motivation that might occur over time through a lesson. Their results suggest that CAI can respond to changes in motivation levels of learners across time. They also support the use of the ARCS model areas of attention, relevance, confidence, and satisfaction as a useful and effective tool in the design of such dynamic aspects of motivation.

29.6 FEEDBACK FROM A CONSTRUCTIVIST VIEW

29.6.1 Paradigm Shifts

The majority of feedback studies in the literature have examined feedback under the traditional learning theory paradigms of behaviorism and information processing. Both of these theories can be classified as viewing learning from an *objectivist* perspective. The philosophy of objectivism basically holds that "reliable knowledge about the world" exists (Jonassen, 1991, p. 8) and that instruction serves to present this real world knowledge to the student, who will in turn be tested and "give back" this knowledge to demonstrate effective learning. Feedback would then serve to correct misinformation about this external, objective reality. This is, indeed, how most feedback studies are conceived.

The latest philosophy of learning, however, postulates that there is no external knowledge the student merely "takes in"; rather, the student must *construct* his or her own reality or knowledge, and this construction will be based on the learner's prior experiences, mental structures, and beliefs (Brown, Collins, & Duguid, 1988; Cooper, 1993; Duffy & Jonassen, 1991; Jonassen, 1991). Put succinctly, "Knowledge is constructed in the mind of the learner" (Bodner, 1986, p. 873). Thus espouses the philosophy called "constructivism,"

TABLE 29.3. Assumptions of Objectivism (from Jonassen, 1991b) and Suggested Use of Feedback

Objectivism	
Assumption	Feedback
• Reality is external to knower	• Feedback is based upon response match to external reality
• Mind acts as processor of symbols	• Feedback contains symbols for learner to process
• Thought is independent of human experience; reflects external reality	• Feedback not related to human experience; reflects external reality
• Meaning corresponds to categories in the world	• Meaning within feedback information corresponds to categories in the world
• Symbols represent external reality	• Feedback contains symbols that represent external reality

in which each learner constructs his or her own reality through interpretation of experiences of the external world. And given this new view of learning, feedback will likely function differently than from an objectivist view of learning (Mory, 1995).

Recall how early studies of feedback evolved from a behavioral view of feedback as reinforcement to more recent research that advocates an information processing perspective with an emphasis on error correction. Feedback's main function is providing corrective information. Recall also the recently developed models of feedback (Bangert-Drowns et al., 1991; Kozma & Bangert-Drowns, 1987; Kulhavy, 1977; Kulhavy & Stock, 1989) that attempt to explain what happens within the feedback process. These models also contribute to an organization of the many variables that have been examined or even overlooked in past research. All of these studies were conceived under a philosophy of learning that embraces certain assumptions about learning from an objectivist viewpoint. These assumptions and the resulting use of feedback are listed in Table 29.3.

Although there has been progress in determining ways in which feedback can best be used under certain conditions, there are still many areas in which the feedback literature is not consistent and yet other areas that have been left unexplored. One must critically examine feedback in light of the philosophical assumptions underlying these studies to highlight how feedback functions within such contrived experimental settings. The basic assumptions of the objectivist philosophy are presented (Table 29.3) to contrast them with those of a constructivist view. Suggestions for the use and function of feedback within the constructivist philosophy are presented in light of these basic assumptions in an effort to identify areas in need of further research (see Table 29.4).

Given such an array of inconsistencies in the feedback literature, it is essential to question whether or not researchers are focusing on feedback variables that have real value in the world of the classroom. Many feedback studies are computer-based training (CBT) studies and are not intended to be generalized to a large group setting such as a "typical classroom." In most instructional settings, feedback is presented within some sort of interactional environment, not necessarily one of computer-based or programmed instruction. Perhaps some of the most potent feedback is received within a setting in which the student interacts with some problem he or she is trying to solve, with feedback resulting as a natural phenomenon of the context of instruction. For example, students who are trying to learn to play a musical instrument receive constant feedback from their mistakes just by hearing the sounds that are being produced, regardless of whether or not there is any other external mechanism in place to correct these sounds. Feedback occurs as a natural result of interactions between the learner and his or her own constructions of knowledge. Further, the topics usually being presented in traditional feedback studies are usually a far cry from being anything the learner would be motivated to learn, this being purposefully the case in order to maximize feedback differences. The context in which learning takes place in most of these studies is often artificial and distanced from what a typical learner's interactions with a problem would be. Certainly the inconsistencies in the feedback literature warrant some fresh ideas and perspectives. This researcher proposes that feedback be critically examined within a paradigm that embraces the philosophy of constructivism, in which the learner

TABLE 29.4. Assumptions of Constructivism (from Jonassen, 1991b) and Suggested Use of Feedback

Constructivism	
Assumption	Feedback
• Reality is determined by knower	• Feedback is to guide learner toward internal reality; facilitates knowledge construction
• Mind acts as builder of symbols	• Feedback aids learner in building symbols
• Thought grows out of human experience	• Feedback in context of human experience
• Meaning does not rely on correspondence to world; determined by understander	• Meaning within feedback information determined by internal understanding
• Symbols are tools for constructing an internal reality	• Feedback provides generative, mental construction "tool kits"

must construct his or her own knowledge based on interactions within authentic learning environments.

29.6.2 Applications of Feedback in Constructivism

The philosophy of constructivism opens a new avenue for feedback research. Feedback in a constructivist context would provide intellectual tools and serve as an aid to help the learner construct his or her internal reality. Because learners would be solving complex problems through social negotiation between equal peers and in contextual settings, feedback might also occur in the form of discussion among learners and through comparisons of internally structured knowledge.

Perhaps to understand better what feedback would represent in a constructivist paradigm, consider the earlier transition of research foci from a behavioral view (reinforcement) to a cognitive view (information). As Cooper (1993) suggests,

> The move from behaviorism through cognitivism to constructivism represents shifts in emphasis away from an external view to an internal view. To the behaviorist, the internal processing is of no interest; to the cognitivist, the internal processing is only of importance to the extent to which it explains how external reality is understood. In contrast, the constructivist views the mind as a builder of symbols—the tools used to represent the knower's reality. External phenomena are meaningless except as the mind perceives them. (p. 16)

One constructivist principle is that instruction should occur in relevant contexts (Brown et al., 1989; Jonassen, 1991a). Referred to as *situated cognition,* the notion is that learning occurs most effectively in context and that the context becomes part of the actual knowledge base for that learning (Jonassen, 1991b). One approach to this is called *cognitive apprenticeship* (Brown et al., 1989; Collins, Brown, & Newman, 1987), in which learners engage in activity and make deliberate use of both social and physical context, just as an apprentice would do. Feedback in this view would occur in the form of the interactions between the learner and the activity of solving real-world problems. Rather than providing predetermined instructional sequences, feedback could be used as a coaching mechanism that analyzes strategies used to solve these problems (Jonassen, 1991b).

Another constructivist strategy has been termed *cognitive flexibility theory* and involves the presentation of multiple perspectives to learners (Jonassen, 1991b; Spiro, Feltovich, Jacobson, & Coulson, 1991a, 1991b). By stressing conceptual interrelatedness, providing multiple representations of content, and emphasizing "case-based instruction" that includes inherent multiple themes (Jonassen, 1991b), feedback can help learners acquire advanced knowledge in ill-structured domains. Spiro and associates (1991a, 1991b) propose the use of multidimensional and nonlinear hypertext systems to convey ill-structured aspects of knowledge domains and thus promote cognitive flexibility. When a learner approaches a problem from a certain perspective, feedback can serve to guide the learner to revisit the same material in a rearranged context, for a different purpose, from a different conceptual perspective (Spiro et al., 1991a), or any combination of these. Although implementing cognitive flexibility theory is not just a matter of, using a computer to "connect everything with everything else," as Spiro et al. (1991a, p. 30) state, feedback can be designed into a hypertext system to lead the learner to approach concepts from new perspectives and to provide locator information when a learner feels lost in a "labyrinth of incidental or *ad hoc* connnections" (p. 30). Feedback traditionally has been used to allow the learner to evaluate preset goals through reinforcement of matching responses or through control of instruction. But in the constructivist view, evaluation provided by feedback would become more of a tool for self-analysis (Jonassen, 1991a).

Another constructivist invention is that of the *microworld*—"a small but complete subset of reality in which one can go to learn about a specific domain through personal discovery and exploration" (cited in Rieber, 1992, p. 94). Instructional applications of microworlds conform to Vygotsky's idea of the "zone of proximal development," in which learners who are on the threshold of learning are often unable to attain understanding without some external intervention or assistance (Rieber, 1992). Rieber contends that learning environments such as microworlds should be designed with a "self-oriented feedback loop" (p. 100) that provides a rich and continual stream of information to help students establish and maintain goal setting and goal monitoring. Further, because many complex problems contain so many individual variables that can inundate a novice to the point of frustration, microworlds offer a way to structure the learning environment to a finite set of variables, something Piaget termed *variable stepping* (Rieber, 1992). Feedback received can be judged against a learner's individually defined goals. Rieber (1992) also suggests using a variety of feedback features to complement one another, such as presenting verbal feedback at the same time as visual feedback.

A report by Edwards (1991) focused on how children used feedback from a computer microworld for transformational geometry to discover and correct instances of overgeneralizations that emerged as they solved problems with the microworld. Although there was a tendency toward symbolic overgeneralization in some activities, the children were able to use visual feedback from the microworld and discussions with their partners to correct their own errors.

A summary of the functions of feedback under a constructivist philosophy is presented in Table 29.5. Researchers

TABLE 29.5. Suggested Constructivist Functions of Feedback (Mory, 1995)

- Aids learner in constructing an internal reality by providing intellectual tools
- Helps learner solve complex problems within contextual, relevant settings
- Occurs as social negotiation between equal peers
- Provides guidance for multiple modes of representation
- Guides learner through ill-structured domains, reminding learner of goals
- Challenges learner toward potential development

are encouraged to pursue the study of feedback under this paradigm.

29.7 BRIDGING THE GAP: A SYNTHESIS MODEL OF FEEDBACK WITH SELF-REGULATED LEARNING

The most recent synthesis of contemporary feedback models views feedback in the context of self-regulated learning (SRL; Butler & Winne, 1995). Butler and Winne (1995) propose a more elaborated examination of feedback that takes into account how feedback affects cognitive engagement with tasks and how engagement relates to achievement. Self-regulated students are aware of aspects of their own knowledge, beliefs, motivations, and cognitive processing, and the most effective learners are self-regulating. The model couples elements from traditional feedback research with processes involved in self-regulation. My view is that the Butler and Winne (1995) model quite possibly may supply the "missing link" between the findings presented in recent reviews (Bangert-Drowns et al., 1991; Kulhavy & Stock, 1989; Mory, 1992) and elements of motivation theory and constructivistic philosophies. Butler and Winne (1995) point out that many studies of SRL have looked at global or aggregate results of multiple SRL activities, rather than at individual instances of self-regulation. They suggest a more "fine-grained analysis of feedback's roles in dynamic cognitive activities that unfold during SRL" (p. 247).

Whereas most studies of feedback have focused on externally provided information, Butler and Winne (1995) postulate that internal feedback is also inherent, as self-regulated learners monitor their own engagement in tasks. The most effective learners develop their own distinct cognitive routines for creating this internal feedback, which in turn affects how they will use information presented within feedback externally. Thus, the feedback serves a multidimensional role in aiding knowledge construction that fits into a model of self-regulation.

Although not usually found in feedback or SRL research, Butler and Winne (1995) cite several areas of research and integrate these areas to aid in understanding the process of self-regulation as it relates to feedback. These include (a) how affect relates to persistence during self-regulation, (b) the role that learner-generated feedback plays in decision making, (c) how students' beliefs affect learning, and (d) what beliefs learners have in the process of conceptual change or restructuring when faced with misconceptions.

Self-regulation is the recursive process of interpreting information based on beliefs and knowledge, goal setting, and strategy applications to generate both mental and behavioral products (see Fig. 29.6). Mental products can include both cognitive and affective domains. Learners monitor their own process of engagement and updated products through internal feedback. They then reinterpret the task and their own engagement, which affects subsequent engagement. Modifications can include altering goals or setting new ones, reviewing and adapting their strategies of learning, and developing new skills. At this point, if external feedback is provided, additional information can be added to help the learner in this process (see Fig. 29.6).

29.7.1 Self-Regulated Engagement

Four lines of research are featured in Butler and Winne's (1995) review of self-regulation. One is a model of self-regulation in

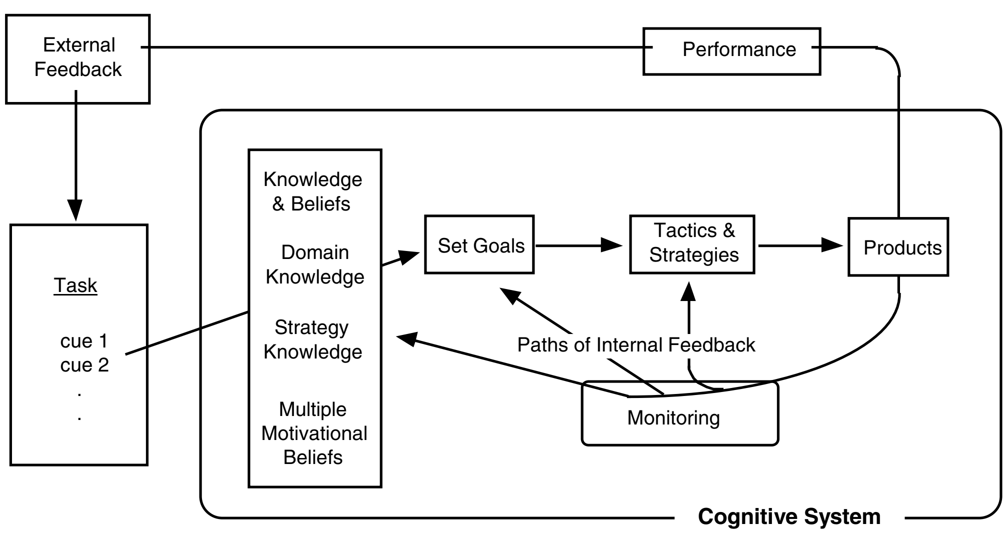

FIGURE 29.6. A model of self-regulated learning). From "Feedback and Self-Regulated Learning," by D. L. Butler and P. H. Winne, 1995, *Review of Educational Research*, 65, 248. Copyright 1995 by the American Educational Research Association. Reprinted with permission.

terms of engagement and affect. Several researchers (Bandura, 1993; Carver & Scheier, 1990; Kuhl & Goschke, 1994; Mithaug, 1993; Zimmerman, 1989) have found that "students' goals couple with motivational beliefs and affective reactions to shape self-regulation" (Butler & Winne, 1995, p. 249). Positive affect results when progress is achieved faster than predicted, and negative affect results when the learner's rate of progress is slower than predicted. According to this model of SRL (Carver & Scheier, 1990), it is predicted that when learners make progress exactly as planned, the affect level that results is neutral rather than positive and that, under some conditions, achievement actually results in a negative affect. These affect levels influence future engagement in the task by shaping confidence judgments during the learner's internal monitoring process (Carver & Scheier, 1990; Eisenberger, 1992; Kuhl & Goschke, 1994).

29.7.2 A Lens Model

The second line of SRL research is from the viewpoint of what is termed a lens model, in which both task characteristics and students' progress on tasks are used to predict final performance. Traditional feedback studies focus on *outcome feedback,* often referred to as knowledge of results. Whereas several studies do focus on adding elaborations to outcome information, most have ignored the role of giving learners guidance that can aid in their own self-regulation. Butler and Winne (1995) propose that data on students' perceptions of cues and their value, along with expectations of success and perceptions of actual achievement, can help researchers know what to provide in elaborated feedback to support self-regulated engagement and to enhance self-calibration. Such feedback has been termed *cognitive feedback* (Balzer, Doherty, & O'Connor, 1989) and can provide learners information that links cues and achievement. Cognitive feedback includes (a) task validity feedback, (b) cognitive validity feedback, and (c) functional validity feedback. *Task validity feedback* includes information provided from an external source that describes that source's perceived relationship between a task's cues and achievement (Butler & Winne, 1995; Elawar & Corno, 1985; Winne, 1989, 1992; Zellermayer, Salomon, Globerson, & Givon, 1991). *Cognitive validity feedback* includes information describing the learner's own perceptions about the cue and achievement relationship (Butler & Winne, 1995). And *functional validity feedback* describes the relationship between the learner's own achievement estimation and the actual end performance. In a review by Balzer and associates (1989), feedback that provided various forms of validity-related information was found to be more effective than outcome feedback, and task validity feedback was somewhat more effective in supporting learning and problem solving than cognitive validity feedback information alone.

Several implications of examining feedback from a lens model viewpoint become evident. When providing outcome feedback, researchers should realize that the effectiveness of the feedback depends on several learner characteristics and behaviors. Students must be attentive to many cues, have accurate memories of cue features when receiving outcome feedback, and be strategic enough to generate effective internal feedback to themselves. Outcome feedback provides little guidance to the learner on how to self-regulate. However, when applying cognitive feedback, researchers should use information that helps students identify cues and monitor their own task engagement. This monitoring is an essential part of self-regulation.

29.7.3 Learners' Beliefs.

The third line of SRL research examines the relationships among the learner's beliefs about learning, use of strategies, and resulting performance (Schommer, 1990, 1993; Schommer, Crouse, & Rhodes, 1992). Beliefs about learning can affect a student's persistent effort on a given task and goal orientation (Boekaerts, 1994; Carver & Scheier, 1990). These beliefs thus influence subsequent engagement on a task.

29.7.4 Misperceptions in Content

A learner's prior misconceptions about content area can hinder his or her subsequent revisions of that incorrect knowledge (Chinn & Brewer, 1993; Perkins & Simmons, 1988). Whereas students can be receptive and correct misunderstandings through feedback, Chinn and Brewer (1993) identify six negative responses to feedback under such conditions. Students can (a) ignore the feedback, (b) reject the feedback, (c) judge the feedback to be irrelevant, (d) consider the feedback to be unrelated to the belief, (e) reinterpret the feedback to fit the misconceived belief, or (f) make superficial as opposed to fundamental changes in the erroneous belief. In this way, feedback is "filtered" through a learner's existing beliefs about the content.

Butler and Winne (1995) conclude that SRL is inherent in students' construction of knowledge. They assert that differentiating functions of feedback using a broadly framed model of self-regulation synthesizes the diversity of students on feedback and instruction. They identify the potential roles of feedback in remedying both strategy implementation failure and ineffective monitoring.

Students' knowledge and beliefs are linked with their self-regulated engagement in tasks. In addition to their epistemological beliefs, research on self-regulation also points to four other types of knowledge that learners bring to a task: domain knowledge, task knowledge, strategy knowledge, and motivational beliefs. In terms of domain knowledge, students' strong incorrect knowledge structures within a domain result in erratic application of productive learning strategies (Burbules & Linn, 1988). As domain knowledge increases, students tend to acquire, use, and transfer cognitive strategies that support SRL (Salomon & Perkins, 1989). Task knowledge influences self-regulation as well, and learners' beliefs or interpretations of tasks can influence the goals they establish, as well as the cues attended to and acted on as they work on a task (Schommer, 1990).

Strategy knowledge results as students complete tasks. Winne and Butler (1994) identify three types of strategy knowledge. The first, declarative knowledge, involves stating what the strategy is. The second, procedural knowledge, involves how to use a particular strategy. And the third, conditional knowledge, addresses the utility of a strategy, such as when and where to use a strategy and how much effort will be required.

Finally, motivational knowledge involves learners' "beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives" (Bandura, 1993, p. 118), referred to as *self-efficacy*. Self-efficacy affects the goals learners will set and their commitment to those goals, decision making while striving to reach those goals, and persistence (Bandura, 1993).

As mentioned in the research on motivation, students can adopt two types of task-related goals—learning goals and performance goals. Butler and Winne (1995) hypothesize that cognitive feedback containing information about task cues will be most effective when given to students that adopt learning goals. Further, the effects of feedback depend on both students' overall goal and the item-to-item change in their total knowledge as they review their wrong answers. The goals that students adopt may be different from the goals intended by the instructor, designer, or researcher. When that is the case, feedback will probably have less stable or predictable effects. Because goals are central in the process of SRL, feedback must address the types of goals students adopt and support their processes for prioritization, selection, and maintenance of these goals (cited in Butler & Winne, 1995).

In terms of students selecting and generating strategies to reach their goals, Winne (1982) notes four particular problems that students encounter. First, learners may fail to recognize the conditions under which to employ the strategy. Second, learners may not understand the task or perceive the task goals and mismatch strategies to goals. Third, students may select good strategies but not know how to apply them. And, finally, students may lack the motivation to expend effort in applying a strategy.

Monitoring is another important aspect of SRL. Monitoring generates internal feedback in the learner that links his or her past performance to the next successive task. The points of linkage are the prime times at which feedback should be given to be most useful (Butler & Winne, 1995).

The ideas put forth by Butler and Winne (1995) may well be the key to linking the two areas of motivation and constructivist philosophy presented earlier in this chapter. Through the blending of SRL research with research on feedback, both the motivational elements involved in learning and the philosophy of constructivism can be addressed. Their model (Butler & Winne, 1995) suggests that feedback is contextualized according to the learner's prior knowledge and beliefs and, consequently, provides insufficient information to affect knowledge construction. They further suggest that for learning in authentic complex tasks, feedback should provide information about cognitive activities that promote learning and the relationships between cues and successive states of achievement.

Note also that the Kulhavy and Stock (1989) model emphasizing response certitude judgments adds credence to the notion that learners both set goals and monitor themselves. But Butler and Winne (1995) fine-tune the issue by hypothesizing that students actually monitor their own *calibration*. Calibration is the extent to which monitoring creates accurate certitude judgments. Butler and Winne (1995) suggest that high-confidence errors result in longer and more intense study of feedback because it is at this point that calibration is at its worst.

Traditional feedback research has been directed narrowly to the effects of feedback on achievement. The Butler and Winne (1995) model is a bridge allowing us to combine diverse studies on feedback, self-regulation, and instruction in such a way that future researchers have a schema for integrating instruction, self-regulation, feedback, and knowledge construction.

Recent research has included the study of the interaction of cognitive styles with varying levels of feedback in multimedia (Khine, 1996), the use of student-to-teacher feedback in Web-based courses (Hazari & Schnorr, 1999), the examination of varying types and uses of tutor feedback (Anderson, Benson, & Lynch, 2001), and the use of global and local feedback in relationship to motivation and anxiety in students (Wiltse, 2001).

In specialized areas of feedback research, metacognitive feedback in SRL resulted in improved performance in mathematical reasoning and explanations. Metacognitive feedback was based on SRL using metacognitive questions that served as cues for understanding math problems (Kramarski & Zeichner, 2001). In self-directed learning in a Web course, elaborative feedback was found to be more valuable to students than just knowledge of a score (Cennamo & Ross, 2000). And in a distance learning course designed for the development of higher-level cognitive skills, evaluation is described as feedback, and not a performance measurement, and, as such, must be diagnostic and prescriptive, be formative and iterative, and involve peers and group assessment (Notar, Wilson, & Ross, 2002).

29.8 ADVANCES IN TECHNOLOGY

The development of the microcomputer and its use for instruction has been perhaps the most important technology for allowing for adaptive feedback. Unlike many technologies of the past decades, the computer opened a door to interactivity, the precise recording of student response information, and the ability to adapt feedback and instruction to the changing needs of the learner within the interactive environment almost instantaneously.

Further, developments in the use of multimedia and hypermedia open a vast set of questions for researchers to consider. For example, how does feedback function when presented via different modes of sensory input? Multimedia PCs common today involve the use of both auditory and visual stimuli to aid learning. What was once possible only through the integration of specialized media such as the interactive laser disc now becomes more commonplace as newer technologies such as CD-ROM and DVD become increasingly common and available. Hypertext and hypermedia designs await the learner using today's interactive CD software, with icons and "hotwords" linking vast amounts of information in the form of text, pictures, animations, and sounds.

A common problem with such open hypermedia environments is that learners often get lost along their exploratory way, unaware of how they were taken to the point at which they now rest. Navigation is just one of many variables to consider when examining such complex environments. Search (1994) suggests that if the communication potential of hypermedia is to be realized designers must develop interfaces with orientation cues that help users navigate through large, multimedia databases. As she phrases it, "Hypermedia computing is a temporal medium in which spatial relationships change dynamically, leaving the user with few references for orientation" (p. 369).

To understand adequately how the nature of computer-based learning has evolved, it is helpful to consider how differently it was utilized in the 1960s compared with how it is used now for interactive computer-based instruction, hypermedia environments, simulations and microworlds, and Web-based instruction (WBI). Jonassen (1993) notes that even early CAI was merely programmed instruction delivered on a computer. The evolutionary path unfolded from programmed instruction, computer-based drills and tutorials, adaptive tutorials, and simulations. An important conceptual framework for hypertext and hypermedia environments is presented by Jonassen (1993). The growth of hypertext, hypermedia, and multimedia since the 1980s has provided designers with the capabilities necessary to develop complex, content-oriented learning environments. To make such large quantities of information more accessible, a variety of conceptual models is being "mapped" onto these environments. The subsequent rapid expansion of information connectivity of the Internet during the 1990s has provided designers with the capabilities necessary to develop complex, content-oriented learning environments.

As Jonassen (1993) so aptly described it,

> Recent advances in learning theory have fueled a more rapid and extensive revolution in computer-supported learning systems. Rather than using the computer as a delivery vehicle for displaying and purvey information, generative learning systems and knowledge construction environments are designed to form partnerships with learners/users, to distribute the cognitive load and responsibility to the part of the learning systems that performs the best. Learners are engaged by these environments because their intellectual involvement in the learning process is essential. They are no longer passive recipients of information . . . they are actively involved in knowledge construction and meaning making. The computer's computational functionality is being used to support those processes rather than to present information. (p. 332)

The open architecture of hypermedia and multimedia has made them the platform of choice for implementing such knowledge construction environments. The computers of the future will function as "intellectual toolkits for enhancing the intellectual and perceptual capacities of humans" (p. 333).

A useful framework for designing feedback by incorporating the powers of emerging instructional technologies to present, manipulate, control, and manage educational activities has been proposed by Hannafin et al. (1993). They point out that emerging technologies provide the potential for a dramatic range of varied feedback not possible or practical before.

Feedback design helps in the ability to present information and support encoding. The range of presentation dimensions includes visual, verbal, sensory, and multiple modalities. To optimize both individual processing capabilities and technological potential requires an expansion of our notion of both feedback and technology.

According to Hannafin et al. (1993), emerging technologies have provided six major areas of improvement for instruction: adaptability, realism, hypermedia, open-endedness, manipulability, and flexibility. To design feedback effectively requires the psychological, technological, and pedagogical foundations of lesson design (Hannafin, 1989). The use of the World Wide Web as a delivery system and information database for on-line instruction has enhanced the computer's capabilities and connectivity dramatically.

29.8.1 Web-Based Instruction

The advances and growth in Web-based instruction have certainly changed the types of feedback mechanisms that are being actively used by students. WBI lends itself to a student-centered or constructivist approach that involves learner-to-learner interaction options and provides meaningful peer and instructor feedback (Dabbagh, 2002). The role of feedback in on-line teaching is critical for students' success in the on-line environment. Students have stressed that "they needed regular feedback to know how their performance was judged, how they could improve, and how their final grade was calculated" (Bischoff, 2000, p. 62). Effective elements of on-line teaching are known to include frequent and consistent on-line feedback, timely on-line feedback, diplomatic on-line feedback, and evaluative on-line feedback (Bischoff, 2000).

Schwartz and White (2000) emphasize the distinction between *formative* feedback, which modifies a student's thinking or behavior for the purpose of learning, and *summative* feedback, which assesses how well a student accomplishes a task or achieves a result for the purpose of grading. These researchers emphasize the importance of the need for on-line feedback to be (a) multidimensional, (b) nonevaluative, (c) supportive, (d) student controlled, (e) timely, and (f) specific. These equate to the following qualities that students expect from feedback in the on-line environment.

- Prompt, timely, and thorough on-line feedback
- Ongoing formative feedback about on-line group discussions
- Ongoing summative feedback about grades
- Constructive, supportive, and substantive on-line feedback
- Specific, objective, and individual on-line feedback
- Consistent on-line feedback

Others (Ritchie & Hoffman, 1997) suggest that there should be a relationship between descriptors and the links they represent by the use of a meaningful system. "A more meaningful system would be to use words such as 'definition,' 'example,' or 'nonexample' when teaching concepts or principles; 'definition' or 'mnemonic' when teaching facts; and 'shortest path' or 'alternative path' when teaching a procedure" (p. 137). They also recommend requiring students to make an informed choice among alternatives after engaging a segment of instruction. Another, more complex method of providing feedback uses CGI (Common Gateway Interface) codes to provide learners with detailed information and alternative choices. With such CGI scripts, information that students place in text fields, buttons, or check boxes can be compared to preset answers in a database or text file. This allows for feedback to provide students with a deeper explanation of the consequences of their choices, along with active links to guide them to additional information. The use of feedback in Web-based assignments is also discussed in detail in terms of pedagogical aspects of feedback, the frequent lack of feedback in on-line courses in higher education, and instructor support for feedback in a Web system by other researchers (Collis et al., 2001).

The use of dynamic Web databases opens up an extremely fertile area for both gathering student information that can be used to give individual feedback based on background variables, as well as providing specific feedback about various misconceptions or insights during on-line learning. Dynamic databases are currently being studied and implemented to facilitate collaboration, knowledge construction, and communication in on-line courses (McNeil & Robin, 2000a, 2000b).

Other emphases in on-line learning environments include the need for building on-line communities (Ravitz, 1997) and interactions in both synchronous and asynchronous modes (Vrasidas & McIsaac, 2000). Feedback can be used to help foster on-line learning communities and a feeling of "connectedness" through peer-to-peer interactions as well as student-to-instructor interactions. The type and the timing of such interactions in terms of synchronous and asynchronous are a ripe area for researchers to begin to study the effects of these communications in terms of feedback in the learning environment. Web-based learning opens the door for more of a constructivist view of learning and its implications for new ways of utilizing feedback (see also Mory, 1996).

Psychological foundations emphasize the role of the learner in processing inputs, organizing and restructuring knowledge, and generating responses. Particularly relevant are processing requirements, the role of prior knowledge, the role of active processing, and strength encoding (Hannafin et al., 1993, p. 272).

Technological foundations concern the capabilities of the actual hardware and devices for providing output, receiving input, and processing data. Emphasis is on input–output capability, symbol manipulation, and management. In many instances, technological capabilities far exceed human processing capacity. Therefore, what is most important is not what the outer limits of technology are but, rather, how to utilize those technological capacities (Hannafin et al., 1993).

Pedagogical foundations of design are rooted in beliefs about how to organize lesson knowledge, how to sequence activities in the lesson, and how to support the learner as he or she acquires knowledge. Many times pedagogical factors are identified during a needs assessment or front-end analysis and include the resources and constraints of learner, task, and setting characteristics (Hannafin et al., 1993).

As one might expect, even with emerging, high-profile technologies, distinctions of "good instruction, bad instruction" hold true (Hannafin et al., 1993). This includes the design of "good and bad" feedback within instruction as well. Research issues in the area of motivating students within the WBI environment have been examined by Song (2000), looking individually at the motivation to initiate, motivation to persist, and motivation to continue within such an environment. Song (2000) has identified motivational issues related to each area, and Song and Keller (1999, 2001) have suggested motivational adaptations in the area of CAI (detailed under *Motivation*). One can easily understand how results from the CAI studies (Song & Keller, 1999, 2001) could easily be transferred to the WBI environment.

29.9 RECOMMENDATIONS TO FUTURE RESEARCHERS

To summarize areas in feedback research that need further attention, this author offers the following suggestions.

1. Examine how feedback functions within a wider variety of learning domains. Higher-order learning such as concept acquisition, rule use, problem solving, and the use of cognitive strategies offers a rich source for researchers to explore.
2. Analyze individual learner motivations and attitudes and prescribe feedback based on factors such as tenacity, self-efficacy, attributions, expectancy, and goal structure.
3. Identify measurable variables that can reflect internal cognitive and affective processes of learners that might potentially affect how feedback is perceived and utilized.
4. Examine how feedback functions within constructivist learning environments and test new feedback strategies within these environments.
5. Examine the role of monitoring and how both external and internal feedback generation affects the learning from a viewpoint of self-regulation.
6. As technologies continue to advance, design feedback that utilizes the improved capabilities for instruction.
7. Continue to identify and test interactive patterns among the learner, the environment, individual internal knowledge construction, and varying types of feedback.

One could venture to say that no learning would occur unless some type of feedback mechanism was at work. What we do know is that feedback serves a critical function in knowledge acquisition, regardless of the particular learning paradigm through which we choose to examine it.

Although the study of feedback in instruction has a vast history and an ever-evolving set of variables of interest, researchers are challenged to go back and study further the complexities of feedback under the variety of models and conditions described here and in past reviews (Mory, 1992, 1996). There are many questions that have been left unresolved from older paradigms and theoretical views. And yet there is an ever-increasing need to consider how new technologies and views of learning change and impact the functions of feedback, its forms, and its dynamic potential for use in instructional settings. Future researchers are encouraged to consider past research variables, carefully, in combination with new pedagogical views of learning and changes in learning environments as technology continues to develop, as they seek to tease out how feedback is used by learners in various learning environments. Particularly as learning environments become more disparate in terms of time and space, feedback is going to be an increasingly complex and critical aspect of successful learning.

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