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ABSTRACT

The effects of four methods of immediate corrective feedback delivered by computer within a question-based concept and rule learning setting were investigated in this study. A second purpose of the study was to probe the complex relationship between types of corrective feedback and the types of errors made by learners. One hundred and fifty-three students enrolled in an undergraduate biology class for nonmajors were randomly assigned to one of four immediate corrective feedback conditions commonly used in computer-based instructional situations. The types of errors made by learners during instruction were analyzed and compared across groups. Dependent variables were achievement on a retention test, feedback study time, on-task achievement, and feedback efficiency. An adaptive design template, the rational set generator, was applied in the design and delivery of instruction. Results indicated the group which received simple knowledge-of-correct-results feedback used significantly less feedback study time and was more efficient than any other condition. Consistent with prior studies, the adaptive design strategy overcame differences in retention which may have been observed with an instructional strategy using a fixed number of interrogatory instances. Learners who made fewer fine discrimination errors during instruction, however, scored higher on a retention test. As expected, a significantly higher number of fine discrimination errors were made on the retention test. An important finding of this study is that almost twice as much feedback study time was consumed for fine discrimination errors across all conditions. Results of data analyses are presented in 10 tables. (37 references) (Author/GL)

The Effects of Four Methods of Immediate Corrective Feedback on Retention, Discrimination Error, and Feedback Study Time in Computer-Based Instruction

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Running Head: Feedback, Retention, Discrimination Error, and Feedback Study Time

Abstract. This study examined the effects of four methods of immediate corrective feedback delivered by computer within a question-based concept and rule learning setting. A second purpose of the study was to probe the complex relationship between types of corrective feedback and the types of errors made by learners.

One hundred and fifty-three students enrolled in an undergraduate biology class for nonmajors were randomly assigned to one of four immediate corrective feedback conditions commonly used in computer-based instructional situations. In addition, the types of error made by learners during instruction was analyzed and compared across groups. Dependent variables were achievement on a retention test, feedback study time, on-task achievement, and feedback efficiency. An adaptive design template, the rational set generator, was applied in the design and delivery of instruction.

Results indicated the group which received simple knowledge-of-correct-results feedback used significantly less feedback study time and was more efficient than any other condition. Consistent with prior studies, the adaptive design strategy overcame differences in retention which may have been observed with an instructional strategy using a fixed number of interrogatory instances. Learners who made fewer fine discrimination errors during instruction, however, scored higher on a retention test. As expected, significantly higher number of fine discrimination errors were made on the retention test. An important finding of this study is that almost twice as much feedback study time was consumed for fine discrimination errors across all conditions.

The development of mechanisms that seek to optimize a learner's acquisition and retention of intellectual skills is a central issue of computer-based instruction (CBI). One of the most commonplace techniques to achieve this goal to provide immediate corrective feedback after a learner has incorrectly responded to a question.The focus of this study was to examine the effects of four methods of immediate corrective feedback delivered within a question-based, concept and rule-learning environment. A second, perhaps more important purpose was to probe the complex relationship between types of corrective feedback and the types of errors made by learners during computer-based instruction and, later, during a retention test.

The research literature is highly inconsistent in the use of the term immediate feedback. For example, some studies refer to immediate feedback as that received at the end of an instructional session (e.g., Wager, 1983). From the practitioners point of view, however, immediate feedback delivered by the computer may be defined as informative, primarily corrective information given to a learner or examinees as quickly as the computer's hardware and software will allow. From this assumption, Dempsey & Wager (1988) have described several forms of immediate feedback including the item-by-item feedback used in the present study.

In discussing feedback literature, one would naturally consider the many feedback studies conducted using programmed instruction. As Anderson, Kulhavy and Andre (1972) have demonstrated, however, much of what would have been helpful in programmed instruction literature related to immediate corrective feedback, is simply not usable because of the high presearch availability present during many of these experiments. Possibly as a reaction of cognitive researchers to techniques ascribed to behavioral psychologists or the possibility of making pioneering breakthroughs in the less familiar area of delayed instructional and testing feedback, there has been a shortage of research about immediate feedback in the last fifteen years.

Paradoxically, during the same period, immediate feedback delivered by computer has blossomed. The conclusions of many computer-based feedback studies, however, are limited in their usefulness. Frequently, affirmative and corrective feedback are studied together instead of separating this obvious dichotomy. Often, no attempts were made to monitor the number of error responses made during the instructional treatment. In many cases, delayed posttests were not employed, so readers were unable to judge the extent to which various feedback methods reduce forgetting. Perhaps most serious of all is the implied assumption that results may be generalized to any learning situation or any learning outcome.

Another of the several weaknesses in the literature concerned with feedback and computer-based instruction is the fact that experimenters to date tend to concentrate on feedback related to testing instead of instruction (Kulik & Kulik, 1988). Even fewer researchers use the remarkable data-collecting powers inherent with computer-based instruction to observe the on-task effects of corrective feedback on achievement and efficiency.

The authors chose to concentrate on knowledge-of-correct-response feedback in this study for two reasons. The first is the proliferation of this type of feedback in computer-based instructional texts and development activities. The second is that studies in the available literature concerning text-based immediate corrective feedback often have found that feedback providing the correct response (KCR) was superior to simple knowledge of results feedback (KR), and both were superior to no feedback (Travers, Wagenen, Haygood, & McCormick, 1964; Gilman, 1969; Roper, 1977; Waldrop, Justin, & Adams, 1986).

Accepting that KCR feedback has utility, other questions are raised by practioners on a regular basis. Is it worth the expenditure of scarce instructional resources to develop elaborated feedback? Should corrective feedback require the learner to try again before the computer relays the correct answer? Should the learner who has made an error and is informed of the correct one be forced to type in the right answer before proceeding in the program?

Certainly, there has been much pedagogical and some empirical support for elaborated feedback. Three of the studies mentioned above (Gilman, 1969; Roper, 1977; Waldrop et al., 1986) all supported elaborated feedback to some extent. Others, notably Kulhavy, White, Topp, Chan, & Adams (1985) have found that simple KCR feedback actually yielded higher error correctability than elaborated feedback. The later study, of course, is an obvious contradiction of the practices suggested in many instructional software development texts.

A similar practice used as a convention in much instructional software is to require the learner to try again after making an error. Unfortunately, there is little controlled empirical investigation to support or deny this practice. One study by Noonan (1984) which did explore "try again" feedback found that giving knowledge of results with an explanation and a second attempt was no more effective than giving simple KCR feedback and moving on to the next question.

Another common debate in computer-based instruction concerns whether or not students should be required to make overt responses after an error. Some writers (Siegel & Misselt, 1984; Wager & Wager, 1985) suggest an overt response is unnecessary unless the student is forced to make a connection between the correct answer and the question. Other educators assume that overt responses after an error may assist learners to more actively process information. For example, a well-known study by Suppes & Ginsberg (1962) supports the use of overt correction responses while another by (Tait, Hartley, & Anderson, 1973) failed to confirm that active (overt response) feedback would be more beneficial to learners than passive feedback. Hundreds of CBI modules uniformly espousing both philosophies are available in the marketplace.

Based on our review of the literature and on our prior studies (e.g., Driscoll & Dempsey, 1987), we expected no real differences in retention as a result of type of KCR feedback in an adaptive delivery system such as that used in the present study. Adaptive instruction is designed to account for deficiencies in learners and provide additional practice where practice is needed

(Dempsey, 1986; Litchfield, Dempsey, & Driscoll, 1988). This effect alone should be expected to collapse detectable differences in retention among different types of feedback.

On the other hand, we did expect that different types of feedback would require a varying expenditure of feedback study time. That students spend less time in reading and processing simple KCR feedback than more complex feedback forms, was both logical and supported by recent feedback literature (e.g., Spock, 1987). Likewise, we hypothesized that simple KCR feedback would be more efficient in terms of retention test yield per unit of feedback study time invested compared to more complex forms of feedback. This hypothesis was consistent with the above mentioned study by Kulhavy, et al (1985) involving feedback and computer-based instruction. From a practical perspective, this was particularly important considering the time it takes to develop complex feedback forms and the possibility that complex feedback interferes proactively to some degree with the acquisition of concepts and rules (Kulhavy, 1977).

Although the research in concept and rule learning has been questionable in its support the use of elaborated feedback, little attempt has been made to monitor the number and patterns of error responses during instruction comparing different types of feedback. Elaborated feedback has shown promise in clearing up discrimination errors when anticipated wrong answer (AWA) feedback was provided in verbal information tasks (Siegel & Messelt, 1984). Therefore we felt the number of error responses made during actual instruction would be least for subjects who received elaborated (KCR + AWA) feedback than for any other feedback condition.

A conscious venture in this study concerned the connection between the type of error made by learners and the degree of effort made by learners when confronted with information regarding their errors. Print-based studies by Driscoll and Tessmer (1985b) and Tessmer and Driscoll (1986) have suggested that the adaptive matrix template used in this study, the rational set generator, may be used reliably to predict fine and gross conceptual error. The rational set generator (Driscoll &Tessmer, 1985a) is a mechanism that incorporates multiple interrogatory examples of concepts and rules and provides for discrimination and generalization learning. We expected that learners would make a higher number of incorrect answers that were predicted to be fine discrimination errors than gross discrimination errors on a retention test regardless of the type of feedback. Discrimination error here refers to distinctions among examples and nonexamples as opposed to simple distinctions between same and different.

In the same vein, we posited that learners who made fewer fine discrimination errors during instruction would perform better on a retention test than learners who made more fine discrimination errors during instruction. Because fine discrimination errors typically occur with close-in nonexamples (Markle & Tiemann, 1970), we reasoned that learners who made fewer of these types of error may have a lower "fog index." This would indicate errors which were more typically overgeneralization and, less so, of outright misconception. Thus, learners who exhibited less of an inclination to make fine discrimination during instruction errors were predicted to classify correctiy a greater number of examples of concepts or rules in the future. Typically, a given response is judged in a dichotomous fashion. That is, the response is either right or wrong. For sophisticated learners this dichotomy is counterintuitive. In the first of eight "empirical generalizations", Ammons (1956) proposed that learners form hypotheses which interact with knowledge of performance. Studies by Kulhavy, Yekovich, and Dyer (1976, 1979) have suggested that learners make answer choices based on a hierarchy of confidence of response. According to their model, high confidence errors yield the longest study time, correct answers the lowest, and low confidence incorrect answers fall somewhere in between. Kulhavy and his associates support the notion that students expectancy for success is related to the amount of time students spend in studying feedback.

In linking fine and gross discrimination errors made by learners to the degree of effort exerted when confronted by corrective feedback, we also felt the amount of feedback study time expended would play an essential descriptive role. Dissimilar patterns in corrective feedback study time are important because they have the potential to act as systematic indicators of the amount of time students expend effort in correcting classification errors. Because, to our knowledge, no other studies have used content analysis to predict the effects of fine and gross discrimination error on feedback study time, we honestly could not agree on the interplay of these types of errors and the amount of effort expended studying feedback. Kulhavy and his associates' model clearly points to fine discrimination error as a high confidence error type. Conversely, the work of Markle and Tiemann (1971), postulates that gross discrimination error is related to both undergeneralization and misconception. We wondered if gross discrimination error could infer a sense of "false confidence" which would subsequently arouse learners' curiosity about their mistakes. Examining the effects of fine and gross discrimination error on the amount of effort expended studying feedback then, provided a final objective of this study.

In summary, the specific research questions that we attempted to answer are stated below:

1. Do differences in retention actually result from using different types of KCR corrective feedback?

2. How would the four types of KCR feedback measure up against each other considering the amount of feedback study time expended during instruction?

3. Would simple KCR feedback be more efficient in terms of retention test yield per unit of feedback study time invested?

4. Are there differences in the number of errors made during instruction itself as a result of using one feedback method or another?

5. Would learners make a higher number of incorrect answers predicted to be fine discrimination errors than gross discrimination errors on the retention test?

6. Can the number of fine discrimination errors made during instruction be used as a predictor of retention test performance?

7. Would errors of either fine or gross discrimination cause learners to increase the amount of effort (study time) expended when confronted with corrective feedback?

Method

Subjects and Design

The subjects in this study were 153 undergraduate university students (mostly freshmen and sophomores) enrolled in a biology class for nonmajors. Descriptive information (age, sex, major, year in school, and familiarity with the topic area) was collected before each student began instruction. Slightly more than twice as many females as males participated in the study. Most students felt "somewhat familiar" with the topic. The class was required for approximately two-thirds of the students.

Subjects were randomly assigned using a posttest-only factorial design to one of four immediate corrective feedback conditions: (1) knowledge of correct response only (KCR); (2) knowledge of correct response and forced correct response (KCR + Forced CR); (3) knowledge of correct response and anticipated wrong answer remediation (KCR + AWA); (4) knowledge of correct results and a second try to respond to the item (KCR + Second Try). To provide for baseline data from which the degree of learning could be inferred, a no-treatment comparison class (n=25) received classroom instruction on the topic and the retention test, but did not receive the adjunct instruction used in this experiment.

Consistent with many studies in this area, Alpha was set at .05. For the first research question considered in this study, however, we expected a failure to reject the null hypothesis. The danger of accepting Ho when it is false (Type II error) is higher when the null hypothesis is expected. Accordingly, Alpha was set to .10 for this one research question only. We used Cohen's (1969, p. 383) convention and set Beta at 20 (Power =.80). Cohen's tables were again referred to in setting the effect size to .30 (df = 3).

Learning Materials and Instrumentation

Instructional Module. The subject matter being taught in this study was concerned with substance abuse and chemical dependency. This module was part of a regularly scheduled general Biology laboratory for nonmajors which took place at different times during during a two-week period. Selected concepts and rules on the topic area were chosen to be delivered on the PLATO computer system. An instructional design strategy, the rational set generator, was applied in the design and implementation of the module.

The objectives for the computer-based lesson were developed by the two investigators and three subject matter experts. The actual modules were written by two biology subject-matter experts. The interrogatory instances consisted of four adaptive rational set generator matrices which focused on (1) Parts of the Brain -- six concepts X four levels of generalization difficulty; (2) Types of Drugs -- four concepts X four levels of generalization difficulty; (3) Effects of Drugs on the Nervous System -- four rules with four levels of generalization difficulty; (4) Alcohol Use and Abuse -- four rules with four levels of generalization difficulty. The levels of generalization difficulty of the interrogatory instances were established by formulae designed by Litchfield (1987) involving the number of constant and variable attributes of the concept or rule.

Subjects in the rational set generator matrices responded to various levels of questions depending on their on-task performance. That is, subjects who answered a question incorrectly would transverse to a subordinate level. In contrast, subjects who responded correctly on the first try would progress to a superordinate level. Presentation of concepts or rules in a given rational set were random within a specific level. To discard a particular instance in the adaptive instruction, subjects were required to respond correctly to the instance on the first try. To complete the instruction for any particular matrix, subjects were required to discard all interrogatory instances on the most difficult level. A sample interrogatory instance illustrating the four feedback conditions is shown below:

In her laboratory experiments, Jane isolated an unknown substance from an azalea plant. She noticed when she injected this substance into laboratory rabbits, their tolerance to heat increased. What might be occurring in the nervous system?

a. binding of the postsynaptic receptor sites

b. enhanced secretion of excitatory neurotransmitters

c. enhanced secretion of inhibitory neurotransmitters

d. increased amount of neurotransmitter substances

Feedback:

CA: That's it!

KCR: No. The correct answer is binding of the postsynaptic receptor sites.

KCR + FORCED CR: No. The correct answer is binding of postsynaptic receptor sites. Type the letter of the correct answer to continue.

KCR + AWA: No. the correct answer is binding of the postsynaptic receptor sites.

(if b) Enhanced secretion of excitatory neurotransmitters would cause decreased appetite.

(if c) Enhanced secretion of inhibitory neurotransmitters would cause drowsiness.

(if d) Increased amount of neurotransmitter substance would produce hallucinations.

KCR + Second Try: No. Your response was incorrect. Try again.

(2nd try) No. The answer is A -- the binding of the postsynaptic receptor sites.

Retention Test. The retention test was a 24-item, paper-based, domain-referenced test constructed using a rational set generator matrix. The 24 items were chosen from either of two matched 18-item retention tests from a prior study involving the same content and a similar population of students. KR-20 coefficients from these tests were r = .71 (form A) and r = .69 (form B). The KR-20 for the resultant 24-item test, which was administered to students who received the instructional treatment as well as those who did not, was r = 66.

The difficulty levels of the testing matrix were arranged by calculating the percent of students who correctly answered each item on the previously mentioned study. The mean retention percentage score of the resultant retention test was predicted to be 77.5%. Presentation order of each item was decided using a random number table. Each item of the retention test was reviewed to assess content validity by the five members of the research and development team and several Biology Department graduate teaching assistants. Because students were graded on their performance on the retention test, three forms of the test were constructed to increase security. Each form of the test was actually identical except for the order and the proper names of the individuals described in the interrogatory instances which composed the stimuli.
A sample test item is shown below:

> Doreen had a severe headache and took a pill she found in her roommate's pill box. In about an hour she saw the rug turn green and orange. She looked outside and saw little cartoon characters coming up the street. What was happening in her nervous system?

a. increased secretions of inhibitory neurotransmitters
b. binding of receptor sites
c. abnormally high levels of neurotransmitters in the synapses
d. increased secretions of excitatory neurotransmitters

Feedback Study Time. This measure was collected by the computer during instruction for each cell of all matrices. Feedback study time is the elapsed time from the moment when response-contingent feedback is first presented on the computer screen until the learner presses the appropriate key to view the next item (i.e., the next cell in the matrix).

Feedback Efficiency. This technique was similar in terminology and somewhat similar in methodology to one used by Kulhavy, et al. (1985). Feedback efficiency was computed by dividing the correct retention percentage score by the square root of feedback study time.

Discrimination Error. Fine discrimination errors are those related to close-in nonexamples of a concept or rules (Markle & Tiemann, 1970). Gross discrimination errors are related to far-out nonexamples. Fine and gross discrimination errors were determined using a two-step approach: the predictive capability of the rational set generator model and student performance data. First, one of the authors of the instruction predicted the relative probability of making discrimination error for each nonexample by considering the content relationships among concepts and rules in a particular rational set matrix (e.g., critical and variable attributes, as well as perceived familiarity). Second, during a pilot study, the author's prediction was compared to actual student responses and, where necessary fine and gross distractors were adjusted slightly to reflect discrimination error trends.

Procedure.

Classes were chosen to participate in the experiment by the Biology Department on the basis of their schedules and the the willingness of their instructors to become involved in the experiment. Instructors were requested on more than one occasion to avoid biasing their classes with their opinions (either positively or negatively). Instructors were not informed about the exact nature of the experiment but were informed of the general goals of the instructional program. Additionally, they were given the opportunity to view the instructional module if they so desired.

Printed information to be read to students was given to each instructor so that all students received identical instructions. Additionally, each instructor received a quantity of printed instructions to be given to each student concerning the sign-on on procedures and use of the computer for the instructional module.

Two hours of regular class time were devoted to expository instruction on the module topic. Prior to the classroom session, students were assigned to read a 12-page chapter on the topic of substance abuse in a required text written by members of the Biology Department.

The computer-based assignment was completed in a two-week period subsequent to the classroom lecture. To participate in the instructional treatment, students located an unoccupied terminal at one of the several public access locations on campus and used the printed instructions they had been given to "sign-on" to the system. From that point on, the students were given instructions by the computer program. To complete the computer-based program, students responded on-line to a demographic questionnaire and matrices of questions pertaining to substance abuse. Additionally, an eight-item semantic differential scale based on Ross (1984) was administered to subjects in order to determine their attitude toward the software program.

A paper-based retention test and qualitative questionnaire were given during the next regular class following the 14-day period in which the computer-based instructional module was available.

Results

Retention Test Performance

Table 1 presents the means and standard deviations for retention test performance for the four treatment groups. Sample statistics, which were calculated for all matrices, showed similar trends. A 1 X 4 analysis of variance on this data revealed no appreciable differences in retention among the four feedback conditions [$F(3, 152) = .69$, $p = .555$]. This result suggests superior performance on a retention test cannot be attributed to the type of KCR corrective feedback supplied to the learner.

Insert Table 1 About Here

Feedback Study Time

The mean feedback study times for the four experimental groups are shown on Table 2. As expected the mean feedback study time for simple KCR feedback is much lower than the other conditions. One apparent problem may be observed in Table 2: the large standard deviations of each group. In this study, feedback study time was gathered for corrective feedback only. Therefore, a subject who did very well during instruction would have a low feedback study time recorded. Conversely, a subject who needed more instructional support would have made many incorrect responses and therefore would have a much larger feedback study time.

Insert Table 2 About Here

In an attempt to understand this phenomena better and isolate previously unexplained outliers, an SPSS technique referred to as LIST CASES was employed. In columns next to each subject's social security number, the data for the experimental group, total attempts, total feedback study time, and number wrong was printed. A visual explanation of this data revealed that large variances in feedback study time had plausible explanations within the varying performance c. _acteristics of an adaptive instructional system.

Results of the overall analysis of variance of feedback study time for the four treatment groups show significant differences among groups [$F(3, 152) = 16.?7$, $p < .001$]. Because of the irregularity in variances, a Hartley test for homogeneity of variances was performed. The computed H-value of 7.85 was greater than H (.05, 4, 41) = 2.44. Therefore, the decision was made to reject the null hypothesis of equal variances. As one would expect from viewing the sample statistics, this finding revealed a violation of the equal variances assumption. Nevertheless, when sample sizes are approximately equal, F-tests are usually considered robust enough to assume the tests discussed here are not affected by the departure from the assumption of homogeneity of variances.

Feedback Efficiency

The third research question we proposed concerned whether simple KCR feedback was more efficient in terms of retention test yield per unit of feedback study time invested. Because feedback efficiency was a computed variable (i.e., feedback efficiency = retention score ÷ feedback study time) the problems mentioned above with using corrective feedback study time would have contributed to a more severe departure from a normal distribution. Therefore, feedback study time was transformed in analysis by using the square root of each observation analysis rather than the original values according to a method suggested by Iversen & Norpoth (1987).

Overall means and standard deviations of feedback efficiency for the four treatment groups are shown on Table 3. The sample statistics suggest the simple KCR group was most efficient followed by the KCR + AWA group, the KCR + Forced CR group, and the KR + Second Try group respectively.

Insert Table 3 About Here

An analysis of variance indicated significant differences among the means when retention test score is considered in relation to feedback study time [$F(3, 152) = 14.66$, $p < .001$]. A susequent comparison between the simple KCR and KCR + AWA, however, did not quite reach significance [$\underline{t}(152) = 1.89$, $p = .06$].

Error During Instruction

Another research question concerned the number of errors made during instruction. Means and standard deviations of the number of incorrect responses made during instruction for the four feedback groups are shown in Table 4 . Little difference may be observed between the overall means of the four treatment. Although the differences are slight, the KCR + AWA group actually made more errors than any other group. Put differently, using different methods of feedback made no real difference in the number of errors students made during instruction.

Insert Table 4 About Here

A specific research question was not formulated concerning efficiency of feedback during instruction itself. Even so, it seemed useful to determine if this general pattern of feedback efficiency were applicable in a like manner to the process of learning and the performance of learned skills on a retention test. For this reason a post hoc analysis was performed using an additional dependent variable: efficiency of feedback during instruction only. This variable was computed by dividing the number of correct answers during instruction by the number of attempts to correctly answer each question times the amount of feedback study time. Descriptive statistics are presented in Table 5. Once again, the pattern for feedback efficiency during instruction only is similar to that of feedback efficiency computed using a retention test score.

Insert Table 5 About Here

Discrimination Error and Retention

Our fifth research question was concerned with whether or not learners would make a higher number of predicted fine discrimination errors on the retention test. Sample statistics disclosing the means and standard deviations of fine and gross discrimination errors for the four treatment groups are shown in Tables 6 and 7.

Insert Tables 6 & 7 About Here

Results of a t test confirm that the difference in the number of predicted fine and gross discrimination errors was significant [$t(152) = 14.92$, $p = .001$].

We also questioned whether the number of fine discrimination errors made by learners during instruction itself may be used as a predictor of retention test performance. After determining the mean number of fine discrimination errors for the instructional module, learners were split into two groups: those who made fewer than average number of errors of fine discrimination and those who made greater than average number of errors. The retention test scores of these two groups were then analyzed. The overall means and standard deviations of retention test performance for learners who made fewer and greater than average fine discrimination errors during instruction are presented in Table 8.

Insert Table 8 About Here

An analysis of variance of these two conditions was significant [$F(3, 167) = 5.02$, $p < .05$], although the reader should be cautioned to observe the unequal N-sizes in the two groups.

Discrimination Error and Feedback Study Time

A final experimental question considered whether errors of fine or gross discrimination would cause learners to increase the amount of effort (study time) expended when confronted with corrective feedback. Overall means and standard deviations for feedback study time of both fine and gross discrimination errors during instruction are presented on Tables 9 and 10 .

Insert Tables 9 & 10 About Here

As these results suggest, combined feedback study times for fine discrimination errors were, on the average, almost twice as long as those for gross discrimination. A two-tailed t-test confirmed that these differences were significant [$t(168) = 8.29$, $p < .001$]

Student Opinion

A 16-item paper-based opinion questionnaire was administered to students after they took the retention test. Most of the questions pertained to support and process variables specific to the university's Biology Department. Three items on this questionnaire, however, concerned immediate feedback (128 respondents).

The first of these queried learners about their feelings toward immediate feedback. Most (60%) responded that it helped them learn more.

A second question asked learners to choose which statement concerning immediate feedback was most true for them. The largest percentage of learners (46%) responded that it satisfied their curiosity about whether the answer was correct. Thirty-three percent of the learners felt that it helped them learn information more quickly, Only 13% replied that it encouraged them when they got the correct answer. Even fewer learners (7%) answered that feedback was helpful, but could wait to the end of the lesson.

Lastly, learners were asked which feature of the computer-based assignment was most helpful. The most frequent response to this question (29%) was immediate feedback. A close percentage of learners (26%) felt it was working at their own pace. Twenty-two percent responded that being able to see the question more than once was the best feature.

No significant differences existed among the four experimental conditions for any of these questions.

Semantic Differential Scale

An eight -item semantic differential scale (Ross, 1983; Litchfield, 1987) was administered immediately after the instructional treatment. This instrument was implemented to assess learners' attitudes toward the instruction. It was felt that use of this scale immediately after instruction would have been useful in interpreting outcome differences among groups if differences were found. Subsequent analysis resulted in no significant differences among groups as a result of feedback type on any item on the scale.

Overall Effectiveness of the Adjunct Instruction

A problem with some instructional experiments is that they may record significant findings but fail to teach anything. Because students' grades, regardless of feedback condition, were dependent in part on the effectiveness of our instruction, we believed it was important that we gather some indication of the usefulness of the computer-based material presented.

A discrimination index (Hoffman, 1974) of each of the the 24 retention test items was conducted by comparing baseline scores of a class (N=22) of General Biology students who did not participate in the experiment with the retention test scores of all students who completed the experiment regardless of treatment. These calculations were intended to give an indication of how well each test item discriminated masters from nonmasters. The overall mean for the baseline (pretest) was 55.30 percentage points. The overall mean retention test score for students receiving one of the four instructional treatments was 77.88 percentage points.

Finally, the overall mean retention score for a separate no-treatment class (N=22) of students who completed the classroom instruction but did not receive adjunct computer-based instruction was 63.49 percentage points. As mentioned in the preceding paragraph, the mean retention test score for students (N=153) receiving one of the the treatment conditions was 77.88. This is less than four-tenths of a percentage point deviation from the mean retention test score predicted before the experiment.

Discussion and Implications

This study was a seminal attempt to explore the complex relationships among types of corrective feedback, concept and rule learning, feedback study time, and types of error made by learners. To provide a context for considering the outcomes of this experiment, the discussion section will first discuss the seven specific research questions we attempted to answer. In conclusion, we will offer practioner guidelines for enhancing the value of corrective feedback in learning concepts and simple rules with computer-based instruction.

Type of Feedback, Retention, Feedback Study Time, and Feedback Efficiency

The results of this study do support, to some extent, our hypotheses concerning retention, feedback study time, and feedback efficiency as a function of type of feedback.

As predicted there were no significant differences on the retention test as a result of type of feedback alone. This may even be an understatement (see Figure 1). The dearth of well-structured research studies which find differences in test performance as a result of using one type of knowledge of correct response feedback or another seems especially predictable in an adaptive environment. The findings of this study are consistent with what should be expected: the effect of presenting a varying number of instances based on learner needs overcomes any differences in retention which may have been observed with a fixed number of interrogatory instances. Although this finding may not be generalized without reservation to nonadaptive environments, there would appear to be no reason to believe learners will improve retention of concepts or simple rules by using one form or other of knowledge of correct response feedback.

Insert Figure 1 About Here

With few exceptions, more complex forms of feedback have shown no increase in performance over simpler forms of KCR corrective feedback. A number of the studies which have shown complex forms to be more effective could be been criticized for using only immediate posttest measures and have been inconclusive in other ways. In addition to being unsupported as a universal prescription, complex forms of feedback increase the resources needed to develop, deliver, and learn from computer-based instruction.

Our second research question attempted to verify the prior work of Kulhavy et al. (1985) and Spock (1987) in the context of four commonly-used types of corrective feedback. As Figure 2 illustrates, there were large difference in feedback study time for the four feedback groups. As expected, simple KCR feedback consumed much less feedback study time than any of the other feedback conditions.

Insert Figure 2 About Here

Kulhavy and Anderson's (1972) perservation-interference theory has proposed that the memory of incorrect responses made during acquisition interferes with the learning of new correct responses during feedback. Interference may be reduced if the learner is given a chance to forget their incorrect responses. Although we do not believe that delays in delivering feedback in an concept and rule learning instructional environment are helpful (Kulik and Kulik, 1988), there is reason to speculate that complex forms of feedback may even interfere with retention.

For example, in a pilot study (N = 53) related to the present experiment, we compared three simpler forms of KCR corrective feedback with a complex feedback condition which we hoped would assist students in concentrating on the correct response. Students were told the correct answer and and then moved to a "help" screen which required them to choose from among several explanations explaining why the correct answer was correct. The text of the interrogatory example remained on the screen for the simpler feedback conditions but did not for the "correct answer help" feedback condition. Students in this more complex feedback condition actually scored 10 percentage points lower on a retention test than any of the other feedback conditions. This pilot data would support Kulhavy, Yekovich, and Dyer's (1979) position that learners provided with corrective feedback rescan the question text in order to locate the source of error.

Clearly, based on the findings regarding our third research question, complex forms of feedback are also less efficient. Although the difference between simple KCR feedback and anticipated wrong answer did not quite reach significance in terms of retention test yield per unit of feedback study time invested (p = .06), simple KCR was far more efficient than the other complex forms. Considering the time it takes to develop anticipated wrong answer feedback particularly, the results of this study would imply that instructional developers teaching concepts and simple rules could better expend scarce resources increasing the quality and quantity of interrogatory examples and nonexamples.

Of course, there is a danger of ignoring other areas of inquiry by overgeneralizing. For example, it would be unfair to apply the findings of this study in deciding whether to have the learner supply her own feedback. This study does offer evidence that within an adaptive environment, simple knowledge of results functions very efficiently.

Type of Feedback and Error During Instruction

Our fourth research question was an attempt to find out if there were differences in the number of error responses made during instruction as a result of using one type of feedback or another. As we mentioned before, anticipated wrong answer feedback has been effective in overcoming discrimination errors in verbal information tasks (Siegel & Messelt, 1984). In addition, it made sense intuitively that learners provided with more elaborated feedback would require less instructional support during instruction itself. Good teachers do it in the classroom. Many instructional software texts recommend it.

Although the differences were not significant, subjects in the elaborated feedback group made more errors during instruction, not less. Of course, subjects in all groups participating in the computer-based instruction varied in the number of number of correct responses and interrogatory instances they encountered. These differences, however, were within groups and were a function of on-task performance, not type of feedback. In addition, a post hoc analysis of feedback efficiency during instruction only suggests a similar pattern to feedback efficiency where retention is considered. It would appear from this analysis that simply being informed of the correct response and receiving appropriate interrogatory examples which promote discrimination and generalization learning are the important corrective factors during adaptive instruction, not the form of the KCR feedback.

Discrimination Error and Retention

We expected that learners would make a higher number of incorrect answers that were predicted fine discrimination errors than gross discrimination errors on a retention test regardless of feedback type. Learners made far more predicted fine discrimination errors. Results confirmed prior findings using paper-based instructional materials (Driscoll & Tessmer, 1985b; Tessmer & Driscoll, 1986) and endorses the use of the rational set generator as a method of anticipating specific types of discrimination error in concept and rule learning tests.

A related question concerned whether fine discrimination errors made during instruction could be used as a predictor of retention test performance. As predicted, learners who made fewer fine discrimination errors during instruction did scored significantly higher on the retention test. This finding encourages analysis of close-in and far-out examples instructional nonexamples which result in fine and gross discrimination error as Markle & Tiemann (1971) have proposed.

An analysis of predicted fine and gross discrimination errors differentiated by the authors of the instruction with data collected during this experiment showed fine discrimination errors accounted for 41.75% of total errors during instruction and gross discrimination error accounted for 19.97%. In other words, four out of ten instructional errors were predicted fine discrimination. Two out of ten were errors of predicted gross discrimination.

The rational set generator matrix, a method employed in this experiment to provide for discrimination and generalization of concepts and simple rules, is a relatively simple instructional strategy to use (Driscoll & Tessmer, 1985a; Dempsey, 1986). With the accurate on-task data collection powers and transversal strategies available using a computer, instructional developers are offered an effective, straightforward technique for teaching and testing concepts and simple rules. Concept attainment is typically measured by a learner's ability to classify novel concept examples (Gagne, 1985). In light of findings regarding the lack of efficiency and effectiveness of using complex forms of KCR feedback in the present study and in prior experiments, employing a systematic method of presenting novel examples of concepts and simple rules seems all the more critical to good instruction.

Feedback Study Time and Discrimination Error

A final research question attempted to answer whether errors of fine or gross discrimination cause learners to increase the amount of effort (feedback study time) expended when confronted with corrective feedback. As Figure 2 indicates, fine and gross discrimination errors function quite independently of type of KCR feedback. Strikingly, feedback study times for fine discrimination errors were, on the average, twice as long as study times for gross discrimination errors.

Insert Figure 3 About Here

Feedback study time in this experiment is a direct measure of learners' time spent during instruction in reaction to telling students they had made an error and informing them of the correct response. From this perspective, we contend that feedback study time may be a useful measure of learners' effort expended as a result of error. Based on our experimental data, when appropriate content analysis is conducted, feedback study time may be used as a systematic indicator of the amount of effort students will expend in correcting classification error.

As we indicated, we were unsure of the effect fine and gross discrimination errors would have on students' effort in the face of error. No other studies we could locate have used content analysis to predict the effects of fine and gross discrimination error on feedback study time. Even so, the results of the present study strongly suggest that learners expend much more effort in correcting fine discrimination errors.

Kulhavy and associates (e.g., Kulhavy, 1977; Kulhavy, Yekovich, & Dyer, 1979; Kulhavy, White, Topp, Chan, & Adams 1985) have long contended that learners make answer choices based on a hierarchy of confidence of response. Accordingly, these researchers believe the degree of confidence a learner has in a particular response determines what benefit she will earn from it. Phrased differently, a learner presented with a question creates a hierarchy of confidence in alternative answers and choose the most probable answer. Errors on high confidence responses (i.e., those the learner expected to be correct) stimulate their curiosity and focus attention on an attempt to correct the error which, in turn, increases feedback study time.

It is tempting to view the effect of fine and gross discrimination error on feedback study time in the context of a learner's expectancy for success. Unfortunately, research in progress by Driscoll & Dempsey casts doubt on making an unrestricted assertion regarding discrimination error and confidence of response. This is not to say there is no relationship. We suspect there is. It may be, however, that the association between concept classification and expectancy for success is too complex to be modeled by cause and effect. Certainly, this is a rich area for future research.

What then, causes learners to increase the amount of feedback study time expended when they make fine discrimination errors? We mentioned our support of other researchers' contention that learners confronted with corrective feedback rescan the question text in order to locate the source of error. Fine and gross discrimination errors are particular types of concept classification errors isolated through content analysis. The literature associated with concept learning has established the existence of critical and variable attributes of a concept (e.g., Merrill & Tennyson, 1977). Critical attributes are those that are essential for determining membership in a particular concept class. Variable attributes are shared by some, but not all, member of a class of concepts. In addition, Markle & Tiemann (1971) have isolated three kinds of concept classification errors. Overgeneralization occurs when the learner classifies a noninstance as an example of a concept. Undergeneralization ensues when a learner classifies examples of a concept as nonexamples. Misconception errors combine both undergeneralization and overgeneralization. Markle and Tiemann have suggested that fine discrimination error is related to overgeneralization and misconception. Whereas, they have linked gross discrimination error to undergeneralization and misconception.

Based on the findings of this study, we suspect that learners who make predicted fine discrimination errors often understand the critical attributes of a concept, but overgeneralize to include variable attributes. Because they understand the critical variables of concept, they are more prone to seek out information in the interrogatory example which would allow them to correct their error. This, of course, amounts to an increase in effort and in feedback study time. This implies that the richness of the interrogatory example or question text has an important function in aiding correction of fine discrimination classification error.

Conversely, learners who make gross discrimination errors may have failed to comprehend the critical variables of the concept and therefore have no existing informational framework on which to base further exploration of the problem. They may have guessed at the correct response to begin with and being informed that they are wrong comes as no surprise. They may have even expected they would be. Seeking out further information in the text serves no purpose. In these cases, they expend no effort and feedback study times are minimal.

Implications for Practioners

Instructional technologists, as specialists who prescribe teaching strategies, are making greater efforts to incorporate research into applied learning settings (Briggs, 1984). We have listed below four implications of the present study for consideration by practitioners. They are limited by the nature of the instructional environment existing in this study, i.e., adjunct, adaptive computer-based instruction for concept and simple rule learning tasks involving non-constructed responses. Further, we remind the reader, the types of feedback were corrective in nature, text-based, and used forms of knowledge of correct response as a given parameter.

1. It is probably not worth the effort to develop more complex forms of text-based KCR feedback. Our findings indicate that complex feedback is no more effective and much less efficient for both the learner and the developer than simple KCR feedback.

2. A template, the rational set generator matrix used in this study, has illustrated the capacity to predict and react differently to specific types of error within particular learning domains. Much more work is needed in the development of shells which incorporate effective, research-based instructional strategies and adapt to particular errors for identified learning outcomes.

3. Isolating fine discrimination error responses may be useful in creating an indicator of how well students are learning concepts and rules. Based on the findings of the present study, it would appear that the number of fine discrimination errors made during instruction may be used as a predictor of retention test performance. Accordingly, those who make fewer predicted fine discrimination errors during instruction of concepts and simple rules will be better able to classify novel examples in the future.

4. To accommodate correction of fine discrimination errors, instructional developers should provide multiple, high-quality interrogatory examples with clear critical attributes, rich in information regarding variable attributes. Learners spend much more time studying feedback when they have made fine discrimination errors than gross discrimination errors. One explanation offered is that a learners who made a fine discrimination error may be familiar with the critical attributes of the concept or simple rule. Therefore, he scans the interrogatory exemplar or question text for the source of his error. In contrast, a learner who made a gross discrimination error may not comprehend the critical attributes of the concept or simple rule. As a result the learner would just give up and move on to the next frame.

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Table 1

Overall Means and Standard Deviations of Retention Test Performance for the Four Treatment Groups

Feedback Group	Mean *	SD	N
KCR	18.25	3.05	40
KCR + Forced CR	18.58	3.27	39
KCR + AWA	18.71	3.44	39
KR +Second Try	19.28	2.67	35
Total	18.69	3.12	153

* (total possible score = 24)

Table 2

Overall Means and Standard Deviations of Feedback Study Time for the Four Treatment Groups

Feedback Group	Mean *	SD	N
KCR	71.76	54.08	42
KCR + Forced CR	197.37	151.60	43
KCR + AWA	129.28	88.25	42
KR +Second Try	219.16	111.17	42
Total	154.65	121.50	169

* (time in seconds)

Table 3

Overall Means and Standard Deviations of Feedback Efficiency for the Four Treatment Groups

Feedback Group	Mean *	SD	N
KCR	2.41	.76	39
KCR + Forced CR	1.56	.56	39
KCR + AWA	2.04	.94	39
KR +Second Try	1.43	.50	39
Total	1.87	.81	152

* (time in seconds)

Table 4

Overall Means and Standard Deviations of the Number of Incorrect Responses Made During Instruction for the Four Treatment Groups

Feedback Group	Mean	SD	N
KCR	13.73	7.06	42
KCR + Forced CR	14.72	11.00	43
KCR + AWA	15.64	8.61	42
KR +Second Try	13.59	7.55	42
Total	14.42	8.67	169

Table 5

Overall Means and Standard Deviations of Efficiency of Feedback During Instruction Only for the Four Treatment Groups

Feedback Group	Mean	SD	N
KCR	.0212	.0448	42
KCR + Forced CR	.0060	.0038	43
KCR + AWA	.0102	.0137	43
KR +Second Try	.0058	.0082	43
Total	.0107	.0243	171

Table 6

Overall Means and Standard Deviations of Fine Discrimination Errors on the Retention Test for the Four Treatment Groups

Feedback Group	Mean	SD	N
KCR	3.67	2.06	40
KCR + Forced CR	3.35	2.10	39
KCR + AWA	3.00	2.33	39
KR +Second Try	2.77	1.68	35
Total	3.21	2.08	153

Table 7

Means and Standard Deviations of Gross Discrimination Errors on the Retention Test for the Four Treatment Groups

Feedback Group	Mean	SD	N
KCR	.67	.82	40
KCR + Forced CR	.74	1.09	39
KCR + AWA	.76	1.03	39
KR +Second Try	.82	.98	35
Total	.75	.98	153

Table 8

Overall Means and Standard Deviations of\Retention Test Performance for Learners Who Make Fewer and Greater than Average Fine Discrimination Errors During Instruction

Fine Discrimination Errors	Mean	SD	N
Fewer Than Average	19.10	2.73	100
Greater Than Average	17.92	3.66	53
Total	18.69	3.12	153

Table 9

Overall Means and Standard Deviations of Feedback Study Time for Fine Discrimination Errors During Instructional for the Four Treatment Groups

Feedback Group	Mean	SD	N
KCR	37.19	42.98	42
KCR + Forced CR	94.46	98.49	43
KCR + AWA	64.90	48.28	42
KR +Second Try	125.38	72.51	42
Total	80.56	76.23	169

Table 10

Overall Means and Standard Deviations of Feedback Study Time for Gross Discrimination Errors During Instruction for the Four Treatment Groups

Feedback Group	Mean	SD	N
KCR	18.21	26.95	42
KCR + Forced CR	34.02	48.41	43
KCR + AWA	44.45	46.09	42
KR +Second Try	72.92	59.68	42
Total	42.35	50.49	169