J. EDUCATIONAL COMPUTING RESEARCH, Vol. 13(2) 111-127, 1995

A META-ANALYSIS OF THE EFFECTS OF FEEDBACK IN COMPUTER-BASED INSTRUCTION

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ABSTRACT

A quantitative research synthesis (meta-analysis) was conducted on the literature concerning the effects of feedback on learning from computer-based instruction (CBI). Despite the widespread acceptance of feedback in computerized instruction, empirical support for particular types of feedback information has been inconsistent and contradictory. Effect size calculations from twenty-two studies involving the administration of immediate achievement posttests resulted in a weighted mean effect size of .80. Also, a mean weighted effect size of .35 was obtained from nine studies involving delayed posttest administration. Feedback effects on learning and retention were found to vary with CBI typology, format of unit content and access to supplemental materials. Results indicate that the diagnostic and prescriptive management strategies of computer-based adaptive instructional systems provide the most effective feedback. The implementation of effective feedback in computerized instruction involves the computer's ability to verify the correctness of the learner's answer and the underlying causes of error.

In general, the term feedback refers to evaluative information that is provided on the functioning of a system that is intended to correct variations from a productive pathway. It is widely recognized that performance feedback is an important ingredient in any effective learning environment [1, 2], but this is especially so for computer-based learning conditions where human tutors are generally not part of the instructional system.

Definitions and terminology in the area of instructional feedback abound, ranging from the now outdated S-R notion of feedback as reinforcement to more recent cognitive perspectives deriving from the information processing tradition.

One common definition focuses on the informational aspect as student answers to instructional queries [3]. Another more radical view argues that feedback restores equilibrium to learning systems by providing the opportunity for the continuation of activities that are proceeding in a desirable and productive direction [4].

The motivating aspects of feedback are often encountered in the literature. Lepper and Chabay describe two categories of motivational feedback, commiseration and encouragement [5]. In both cases motivational feedback attempts to influence the learner's behavior in a lesson by providing incentives for correct behavior or by issuing deterrents for undesirable behavior [6].

Since it is generally agreed that feedback is a critical component of instruction, it is especially important to judge its effectiveness for all of its potential configurations. For instance, feedback in CBI can range from the very simple issuing of right-wrong statements to more elaborate descriptions of correct. More recently, attempts have been made to provide adaptive feedback that adjusts to the individualized learning needs of students (e.g., [7]). Clearly all of these configurations cannot be equally effective, and so it is the purpose of this article to judge the relative effectiveness of feedback in general and based on various CBI typologies. It will also address the issue of the effectiveness of immediate versus delayed feedback issued by computers.

META ANALYSES

The technique that will be used to assess the effectiveness of computer-based feedback is called meta-analysis [8]. Essentially this approach to reviewing the literature in a particular area attempts to establish a standardized difference between a treatment condition (i.e., feedback) and a control condition (i.e., no feedback). This standardized metric is called an Effect Size and can be combined with the effect sizes from a variety of studies to produce an average indice of effectiveness for an instructional treatment. Effect sizes are often converted to a percentile to improve their interpretability. For example, an effect size of 1.0 says that 84 percent of the treatment subjects performed higher than subjects at the mean of the control condition.

Cohen has provided rough guidelines for interpreting effect sizes [9]. Small effect sizes (e.g., .20 or the 58th percentile) are similar to those associated with comparisons among the heights of fifteen- and sixteen-year-old girls. Medium effect sizes (e.g., .50 or the 69th percentile) would be similar to differences between fourteen and eighteen-year-old girls. Large effect sizes (.80 or the 79th percentile) are of the order of magnitude of differences in IQ between holders of Ph.D. degrees and the average college freshman.

In the general area of feedback, four meta-analyses have been accomplished. Bangert-Drowns, Kulik, Kulik, and Morgan selected feedback studies involving the instructional effect of feedback in test-like situations [10]. This study resulted in an average effect size of .26. In another meta-analysis Kulik and Kulik investigated the effects of the timing of feedback in verbal learning, resulting in an estimated effect size of .34 [11]. Lysakowski and Walberg found the highest effect for corrective feedback (ES = .97) especially when it is combined with the instructional effects of cues and student participation [12].

Only one meta-analysis has investigated the effects of feedback on learners in computerized and programmed instruction [13]. This study resulted in a finding of .47 standard deviations above control situations. This is considered a medium effect size by Cohen. Since CBI and paper-based programmed instruction were mixed, an estimate of the pure effects of feedback in computerized instruction is still not available.

Two methods for selecting studies for inclusion in meta-analyses have been articulated and roundly debated. Glass advocates the use of all studies in the area of interest, regardless of methodological flaws and other problematic issues [14]. By contrast, Slavin has made the case for the extreme restriction of selection criteria [15]. He argues that only like studies should be averaged resulting in a "best evidence" synthesis of the research findings. The current study sought to establish a fair balance between these approaches in order not to inordinately restrict sample size while maintaining empirical integrity. The inclusion criteria for this study are presented in the next section.

METHOD

A quantitative meta-analysis of the literature on the effects of computer presented feedback on learning from computer-based education was conducted. Numerous meta-analytic procedures were used to synthesize empirical studies gathered during data collection [16-18].

The overall quantitative meta-analytic approach involved the following steps: 1) data collection; 2) creation of inclusion criteria; 3) development of a coding scheme and subsequent separate analysis of studies involving immediate and delayed administration of feedback; 4) calculation of effect sizes; 5) calculation of unbiased estimators of effect sizes; 6) calculation of average effect sizes; 7) calculation of average weighted effect sizes; 8) calculation of heterogeneity of effect sizes; 9) calculation of frequencies and means for all categories across each study variable; 10) calculation of one-way analyses of variance between all categories across each study feature, and 11) performance of a multiple regression analysis on particular study features in studies involving immediate posttest administration.

Data Collection

The data collection procedure involved acquiring all relevant empirical studies related to the effects of computer-based feedback on learning from computer-based instruction. The inclusion of all possible studies, which met the criteria, ensured that the meta-analysis comprised a representative sample of empirical studies on the topic.

Multiple sources of information were searched to identify all relevant research studies. First, on-line searches were conducted probing various interdisciplinary resources. For example, the *ERIC* database was searched from 1966 to 1992 using various descriptors such as *CAI, CAI and feedback, CAL, CAL and feedback, feedback, knowledge of results, review, programmed instruction, programmed instruction and feedback.* The *PsychLIT* database was also searched from 1983 to 1992 using the *CAI, CAI and feedback CAL, CAL and feedback, feedback, feedback in CAI, computer-based instruction and feedback and learning.* The *Social Citation Index* and MUSE (McGill University Libraries' Online Catalogue) were also probed using the keywords *computer-assisted instruction (CAI), computer-assisted learning (CAL), feedback, knowledge of results, learning processes, computing research, programmed instruction, coaching* and other possible combinations.

Manual searches were conducted to gather research studies that were not catalogued as part of on-line databases and to identify current studies. *The Educational Technology Abstracts, British Education Index, Dissertation Abstracts International, Masters Abstracts, Current Index to Journals in Education, American Education Research Association's* annual meeting program handbooks, card catalogues of Concordia University and textbooks related to the topic were also searched using a wider set of keywords, including *computing research, programmed instruction, coaching, learner model, confirmation, knowledge-based systems, artificial intelligent systems, advisement, knowledge of results, intelligent tutoring systems, and videodisc.*

Research studies which were inaccessible (e.g., master's theses, dissertations, conference papers) through existing library facilities, including Inter-Library Loans, were acquired by contacting the primary author. Thirty-four dissertations were identified as pertinent to the meta-analysis, but only four were received through mail contacts.

The "ancestry approach" of identifying pertinent articles was conducted by inspecting the reference section of all the empirical studies and theoretical articles that were collected via on-line and manual searches. This examination prevented the omission of relevant articles that would have otherwise been excluded from the analysis.

Inclusion Criteria

Fifty-nine studies were collected and critically evaluated for possible inclusion in the meta-analysis. The inclusion criteria were derived from the meta-analytic literature (e.g., [19]), previous research findings on computer-based instruction (e.g., [20-23]), previous meta-analytic reviews on feedback (e.g., [10]) and other empirical features related to both the theoretical and statistical outcomes of the analysis (e.g., [24]). Acquired studies were evaluated systematically, and if they met the following criteria, were subsequently included in the quantitative meta-analysis:

1. Study compared an experimental group receiving computer-presented feedback with a control group receiving no computer-presented feedback (at a minimum one group each);
2. Computer-presented feedback was administered following learner responses (avoided pre-search availability);
3. Study provided operational definitions of all feedback and control conditions;
4. Criterion test of learning was administered either immediately following or sometime after each subject interacted with the computerized instructional lesson;
5. Study provided measures of central tendency, variability, and quantitative statistical results for all experimental and control groups;
6. All groups, experimental and control, consisted of equal sample sizes;
7. Studies with large sample sizes were included in the meta-analysis, defined by Hedges (1982) as n^e, n^c being equal or greater to ten subjects.

In all, twenty-two studies were retained in the analysis and thirty-seven were rejected because they failed to meet one or more of the above mentioned criteria. Of those rejected, twenty-six contained one methodological flaw and the remaining eleven contained more than one flaw.

Coding Scheme

Previous meta-analyses related to CBI [25, 26]; and feedback [12], motivational and cognitive effects of feedback in computer-based instruction [6], Clark's [20, 21, 23] criticism of learning from media, confounding evidence in educational computing research [22] and other coding schemes (e.g., [19]) were used in drafting the initial coding scheme for the extraction of study features.

The studies that met the inclusion criteria were reviewed and their features were coded using an initial coding schema. Subsequently, all unused study variables were deleted and study characteristics were recoded and verified using the revised scheme.

The revised coding scheme comprised the following sections: 1) document characteristics, 2) subject characteristics, 3) instructional materials, 4) criterion test, 5) methodological features, and 6) feedback characteristics. Overall, eighty-three individual study features were taken into account. Following the coding of study features, the studies were subdivided based on the posttest administration, immediate or delayed, and ensuring parallel quantitative analyses were then conducted.

Quantitative Analysis

The quantitative analytic procedures involved two separate major analyses based on 1) studies involving the administration of immediate posttests and, 2) studies involving the administration of delayed posttests. Parallel but separate calculations were performed throughout the quantitative component of the meta-analysis. The information gathered in each study, involving immediate and delayed posttest administration, was recorded for subsequent meta-analytic procedures. Such information included main effects *F*-values related to the feedback group, *t*-test statistic values, total sample size, experimental and control group sample sizes, experimental and control group standard deviations, and experimental and control group means.

RESULTS

Immediate Posttest Data

Nineteen effect sizes were extracted from fourteen studies reporting *F* values related to a main effect for feedback and the total sample size [27-40]. The effect size calculation involved two steps: transformation of the feedback main effect *F* value into a *t*-test statistic [17, p. 268], followed by the transformation of the *t*-test statistic to an effect size, *d*, using the formula described by Hunter and Schmid [17, p. 272].

One study reported an independent *t*-test statistic comparing the difference between a feedback and control group with the respective degrees of freedom [41]. The effect size, *d*, was calculated using a formula described by Rosenthal [18, p. 18].

Fourteen effect sizes were calculated from five studies that provided the experimental and control group means, standard deviations and sample sizes [7, 42-45]. The effect size, *g*, was calculated using the formula described by Hedges and Olkin [16, pp. 78-79].

The fourteen effect sizes just described were converted into unbiased estimators of effect size, *d*, using the formula provided by Hedges and Olkin [16, p. 81]. This resulted in an unbiased effect size estimator.

Average Mean Effect Size

The mean effect size for all the studies involving the effects of computer-presented feedback on learning as measured by the administration of an immediate posttest was calculated by summing the thirty-four effect size values (unbiased estimators) and dividing the total by thirty-four.

The methodology described by Rosenthal [18, p. 78] was used to calculate the estimated variance of effect sizes and subsequently the weighted mean effect size.

Finally, the weighted mean effect size was calculated by applying the formula provided by Rosenthal [18, p. 78].

The unweighted effect size was .73 with a standard deviation of .57. This effect was based on a total sample size of 2201 subjects. The overall weighted effect size was .80 ($p \leq .05$). The magnitude and direction of the effect size indicates that achievement outcomes were greater for the feedback group than the no-feedback control group. The individual effect sizes for each study included in the analysis along with sample size and CBI typology are presented in Table 1.

Homogeneity of Effect Size

A test of homogeneity of effect sizes was performed to determine if the calculated effect sizes could be considered a homogeneous set. This test was carried out using the procedure described by Rosenthal [18, p. 79]. The calculated value of χ^2 ($k = 33$, $N = 22$) = 558.60, exceeded the critical value of 43.77 at $\alpha = .05$. Therefore, the thirty-four effect sizes were considered heterogeneous.

ANOVA on Study Features

For further statistical analyses, twenty-two of eighty-three study features were selected, based on comparable frequencies in each category. One-way ANOVAs for each of the following study features were calculated: document source; academic level; computer-based education typology; subject matter content; use of an instructional design model; computer-based education material construction; type of instructional content; instructional item type; whether CBI materials were modified versions of preexisting materials; format of unit content; accessibility to supplemental instructional materials; administration of criterion test; test material construction; task domain; instructional item type used in the criterion posttest; familiarity with the criterion items; timing of criterion; validation of test items performed by; sample selection; subject participation; and strategy used by feedback group.

Of the twenty-two study characteristics tested, six resulted in significant differences across coded categories. These were: academic level (primary, secondary or college), $F(2,23) = 5.3, p < .05$; CBI typology (linear CAI, Minnesota Adaptive Instructional System, computer-driven interactive video or branching CAI), $F(3,33) = 14.3$, $p < .05$; instructional systems design used (yes or no), $F(1,33) = 14.2$, $p < .05$; format or unit content (graphics, text of multiple format), $F(2,7) = 45.0$, $p < .05$; and accessibility to supplementary instructional materials (yes or no), $F(1,33) = 16.5, p < .05$.

Multiple Regression

A stepwise regression analysis was conducted on study features to determine the possible relationship between these features and effect size. The search for the three study features with the lowest probability values is related to the inclusion of

Table 1. Effect Sizes Extracted from Studies Involving Immediate Posttest Administration

Authors	CBE Typology	N	n^e	n^c	d
Anderson et al., 1971, Study 1	Linear CAI	168			0.03
Hines et al., 1988	Branching CAI	221			0.07
Bumgarner, 1984	Branching CAI	41			0.12
Hodes, 1985	Branching CAI	41	21	20	0.14
Gaynor, 1981	Linear CAI	92			0.15
Arnone et al., 1992	CDIV	52	25	27	0.18
Gaynor, 1981	Linear CAI	92			0.20
Gaynor, 1981	Linear CAI	92			0.22
Schloss et al., 1988	Linear CAI	25	7	18	0.31
Gilman, 1969b	Linear CAI	75			0.38
Schloss et al., 1988	Linear CAI	25	7	18	0.40
Elliot, 1986	Linear CAI	42	20	22	0.42
Anderson et al., 1972	Linear CAI	48	24	24	0.43
Armour-Thomas et al., 1987	Linear CAI	45	22	23	0.45
Armour-Thomas et al., 1987	Linear CAI	46	23	23	0.46
Gilman, 1969a	Linear CAI	75			0.46
Armour-Thomas et al., 1987	Linear CAI	44	21	23	0.54
Elliot, 1986	Linear CAI	42	20	22	0.55
Schloss et al., 1988	Linear CAI	25	7	18	0.57
Tennyson et al., 1980	MAIS	139			0.69
Chanond, 1988	Linear CAI	120			0.77
Clariana et al., 1991	Branching CAI	100			0.80
Tennyson, 1981, Study 2	MAIS	47			0.90
Roper, 1977	Linear CAI	36			0.92
Tennyson, 1980	MAIS	46	23	23	0.93
Schaffer et al., 1986	CDIV	98			0.99
Tennyson, 1981, Study 2	MAIS	47			1.00
Tennyson, 1981, Study 2	MAIS	47			1.36
Schloss et al., 1988	Linear CAI	25	7	18	1.37
Johansen et al., 1983	MAIS	32	16	16	1.48
Tennyson, 1981, Study 1	MAIS	63			1.63
Tennyson, 1980	MAIS	46	23	23	1.81
Johansen et al., 1983	MAIS	32	16	16	1.94
Johansen et al., 1983	MAIS	32	16	16	2.12

Note: N = total sample size; n^e = experimental group sample size, n^c = control group sample size. Unweighted ES = .73, Weighted ES = .80, SD = .57.

a single variable for each 10 subjects in an experiment [46]. In this case, the total number of subjects or effect sizes was thirty-four (n = 34) and thus only three study features could be incorporated into the multiple regression analysis. Three study features with the lowest probability values, *computer-based education typology, format of unit content, and accessibility to supplemental materials*, were chosen for inclusion in the analysis.

Delayed Posttest Data

The calculation of effect sizes for the delayed posttest administration studies followed the same pattern as that just described for those involving the administration of immediate posttests. Five effect sizes were extracted from three studies [10, 31, 32], reporting *F* values related to a main effect for feedback.

One study reported an independent *t*-test statistic comparing the difference between a feedback and control group with the respective degrees of freedom [27]. An effect size was calculated using a formula described by Rosenthal [18, p. 18].

Three effect sizes were calculated from one study that provided the experimental and control group means, standard deviations, and sample sizes [42]. The effect size, *g*, was calculated.

Unbiased Estimators of Effect Size

The effect sizes extracted from one study using the Hedges and Olkin methodology resulted in the calculation of biased effect sizes, *g*, which were converted into an unbiased estimator of effect size, *d* [16].

Average Mean Effect Size

The mean effect size for all the studies involving the effects of computer-presented feedback on learning as measured by the administration of a delayed posttest was calculated by summing the nine effect size (unbiased estimator) values and dividing the total by the sample size.

Weighted Mean Effect Size

The methodology described by Rosenthal was used to calculate the estimated variance of effect sizes and subsequently the weighted mean effect size [18]. Effect sizes, all positive, ranged from a low of .15 standard deviations to a high of .62. The unweighted mean effect size for the sample of 665 subjects was .34 with a standard deviation of .17. The overall weighted effect size was .35 ($p < .05$). The small effect size and its positive direction indicates that achievement outcomes were greater for feedback than non-feedback groups. This is the equivalent of raising achievement scores from the 50th percentile to the 64th percentile. The individual effect sizes for each study conducted, along with sample size and CBI typology are shown in Table 2.

Test of Homogeneity of Effect Size

Procedure was performed to test the homogeneity of effect size within the sample. The calculated value, χ^2 (8, $N = 9$) = 25.39, exceeded the critical value of 15.51 and therefore the nine effect sizes were significantly heterogeneous.

Table 2. Effect Sizes Extracted from Studies Involving Delayed Posttest Administration

Authors	CBE Typology	N	n^e	n^c	d
Gaynor, 1981	Linear CAI	92			0.15
Gaynor, 1981	Linear CAI	92			0.18
Gaynor, 1981	Linear CAI	92			0.22
Chanond, 1988	Linear CAI	103			0.26
Armour-Thomas et al., 1987	Linear CAI	45	22	23	0.28
Armour-Thomas et al., 1987	Linear CAI	46	23	23	0.30
Armour-Thomas et al., 1987	Linear CAI	44	21	23	0.42
Clariana et al., 1991	Branching CAI	100			0.60
Anderson et al., 1971, Study 2	Linear CAI	50	24	26	0.62

Note: N = total sample size; n^e = experimental group sample size, n^c = control group sample size. Unweighted ES = .34, Weighted ES = .35, SD = .17.

ANOVA Procedure of Study Features

The frequencies and means of seventeen of eighty-three study variables were calculated. The study features included: document source, academic level, computer-based education typology, subject matter content, use of an instructional design model, type of instructional content, instructional item type used in the posttest, whether CBI materials were modified version of pre-existing materials, whether subjects were introduced to the instructional unit, format of the unit content, accessibility to supplemental instructional materials, task domain, instructional item type of criterion posttest, timing of criterion, sample selection, subject participation and the strategy used by the feedback group. The calculation of one-way ANOVAs was inconceivable since the frequency distributions revealed study features with category sample sizes of one.

DISCUSSION

Feedback has to be regarded as one of the most critical components of computer-based instruction, its objective being to provide students with appropriate responses thus allowing them to rectify learning difficulties. In the best scenario, one-to-one human tutoring provides the potential for the most flexible and individualized forms of feedback. In contrast, computers must be programmed in advance to recognize learning difficulties and provide information that will aid the student in rectifying mistakes. Ideally, feedback messages should stimulate cognitive processes and strategies so that misconceptions that jeopardize future learning attempts will not be perpetuated.

Crucial Role of Feedback in Computerized Instruction

The importance of feedback as a critical component of instruction and learning is exemplified by the magnitude and direction of the mean effect size involving studies with immediate posttest administration. The unweighted mean effect size of .80 indicates that achievement outcomes were greater for the feedback group than the control group. This large effect size was interpreted as computer-presented feedback raising achievement scores by four-fifths of a standard deviation [9]. Equivalently, learners in the computer-presented feedback group performed better than 79 percent of the learners in the control group.

The present study differs from meta-analytic studies that synthesized feedback-related issues involving immediate posttest administration. The effect size was higher than meta-analyses involving the instructional effect of feedback in test-like situations [10], the timing of feedback in verbal learning [11], but was smaller than Lysakowski and Walberg's quantitative synthesis of the instructional effects of cues, participation and corrective feedback [12]. This difference may be due to the stricter inclusion criteria used in the present study.

Compared to its closest equivalent [13], the current study produced findings that are much more encouraging and suggestive of the potential of CBI feedback interventions. Schimmel's effect size of .47 may have resulted from "mixing apples and oranges" (CBI and PI) or from the lack of incorporating studies involving adaptive feedback.

The failure to meet the assumption of homogeneity of variance of effect size in the current study suggests that other intervening variables, such as type of computer-based typology may be a factor in the interpretation of the overall effect size obtained (see Table 1). Consistently, the typology referred to as the MAIS achieved the highest effect size (ES = 1.38), while Computer-Driven Interactive Video (ES = 59), Linear CAI (ES = .49) and Branching CAI (.28) produced lower mean effect sizes. A test of these different computer feedback typologies produced one of the significant differences in follow-up analyses.

The delayed posttest administration results indicated a decrease in long-term retention (ES = .35) as measured by achievement posttest scores as compared to the overall mean effect size of studies involving immediate posttest administration. A comparison of the general strategies used in the control and feedback groups of studies involving immediate and delayed posttest administration provides partial explanatory evidence as to the difference between the weighted mean effect sizes (.80 versus .35).

Studies involving immediate posttest administration compared control groups that presented the next screen of instruction following the learner's response without the presentation of a feedback message. In contrast, feedback groups generally included adaptive instructional approaches of continuous monitoring of student performance followed by the provision of advice concerning number of examples, and sequence of instruction as well as elaborate feedback messages.

Conversely, studies involving delayed posttest administration incorporated control groups that omitted the presentation of a feedback message and proceeded to the next instructional sequence, while the feedback groups presented messages that differed in immediacy of delivery, format and content. It is clear from these results that immediate delivery of a feedback message provides the best instructional advantage to the student.

This study has addressed an important and contradictory body of research literature using meta-analytic techniques in the area of computer-presented feedback. Obviously, the number of studies excluded from consideration in this analysis bespeaks the somewhat methodologically weak state of research in the area. Naturally, qualitative studies were omitted from this quantitative synthesis. The credibility and contribution of such works must be judged by other means, that are at this point in time still unrefined. However, it is encouraging to note that the sophistication that one would hope to observe in an emerging instructional technology seems to be evident in these results. As adaptive systems become more powerful and capable of offering tailor-made feedback based on dynamic assessment [47], effects due to the inclusion of feedback in computer-based instruction should continue to raise achievement levels in on-line learning environments. Until certain issues are clarified, the future of feedback research lies mainly in advances in student modeling [48], interaction of one-to-one human tutoring [49] and feedback explanations during naturalistic tutoring [51].

APPENDIX A
Studies Included in the Meta-Analysis ($n = 22$)

Anderson, R. C., Kulhavy, R. W., & Andre, T. (1971). Feedback procedures in programmed instruction. *Journal of Educational Psychology, 62*(2), 148-156.

Anderson, R. C., Kulhavy, R. W., & Andre, T. (1972). Conditions under which feedback facilitates learning from programmed lessons. *Journal of Educational Psychology, 63*(3), 186-188.

Armour-Thomas, E., White, M. A., & Boehm, A. (1987). *The motivational effects of types of feedback on children's learning concepts and retention of relational concepts.* Paper presented at the Annual Meeting of the American Educational Research Association.

Arnone, M. P., & Grabowski, B. L. (1992). Effects on children's achievement and curiosity in learner control over an interactive video lesson. *Educational Technology Research & Development, 40*(1), 15-27.

Bumgarner, K. M. (1984). *Effects of informational feedback and social reinforcement on elementary students' achievement during CAI drill and practice on multiplication facts.* Unpublished doctoral dissertation, Seattle University.

Chanond, K. (1988, January). *The effects of feedback, correctness of response and response confidence on learner's retention in computer-assisted instruction.* Proceedings of selected research papers presented at the annual meetings of the Association for Educational Communications and Technology, New Orleans, LA.

Clariana, R. B., Ross, S. M., & Morrison, G. R. (1991). The effects of different feedback strategies using computer-administered multiple-choice questions as instruction. *Educational Technology Research & Development, 39*(2), 5-17.

Elliot, B. A. (1986). *An investigation of the effects of computer feedback and interspersed questions on the text comprehension of poor readers.* Unpublished doctoral dissertation, Temple University.

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

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

Gilman, D. A. (1969b). The effect of feedback on learner's certainty of response and attitude toward instruction in a computer-assisted instruction program for teaching science concepts. *Journal of Research in Science Teaching, 6*, 171-184.

Greer, J. E., & McCalla, G. I. (1994). *Student modelling: The key to individualized knowledge-based instruction.* NATO ASI Series (Vol. 125). Berlin: Springer-Verlag.

Hines, S. J., & Seidman, S. A. (1988, January). *The effects of selected CAI design strategies on achievement, and an exploration of other related factors.* Proceedings of selected research papers presented at the annual meeting of the Association for Educational Communications and Technology, New Orleans, LA.

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

Johansen, K. J., & Tennyson, R. D. (1983). Effects of adaptive advisement on perception in linear-controlled, computer-based instruction using a rule-learning task. *Educational Communication and Technology Journal, 31*(4), 226-236.

Roper, W. J. (1977). Feedback in computer assisted instruction. *Programmed Learning and Educational Technology, 4*(1), 44-49.

Schaffer, L. C., & Hannafin, M. J. (1986). The effects of progressive interactivity on learning from interactive video. *Educational Communication and Technology Journal, 34*(2), 89-96.

Schloss, P. J., Wisniewski, L. A., & Cartwright, G. P. (1988). The differential effect of learner control and feedback in college students' performance on CAI modules. *Journal of Educational Computing Research, 4*(2), 141-150.

Tennyson, R. D. (1980). Instructional control strategies and content structure as design variables in concept acquisition using computer-based instruction. *Journal of Educational Psychology, 72*(4), 525-532.

Tennyson, R. D. (1981). Use of adaptive information for advisement in learning concepts and rules using computer-assisted instruction. *American Educational Research Journal, 18*(4), 425-438.

Tennyson, R. B., & Buttrey, T. (1980). Advisement and management strategies as design variables in computer-assisted instruction. *Educational Communication and Technology Journal, 28*(3), 169-176.

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