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AUTHOR	Bol, Linda; And Others
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ABSTRACT

This paper uses a multi-level model to identify course variables that affect the relationship between study activities and achievement. Data on course characteristics were collected from 12 high school biology classes, and study activity and achievement measures were collected from 136 students enrolled in these classes. The results indicate that more extensive feedback on quizzes was associated with increases in the relationship between effort management study activities and achievement. However, feedback on homework was linked to decreases in the effectiveness of both effort management and autonomous management study strategies. The provision of extra time for student questions during teacher-led reviews increased the effectiveness of autonomous management strategies. Finally, increases in the number of content categories on the teachers' test led to a decrease in the relationship between memory augmentation strategies and achievement. The findings suggest that a multi-level analysis provides a more comprehensive and appropriate explanation of the hierarchical relationship between course characteristics, study activities, and achievement. (Contains 9 figures and 23 references.) (Author)

Explaining the Relationship between Students' Study Activities, Achievement, and Course Characteristics Using a Multi-Level Model

Linda Bol

University of Memphis

Mark Wilson

University of California, Berkeley

Robert Warkentin

Georgia Southern University

Running head: COURSE CHARACTERISTICS, STUDY ACTIVITIES AND ACHIEVEMENT

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Abstract

This paper uses a multi-level model to identify course variables that affect the relationship between study activities and achievement. Data on course characteristics was collected from 12 high school biology classes, and study activity and achievement measures were collected from 136 students enrolled in these classes. The results indicate that more extensive feedback on quizzes was associated with increases in the relationship between effort management study activities and achievement. However, feedback on homework with linked to decreases in the effectiveness of both effort management and autonomous management study strategies. The provision of extra time for student questions during teacher-led reviews increased the effectiveness of autonomous management strategies. Finally, increases in the number of content categories on the teachers' test led to a decrease in the relationship between memory augmentation strategies and achievement. The findings suggest that a multi-level analysis provides a more comprehensive and appropriate explanation of the hierarchical relationship between course characteristics, study activities, and achievement.

Explaining the Relationship between Students' Study Activities, Achievement, and Course Characteristics Using a Multi-Level Model

A question of obvious import for both educational theory and practice is how course variables affect student study activities and in turn, how study strategies impact academic achievement. However, previous research on the relationship between course characteristics, study activities, and achievement has searched for direct links between only two of the three variables in isolation. The traditional approaches to investigating the relationships between these variables separately is portrayed in the upper part of Figure 1. More specifically, researchers have studied (1) the relationship between instructional features and study activities (e.g., Entwistle & Ramsden, 1983; Hamaker, 1986; Martin & Saljo, 1976; Thomas, Bol, Warkentin, Wilson, Strage, & Rohwer, in press), (2) the relationship between instructional features and achievement (e.g., Mayer, 1979; Rothkopf, 1973; Thomas et al., in press), and (3) the relationship between study activities and achievement (Crooks, 1988; Rohwer & Thomas, 1989; Thomas et al., in press). In most cases, regression or ANOVA has been employed to investigate these relationships. In this paper we consider the possibility of a somewhat different relationship among course characteristics, study activities, and achievement. Our conception is that students develop a style of study in response to particular course characteristics which affects the relationship between students' study style and their achievement. Specifically, we ask whether course characteristics might affect the way students' study activities are related to achievement. That is, we ask: Is the relationship between study activities and achievement systematically associated with differences in course characteristics?

This multi-level relationship among the three types of variables is also illustrated in Figure 1.

Insert Figure 1 about here

This kind of question is more appropriately addressed by using a multi-level approach which models two distinct levels of influence on student achievement (Bryk & Raudenbush, 1992; Raudenbush, 1988). We conceptualize the way the multi-level analysis works as follows. First, the multi-level model estimates the within-class relationship between selected student study variables and student achievement. At a second level, the multi-level model estimates the between-class effects by regressing these study activity-achievement relationships on selected course variables identified in classrooms. (The actual estimation algorithm addresses these two levels simultaneously). This approach not only answers a different question to that of traditional analyses, it models the naturally hierarchical nature of data collected on the effectiveness of classroom practices, in this case, student performance measured at the individual level and characteristics of courses assessed at a class or group level.

The employment of multi-level techniques to analyze hierarchical data has become increasingly popular with the realization that both between and within level effects should be considered simultaneously in order to provide a more comprehensive and appropriate explanation of the inherently hierarchical relationship among variables. For example, multi-level models have been used to investigate the relationship between student characteristics and student outcomes as a function of school level variables (Bryk & Raudenbush, 1989; Bryk & Thum, 1989; Raudenbush & Bryk, 1986, 1988). These researchers (Bryk & Raudenbush, 1987, 1989) have also proposed and demonstrated that multi-level techniques allow one to assess psychological change and how it is linked to background characteristics. Similarly, Burstein (1980) reviews findings in school effects research, large scale program evaluation, and instructional effects research and argues that a multi-level approach is beneficial for specifying more appropriate models for multi-level data. Thus, multi-level modeling represents a methodological advance in understanding multi-level relationships in various areas of educational and psychological research.

Though multi-level modeling has been employed to study various classes of within and between level variables, it has never been utilized to examine how course variables influence the relationship between student study activities and achievement. Therefore, the purpose of the present study is twofold: (1) to explore the kinds of course variables that either promote or impede productive study strategies, and (2) to illustrate how multi-level modeling can be used to explain the relationship between student study activities and achievement as moderated by course characteristics.

In our research we have identified three categories of course characteristics which are hypothesized to influence study activities and achievement (Strage, Tyler, Thomas & Rohwer, 1987; Thomas, Bol & Warkentin, 1991; Thomas et al., in press). The first category is composed of the demands imposed on students to meet course requirements and standards. Examples of course demands are the amount of material to be learned, the degree of cognitive challenge associated with teachers' tests, and the salience of different types of knowledge products on these tests (e.g., knowledge of facts versus knowledge of principles). The second category of course characteristics is composed of supports. Supports consist of teacher provisions such as practice opportunities and feedback that prompt and maintain student engagement in study activities appropriate to the demands of the course. The third category of course characteristics we refer to as compensations. Compensations are defined as provisions that act to abrogate the need for students to engage in demand-responsive study activities. For example, allowing students to refer to their text or notes while taking an exam (open-book tests) might dissuade students from engaging in memory augmentation activities while preparing for that test.

We predict that the effectiveness of engaging in different study activities will vary as a function of course characteristics found in high school biology classrooms. The presence of certain characteristics, such as high demands and high supports, should enhance the relationship between study activities and achievement, whereas the presence of other characteristics, such as the presence of compensatory practices, may diminish this relationship.

Method

Participants

Participants were 12 teachers and 136 of their students from seven high schools in the San Francisco Bay Area. Each teacher taught one or more sections of a general biology course. A sample of 10-25 students were randomly selected from each of the 12 courses to serve as the student sample. The grade level of students enrolled in these courses ranged from Grade 9 to Grade 12, with the majority of students coming from the 10th grade.

Instruments and Data Sources

Students' Study Activities

Students' study activities were measured using three of six scales that make up the Study Activity Questionnaire (SAQ): (1) effort management, (2) memory augmentation, and (3) autonomous management. These scales are described briefly below. Additional information on the SAQ and its scales can be found in Thomas et al. (in press).

Effort Management. This is a hierarchical dimension relating to the tendency of students to match their study habits to the demands of the situation. The dimension has three components and four levels. The three components are time, concentration, and learning effectiveness. The four levels are (a) self-monitoring--the disposition to pay attention to time, concentration, or relative mastery; (b) self-regulation--the disposition to take steps to correct difficulties in time allocation, concentration, or perceived mastery; (c) planning--the disposition to take steps to adopt a strategy in advance of studying to deal with possible time, concentration, or learning effectiveness difficulties; and (d) evaluation--the disposition to engage, after studying, in assessment of the relative success of practices instituted to manage time, concentration, or learning effectiveness.

Memory Augmentation. This is a study activity dimension indexing the disposition to engage in activities to make to-be-learned material more memorable. The dimension ranges from (a) no engagement, (b) duplicative activities (e.g., repeating material over and over), (c) interpretive activities (putting material in one's own words), to (d) constructive activities (e.g., making up study aids). A high score for memory augmentation reflects the studen.' disposition to engage in generative activities intended to aid memory.

Autonomous Management. This is a dimension measuring a student's disposition to use study time to engage in self-directed activity (e.g., preparing study material, testing oneself) as opposed to doing assigned activity (e.g., reading, doing homework). A high score in autonomous management reflects the disposition to take control over one's learning.

Course characteristics.

Three course characteristics are described briefly below. Note that we actually estimated HLM effects for additional course characteristics hypothesized to influence studying and achievement. Only those that proved to be stable effects are listed and described here. A description of the full set of course features hypothesized to affect the study-achievement relationship is provided in Thomas et al. (in press).

Feedback. This support variable is a summary measure that represents that extent of feedback that teachers provided to students on their coursework. In interviews, teachers were asked to describe the type of feedback provided to students on quizzes, homework, and tests. The alternatives provided for this questions were: no feedback (scored as 0), an overall score or grade (scored as 1), a score for each item (scored as 2), and the provision of written comments (scored as 3). This scoring scheme also yielded a measure of the extent of feedback provided separately for quizzes, homework, and tests.

Extra time provided for student questions during review. This support variable measures whether teachers provided extra time for students to ask questions during the teacher-led review session immediately prior to the genetics unit test in the course. Data on this dichotomous variable (yes/no) was gathered during the teacher interview on the genetics unit. These responses were cross-referenced with our observation of the review session.

Number of content categories on the test. This variable was classified as a demand characteristic that referred to the number of discrete biology topics covered on the teacher-administered unit test covering the genetics unit. Scores on this measure were obtained by a content analysis of teachers' tests on the genetics unit.

Student Achievement

Achievement was measured using a researcher-developed test of achievement in genetics. The Genetics Achievement Test (GAT) was developed in order to have a valid way of comparing students' knowledge and capabilities across the 12 participating courses and to assess the degree to which qualitative differences in study activities resulted in differences in achievement capabilities. Accordingly, the content covered by the test represented content that received similar weight and treatment across courses and textbooks. The nine items that made up the test were constructed to represent three cognitive processing (encoding/selection, integration, extension) and three representational (facts/details, concepts/definitions, principles) levels assessed with the SAQ.

Procedure

The investigation was conducted during the administration of one particular unit in each course, the genetics unit. Students' study activities were assessed early in the academic year, prior to the start of the genetics unit, and then again at the completion of the unit. Data relevant to course characteristics were collected during and at the end of the instructional unit. These data were collected by means of classroom observation of the unit test review session, document analysis of all materials related to the unit, and teacher interviews focusing on classroom practices during the genetics unit. The Genetics Achievement Test was also administered at the end of the unit.

Method of Analysis

According to our conception, the effectiveness of engaging in various study activities may vary across courses depending on the pattern of demands, supports, and compensations that make up these courses. Note that predictions of this kind pertain to influences on the criterion performance of individuals that stem from two distinct levels, an individual differences level (study activities) and a course level (course characteristics). Such multi-level data can be appropriately analyzed using methods based on a hierarchical linear model (HLM) analysis. Suppose that we represent the performance of student i in classroom j on the criterion variable by Y_{ij} (we follow the notation of Bryk & Raudenbush, 1992). Then if X_{ij} is that student's measure on a selected SAQ variable, we use a within-class equation to model dependence of achievement on study activity:

$$Y_{ij} = \beta_{jo} + \beta_{j1}X_{ij} + r_{ij} \qquad (1)$$

where r_{ij} is a random error associated with student i in class j. Note that this can be done within each classroom, so we end up with as many intercepts (β_{jo}) and linear regression coefficients (β_{j1}) as there are classrooms. A selection of these regressions for a particular study skills variable (effort management) is shown in

Figure 2. These regressions have been arranged down the page in a particular way: At the top is a classroom where the teacher provides written feedback on quizzes. In the next two classes, the teacher provides a score for each item in the quiz. In the next, the teacher provides only an overall score on the quiz, and, finally, in the bottom one, the teacher provides no feedback at all. What is interesting about the regressions that are estimated within each of these classes is that the regression slope becomes more positive (i.e., steeper) as the quality of feedback increases. This is exactly the sort of systematic variation between two variables (in our case study activities and achievement) as influenced by a third variable (in our case course characteristics) that is appropriate for multi-level analysis.

Insert Figure 2 about here

We can display this in a more compact form by plotting the regression slopes as a function of the course characteristics variable, feedback on courses. Figure 3 shows where each of the five within-class regressions from Figure 2 occur on this plot, and Figure 4 gives all of the within-class regressions, with each one represented merely as a dot. Thus, we can interpret this to imply that the effect of effort management on student performance is enhanced by higher quality teacher feedback on quizzes. This analysis occurs at the between-class level, and can be represented by the following equation:

$$\beta_{jk} = \gamma_{ok} + \gamma_{1k}W_j + u_{jk} \qquad (2)$$

where γ_o and γ_{1k} are the between classroom intercept and linear regression coefficient for within-class effect k, respectively (in our case k is either 0 or 1 for within-class intercept and slope, respectively, and we shall concentrate on the slope), W_j is the measure on the course characteristic for class j, and u_{jk} is a random error associated with class j and within-class regression weight β_{jk}. Thus, when we noted in Figures 2-4 that there was a positive relationship between the within-class regression slope and quality of feedback, this corresponds to noting that γ_{1k} is estimated to be positive. This procedure could be done step-wise with many regressions at the within-class level and one at the between-class level. The HLM approach uses an iterative procedure that effectively estimates both levels simultaneously. This can be shown to be more appropriate where the data conform to the error assumptions in equations (1) and (2) (Bryk & Raudenbush, 1992). Moreover, the HLM approach provides a statistical framework in which one can test whether the observed relationship is statistically significant (Bryk & Raudenbush, 1992).

Insert Figures 3 and 4 about here

The present data were analyzed using the computer program, HLM2 (Bryk, Raudenbush, Seltzer & Congdon, 1986). In an attempt to control for pre-existing differences in the naturally occurring classes, and in order to isolate potential effects of the course characteristics for the particular unit under study, we use as within-class predictors (X_{ij}s above) *differences* in student study variables. Thus, we are modeling the effect of *changes* in students' study activities on students' performance (Y_{ij}s above) at the individual level. According to the teachers in the sample, this unit is the first time that students have encountered genetics in their school curriculum. Thus, we assume for interpretative purposes that all students taking a pre-test using the researcher-designed achievement test would receive a score of zero. Scores on the GAT were analyzed by the HLM2 program, with the each of the separate SAQ scale scores used as the within-level predictor variable. Thus, for a given SAQ scale and course characteristic, all other things being equal, an estimate of a statistically significant γ_{1k}, indicates that, assuming the estimate is positive, changes in study behavior (as measured by the SAQ scale) become more effective (i.e., result in greater increases in achievement per unit increase in SAQ scale) with increases in the course characteristic variable. Note that this interpretation relates only to the rate of increase, γ_{1k}. Interpretation may be somewhat more complicated when the intercept , γ_{0k}, is also found to be different from zero. In the analyses reported below, γ_{0k} was found to be non-significant except where reported otherwise.

Results

The course characteristics (the between-level variables) used in these analyses were selected as those hypothesized to affect student engagement in the different levels and dimensions of the study activity hierarchies. Use of every course characteristic with each SAQ subscale would have proved prohibitive in cost, so the course characteristic framework was used as a guide for the selection of course variables that were expected to be relevant for each SAQ scale. Though a large number of analyses were completed, only those significant at the 5 percent level are reported in this paper. These should not be considered strict statistical significance tests, as there was no proper sampling design for either level, and as the analyses share a great number of variables. Rather, the analyses should be considered to be exploratory.

There were five statistically significant course characteristic regression coefficients at the 5 percent significance level. The summary of results that follows is organized by the pairs composed of the study activity and course characteristic variables from each analysis.

Effort Management Change Scores on the SAQ; Feedback on Quizzes

A higher level of feedback on quizzes is associated with increases in the relationship between effort change scores and achievement (see Figure 4). The more feedback provided on quizzes the more effective are effort management scores for enhancing achievement.

The provision of feedback to students on their coursework has been acknowledged as an effective teaching practice for enhancing performance (Crooks, 1988; Kulhavy, 1977). There is also some evidence suggesting that feedback is associated with more productive types of study behaviors. Duckworth, Fielding, & Shaughnessey (1986) found that the students' ratings of teacher feedback were positively correlated with their ratings of effort expended in the course and with their perceptions of efficacy in the course. The present finding extends these results, suggesting that extensive feedback practices prompt students to engage in diligent effort management activities which, in turn, is associated with high achievement.

Effort Management Change Scores on the SAQ; Feedback on Homework

Higher levels of feedback on homework are associated with decreases in the relationship between Effort Management change scores and achievement (see

Figure 5). More feedback provided on homework is associated with diminishing effectiveness of changes in Effort Management scores for enhancing achievement.

Ostensibly, this result contradicts the hypothesis that high levels of support provided by teachers on students' coursework, including homework, would be associated with more effective change in reported Effort Management activities. However, closer examination of the results shows that this apparent contradiction can be resolved. Note that Figure 5 shows the relationship between Feedback on Homework and the regression coefficients relating change in Effort Management to achievement (i.e.., γ_{1k} in (2)), but this is not the only coefficient in (2): We must not forget the intercept γ_{0k}. In this case, the intercept is also significantly different from zero, indicating that interpretation must include the effect of this coefficient. Figure 6 shows the fitted linear regressions relating change in Effort Management to achievement for each of the values for Feedback on Homework. Examination of the figure shows that the "effect" of giving differing levels of feedback is, indeed, in line with our prediction (that is higher levels of feedback are associated with higher achievement for a given level of change in Effort Management), except at the highest levels of change. But, it is also true that the effectiveness of changes in Effort Management diminishes with increasing feedback at a value on the change in Effort Management scale of approximately 2. This diminishment results in a reversal of the "effect" of feedback, so that beyond this point, giving higher levels of feedback is counterproductive. This point on the change in Effort Management scale is one that few students in our sample attained--a typical student at this point would have had to give the most extreme possible responses (negative on pretest, positive on post-test) to all, or all but one, of the questions on the scale. Thus, we can say that for most students, giving higher levels of feedback on homework is associated with higher achievement at a given level of change in Effort Management. However, when the student makes very dramatic changes in Effort Management, the relationship is reversed.

It should be noted that in the Duckworth et al. (1986) study, the student ratings pertained to feedback provided on tests, not on homework or other coursework. It may be the case that students more frequently attend to and modify their study activities based on feedback received on tests or quizzes rather than on homework, which is a more routine class activity. Another possibility is that the type of feedback (e.g., the content and extent of written comments) provided to students may systematically differ for homework versus quizzes and tests. In fact, if teachers tend to give high quality feedback on either quizzes or homework, but not both (which is indeed the trend in our small sample), then this would explain the apparently contradictory relationship between this result and the previous one.

Insert Figures 5 and 6 about here

<u>Autonomous Management Change Scores on the SAQ: Feedback on Homework</u>

The provision of more extensive feedback on homework is associated with decreases in the relationship between change scores on the Autonomous Management scale and student performance on the achievement measure (see Figure 7). These findings are similar to those reported for the effect of homework feedback on the relationship between changes in Effort Management scores and achievement. In fact, the situation is almost identical, with a significant intercept giving a relationship that is very similar to that shown in Figure 6, except that the point at which all the regressions intercept is somewhat further to the right, at a change-score where no student actually scored on the Autonomous Management scale. Thus, the interpretation should be the same as that for Effort management. The "effect" of giving differing levels of feedback is in line with our prediction (that is, higher levels of feedback are associated with higher achievement for a given level of change in Autonomous Management), except at the highest levels of change. But, it is also true that the effectiveness of changes in Autonomous Management diminishes with increasing feedback. These results are complicated and may require further research on the types of feedback provided on different course assignments. Perhaps the provision of extra homework feedback tends to act as a ceiling on the possible effects of increases in Autonomous Management activities.

Insert Figure 7 about here

Autonomous Management Change Scores on the SAQ:
Extra Time Provided for Student Questions during Teacher-led Reviews

The teaching practice of allotting extra time for students to ask questions during the test review session is associated with increases in the relationship between Autonomous Management change scores and achievement (see Figure 8). This finding suggests that providing students with an opportunity to ask questions about the up-coming test enhanced the effectiveness of changes in Autonomous Management activities.

This result confirms our prediction that providing students with the opportunity to ask questions about the test can be a supportive teaching practice that informs students about the kinds of test items to expect and how to best study for the test. The research literature suggests that student expectations about task demands or learning goals influence their study activities and achievement (e.g., Hamaker, 1986; Martin & Saljo, 1976; Rothkopf, 1973).

Insert Figure 8 about here

Memory Augmentation Change Scores on the SAQ; Number of Content Categories Covered on the Unit Test

As the number of content categories on the test increases (see Figure 9), there is a corresponding decrease in the relationship between changes in Memory Augmentation scores and achievement test performance. The greater the number of categories on the test the less effective are changes in memory augmentation strategies.

These results suggest that increasing the difficulty of the test by increasing the number of content categories covered may not lead to more productive memory augmentation strategies. A similar result was reported by other researchers (Entwistle & Ramsden, 1983; Entwistle & Tait, 1990) who found that students who described their courses as demanding in terms of workload tended to engage in more superficial, unproductive types of study strategies. In fact, Natriello (1983) suggested the relationship between workload and study practices is curvilinear. When the workload or requirements of the course become too demanding, students resort to superficial types of study practices. This finding may be of considerable import for those who choose a test format comprised of many small items (e.g., multiple choice tests), which , by the nature of the item design task, tends to reinforce a view of the curriculum as merely an accumulation of finely distinguished objectives.

Insert Figure 9 about here

Discussion

The findings suggest that an multi-level analysis provides a more comprehensive and revealing explanation of the hierarchical relationship between course characteristics, student study activities, and achievement. Had the pairs of variables been analyzed individually using traditional regression techniques, different patterns of results and implications of these findings would have emerged. For instance, there was a significant, positive correlation (.60) obtained between feedback on homework and achievement, suggesting that the more feedback provided on homework, the higher the achievement. However, the results of the multi-level analysis point to the diminishing returns of this type of feedback for promoting the effectiveness of particular study strategies. Thus, multi-level analyses paint a more accurate and sophisticated picture of how context variables impact the relationship between study activities and achievement. Ultimately, we are interested in arranging instructional environments that both promote productive study strategies and enhance achievement, and multi-level techniques allow researchers to examine all three types of variables simultaneously.

In terms of applications to the classroom, the results provide some potentially helpful suggestions concerning how biology educators might enhance the effectiveness of students' study behaviors. The following general summaries of the statistically significant findings would provide a good starting point for a confirmatory investigation.

1. To increase the effectiveness of students' effort management activities (which would, one might presume, reinforce students' use of these effort management activities), teachers might provide enhanced feedback on pre-test quizzes, but refrain from doing so on homework.
2. To increase the effectiveness of students' memory augmentation activities, teachers might refrain from preparing tests with large numbers of items that "cover" large numbers of concepts.
3. To increase the effectiveness of students' autonomous management activities, teachers might provide time for students to ask questions during reviews, but, once again, refrain from providing enhanced feedback on homework.

This summary of the results should not be seen as prescriptive in any way. First, the web of causality is not at all clear among the variables in the regressions. We have made causal assumptions that seem valid to us, but there is no safeguard in the present analysis against reasonable occurrences such as, teachers adapting their course characteristics to the particular sample of students in a particular class. Nor can we be sure that we have recorded all of the important course characteristics--for instance, we have relied heavily on information from the test and the period immediately preceding the test, which may be quite atypical, or quite inconsequential, in some classes. We must also note that, at the between-class level, we have a very small sample size--11. Moreover, we conducted a large number of analyses, so we must be wary of ascribing too much importance to our findings.

The most appropriate next step to take would be to replicate the study with a larger number of classes, seeing whether the results generalize to another sample, and, perhaps, determining the generalizability of the findings to other biology units. Another area appropriate for further investigation is a more systematic and comprehensive study of the extent and content of the feedback provided to students on different academic tasks and its moderating effect on study activities and achievement.

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Figure Captions

Figure 1. A comparison of traditional research approaches and the multi-level approach to examine the relationships among course characteristics, study activities and achievement.

Figure 2. Within-course regression slopes of GAT scores on engagement in Effort Management study activities (post-pre difference scores) as a function of feedback on quizzes.

Figure 3. The fitted linear regressions relating changes in Effort Management to achievement for each value of Feedback on Quizzes for the five classrooms of Figure 2.

Figure 4. The fitted linear regressions relating changes in Effort Management to achievement for each value of Feedback on Quizzes for all twelve classrooms.

Figure 5. Within-course Coefficients of Regression of GAT scores on engagement in Effort Management study activities (post-pre difference scores) as a function of Feedback on Homework.

Figure 6. The fitted linear regressions relating changes in Effort Management to achievement for each of the values for Feedback on Homework.

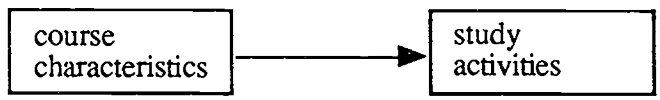
Figure 7. Within course Coefficients of Regression of GAT scores on engagement in Autonomous Management study activities (post-pre difference scores) as a function of Feedback on Homework.

Figure 8. Within-course Coefficients of Regression of GAT scores on engagement in Autonomous Management study activities (post-pre difference scores) as a function of Extra Time for Study Questions.

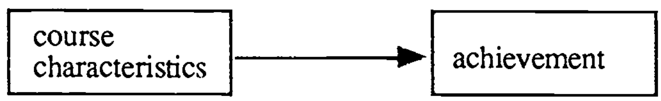
Figure 9. Within-course Coefficients of Regression of GAT scores on engagement in Memory Augmentation study activities (post-pre difference scores) as a function of Number of Content Categories on the Test.

Traditional Research

(1)



(2)



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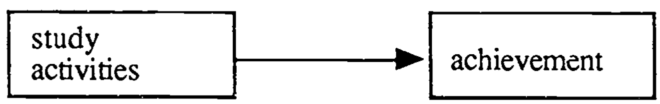
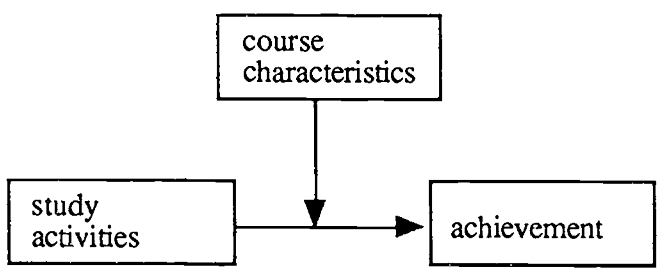
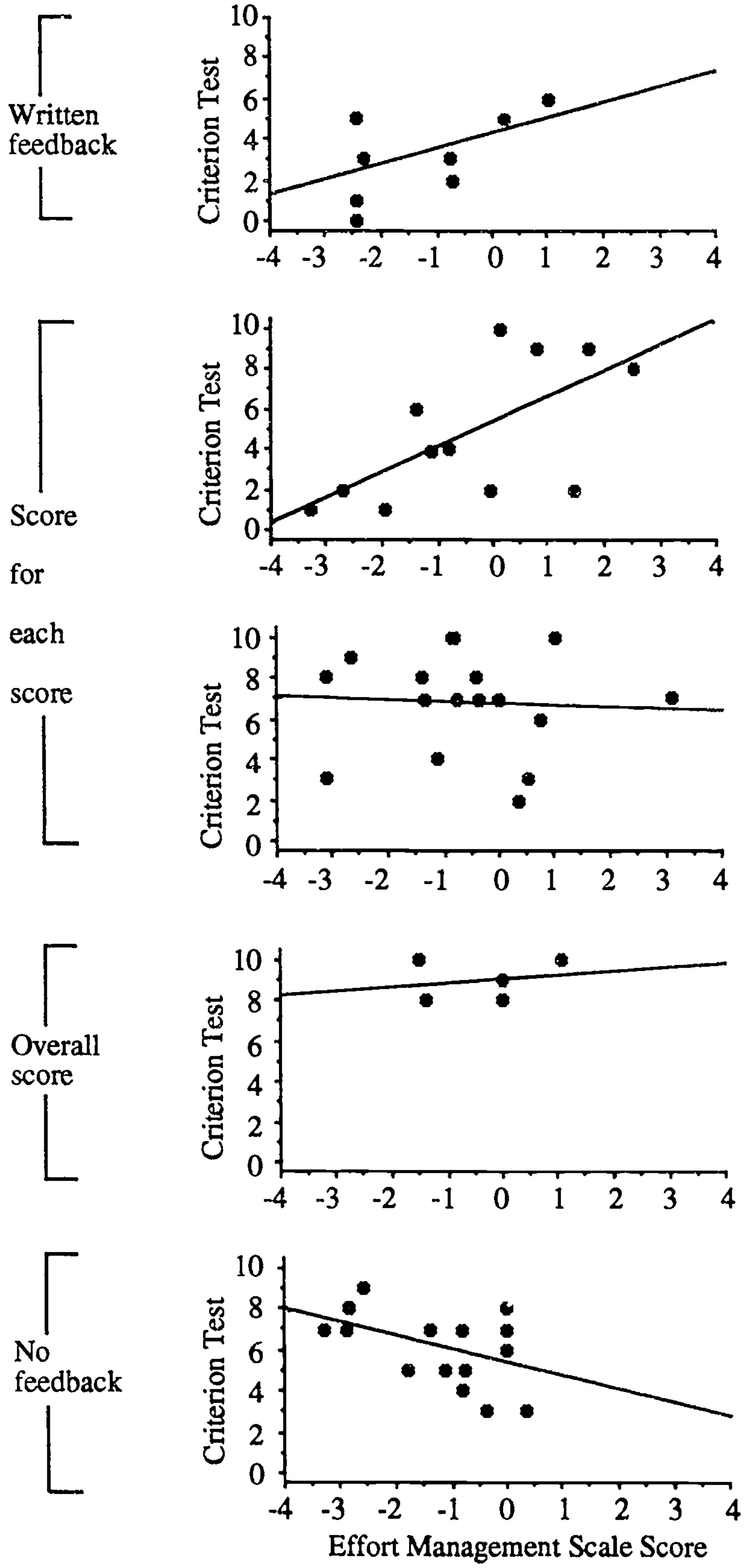
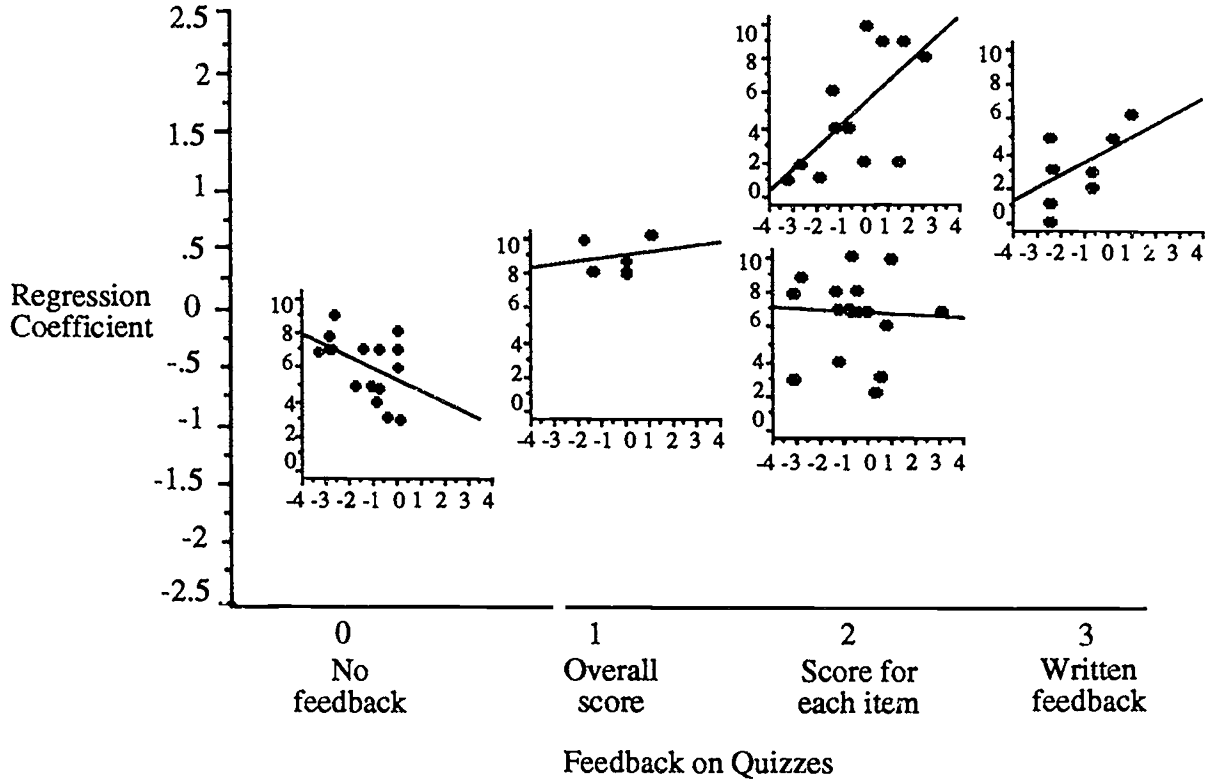


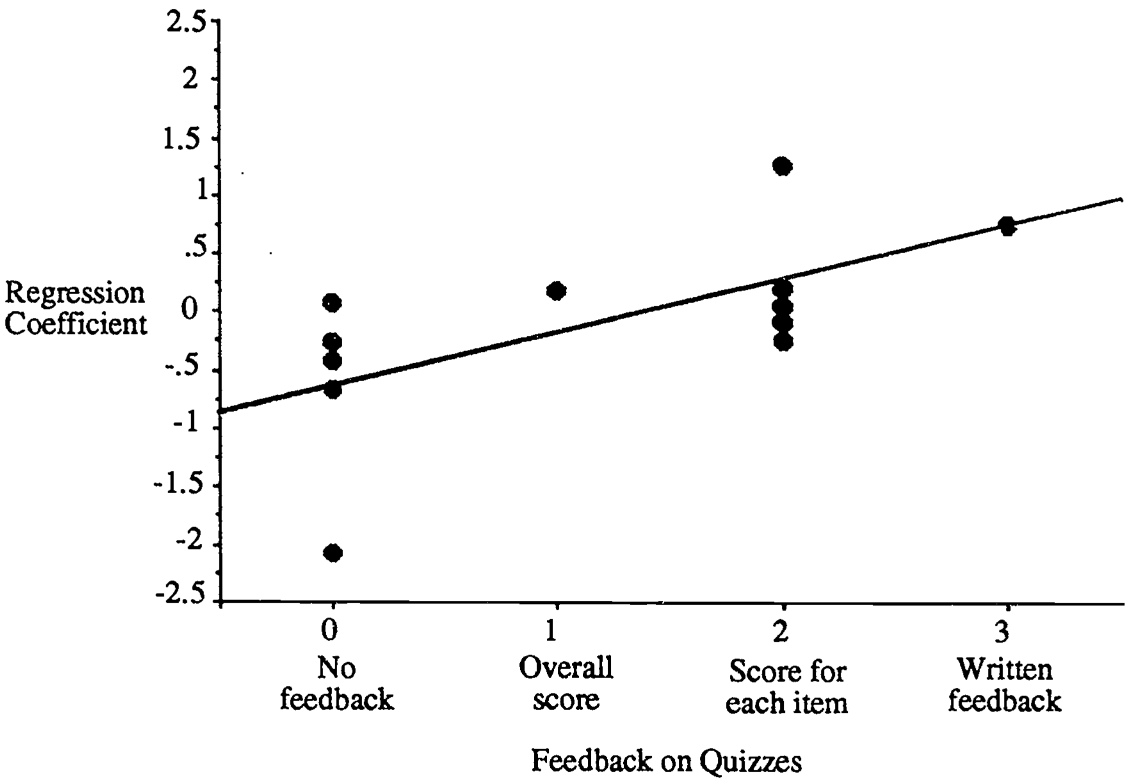
Multi-level Approach




Written feedback
Score for each score
Overall score
No feedback
Criterion Test
Effort Management Scale Score



Regression Coefficient
2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2.5
0
No feedback
1
Overall score
2
Score for each item
3
Written feedback
Feedback on Quizzes


2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
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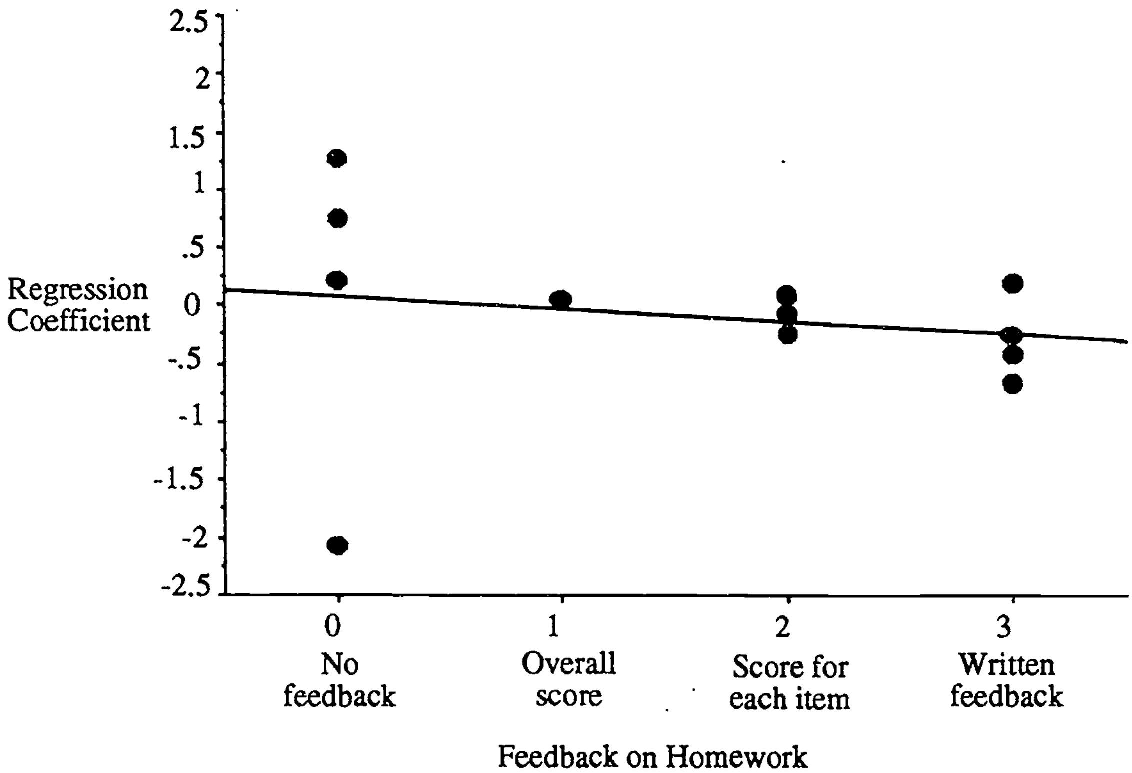
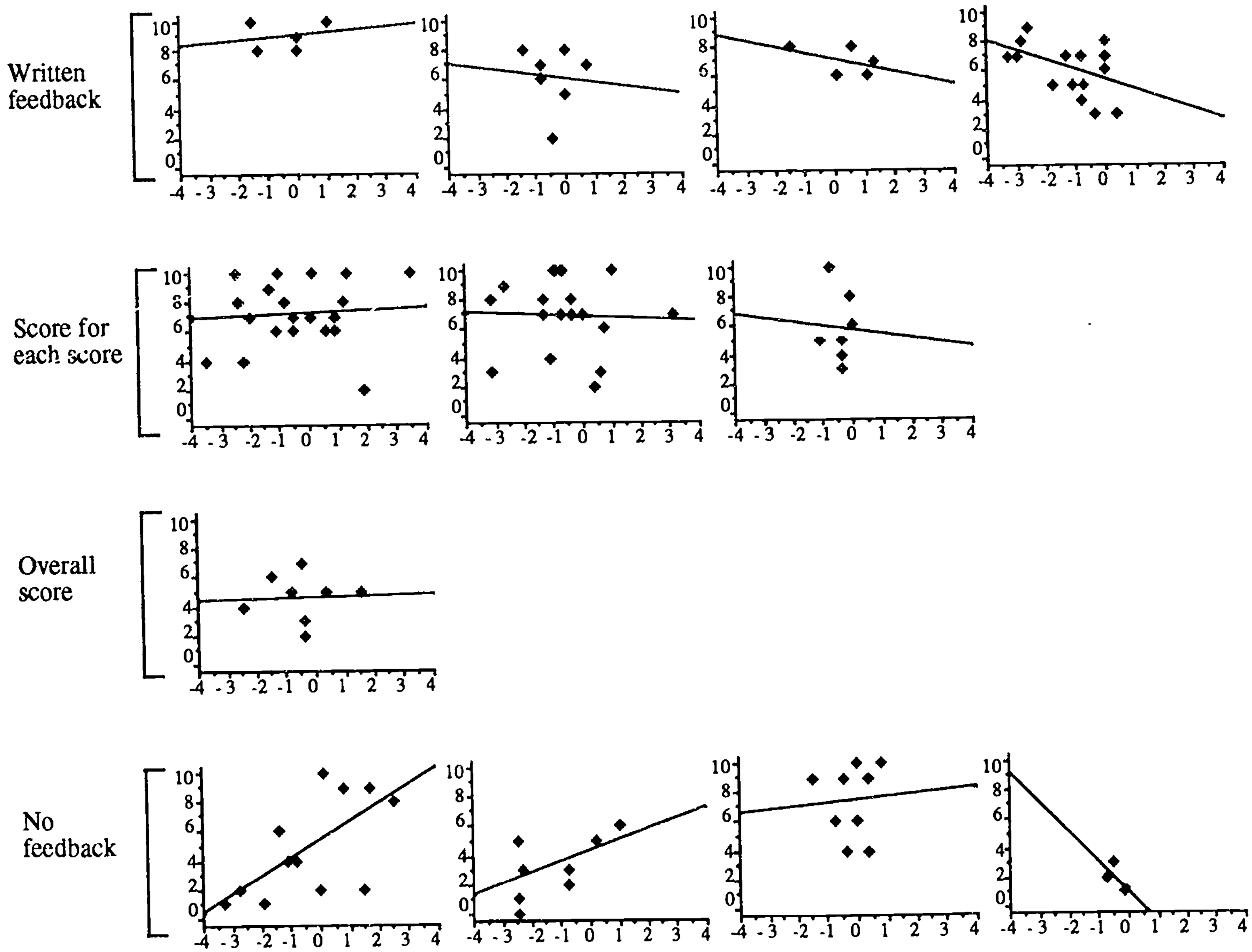
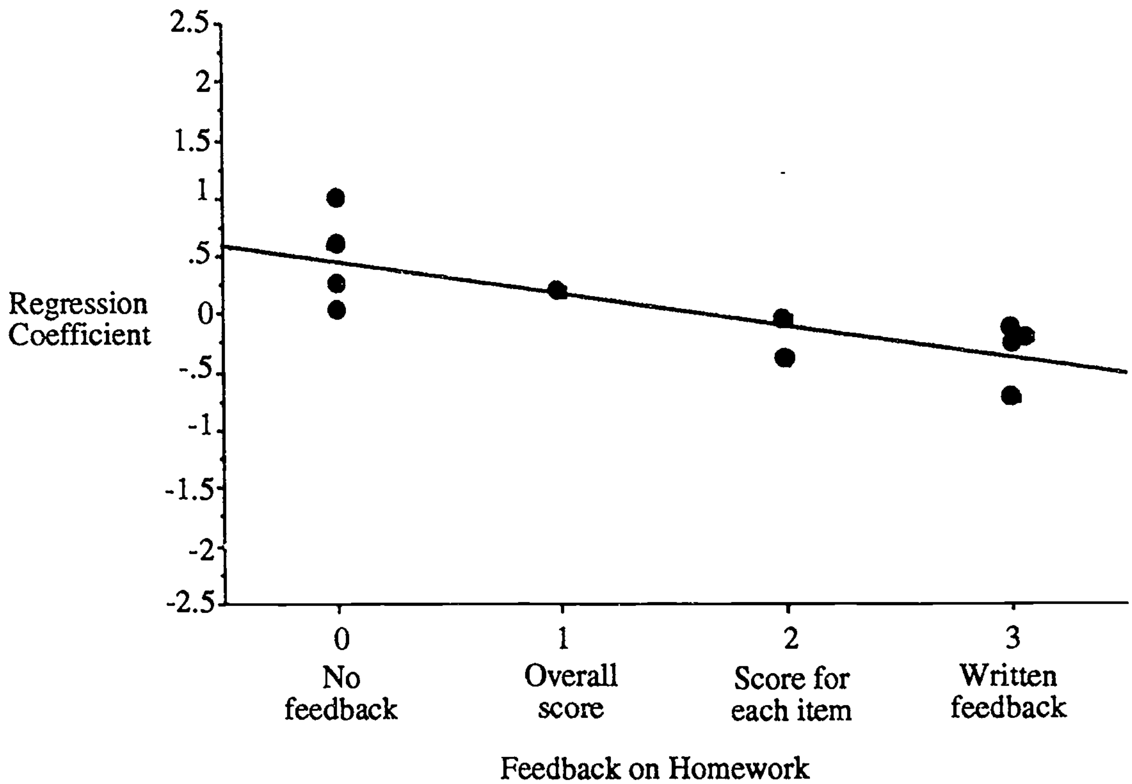
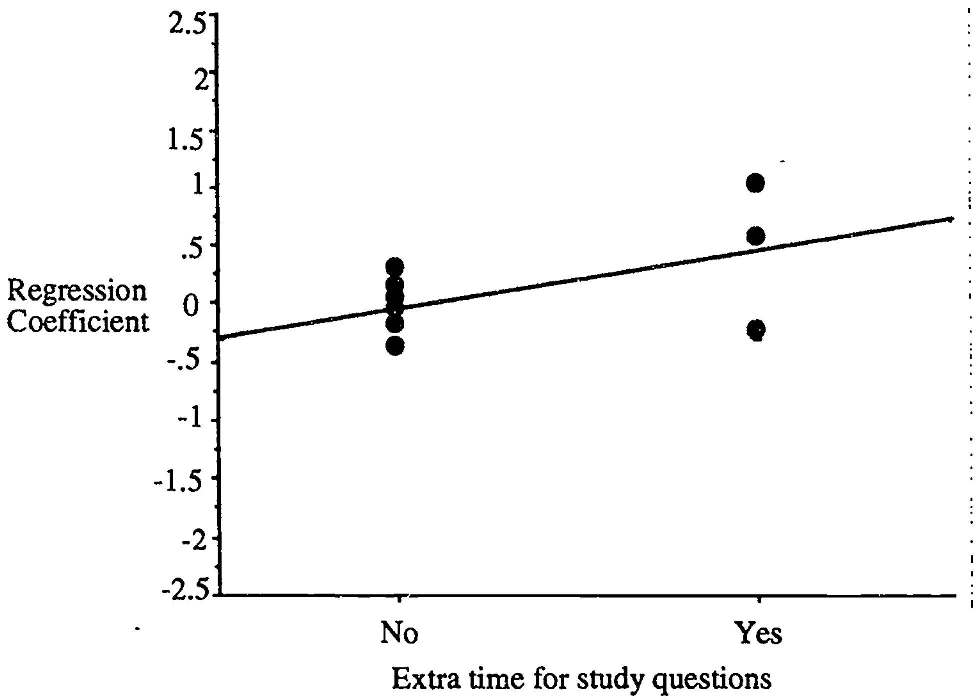
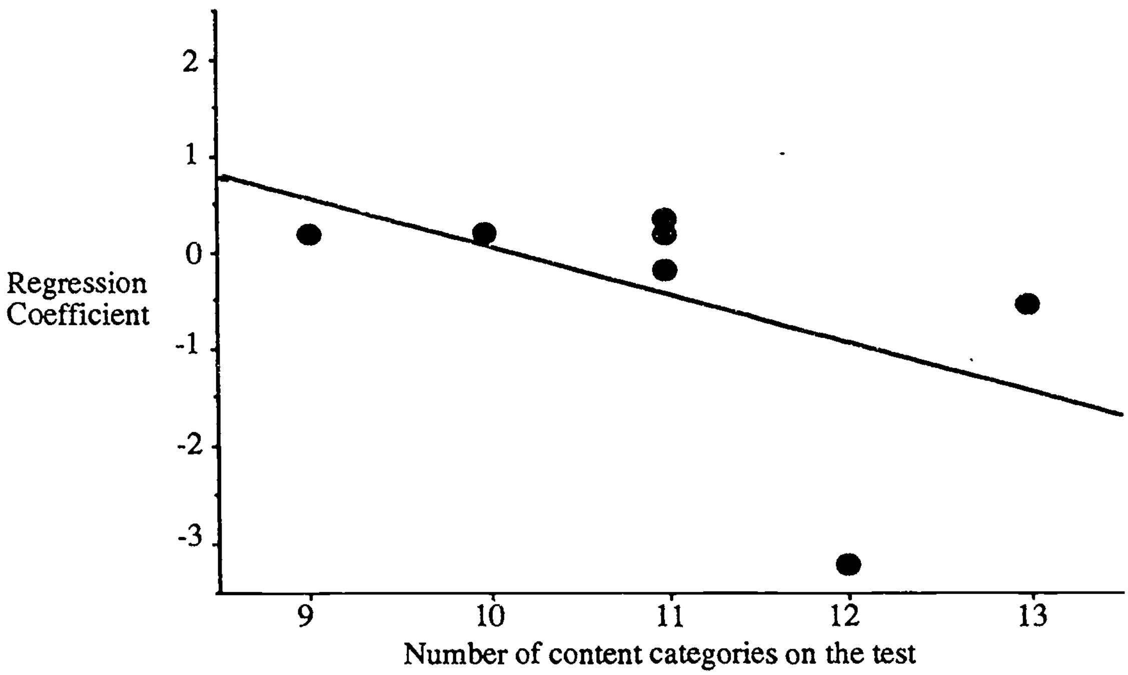
Regression Coefficient
0
No feedback
1
Overall score
2
Score for each item
3
Written feedback
Feedback on Quizzes


2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2.5
Regression Coefficient
0
No feedback
1
Overall score
2
Score for each item
3
Written feedback
Feedback on Homework


Written feedback
Score for each score
Overall score
No feedback


2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2.5
Regression Coefficient
0
No feedback
1
Overall score
2
Score for each item
3
Written feedback
Feedback on Homework


2.5
2
1.5
1
.5
Regression Coefficient
0
-.5
-1
-1.5
-2
-2.5
No
Yes
Extra time for study questions


2
1
0
Regression Coefficient
-1
-2
-3
9
10
11
12
13
Number of content categories on the test