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AUTHOR Peterson, Penelope L.; And Others

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ABSTRACT

To investigate questions concerning relationships among students' cognitive processes, aptitudes, later achievement and attitudes, and direct instruction, fifth- and sixth-grade students (N=72) were randomly assigned to one of six classes using a factorial assignment of ability level crossed with attitude. The questions addressed were: (1) What cognitive processes do students use during direct instruction? (2) How are students' aptitudes, including ability and attitudes, related to their reported cognitive processes during direct instruction? and (3) How are students' cognitive processes during direct instruction related to later achievement and attitudes? Videotapes of teacher and student behavior and classroom observations were made while each class of 12 students was taught a two-day lesson on probability. The teaching followed the direct instruction model and included review, development, controlled practice, and seatwork segments. After the lesson, students were interviewed about their thought processes using a "simulated-recall" procedure, and tested to assess their achievement of the basic concepts and skills taught in the lesson as well as their attitudes toward mathematics. Results showed that, independent of student ability, students' reports of their understanding of the lesson were significantly related to achievement. Moreover, students who reported using specific cognitive strategies did better on the achievement test than students who did not report using such strategies. (Author/RH)

Technical Report No. 581

STUDENTS' APTITUDES AND THEIR REPORTS OF COGNITIVE PROCESSES DURING DIRECT INSTRUCTION

by

Penelope L. Peterson, Susan R. Swing
Marc T. Braverman and Ray Buss

Report from the Project on
Studies of Instructional Programming for the Individual Student

Penelope L. Peterson
Faculty Associate

Wisconsin Research and Development Center
for Individualized Schooling
University of Wisconsin
Madison, Wisconsin

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Abstract

Fifth- and sixth-grade students (N = 72) were randomly assigned to one of six classes using a factorial assignment of ability level crossed with attitude. Each class of 12 students was taught a two-day unit on probability. The teaching followed the direct instruction model. Students were videotaped during the lesson. After the lesson, students were interviewed about their thought processes using a "stimulated-recall" procedure. Results showed that, independent of student ability, students' reports of their understanding of the lesson were significantly related to achievement. Moreover, students who reported using specific cognitive strategies, such as relating the information being taught to prior knowledge, did better on the achievement test than students who did not report using such strategies.

Introduction

For the past two decades, researchers on classroom processes have investigated the relationship between teacher behavior and student achievement (see, for example, Medley, 1979). These researchers have attempted to determine what teaching behaviors are most effective for enhancing the achievement of students. On the basis of this research, Gage (1978), Good (1979), and Rosenshine (1979) have suggested that direct instruction is the most effective approach for facilitating the mathematics achievement and reading achievement of elementary school students. In contrast, research using an aptitude-treatment interaction approach has suggested that the effectiveness of direct instruction depends on differences in student's aptitudes.[1] (See, for example, Peterson, 1979a, 1979b; Peterson and Janicki, 1979; Janicki and Peterson, 1981.)

However, the weakness of both these research approaches is that they ignore students' cognitive processes or thought processes during teaching and learning in the classroom. These processes clearly mediate between student differences and teaching behavior to produce differential achievement levels and attitudes (i.e., aptitude-treatment interactions). Although measures of student behavior, such as the amount of time a student is "on task" or engaged in learning, give us an idea of observable, mediating processes, they do not tell us what is going on inside a student's head while he or she is in the teaching-learning situation. One needs to understand differences between students and their cognitive processes to understand

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[1]"Aptitude" is used here to refer to any characteristic of a student that predicts his/her probability of success in a given instructional approach. Thus, aptitudes can include abilities, motivation, attitudes, and personality characteristics. (See, for example, Cronbach & Snow, 1977, p. 6).

classroom learning and to work toward a theory of teaching that considers differences between students in a classroom.

Doyle (1978) has described a mediating process paradigm for research on teacher effectiveness. Mediating process research is focused directly on "the implicit human processes that mediate between instructional stimuli and learning outcomes" (Levie & Dickie, 1973, p. 877). Mediating processes may include both overt behavior or observable processes and covert or unobservable processes. Doyle (1978) has argued that although overt variables may be useful proxies for initial work, they are relatively gross measures of students' cognitive processes. He suggests, therefore, that it is necessary to define more precisely the covert cognitive processes that operate during the teaching-learning situation.

Little research has been done on students' cognitive processes during a teaching-learning situation. Some early work was done by Bloom (1954) on students' thought processes during lecture and discussion. In his research, Bloom employed a "stimulated-recall" technique in which a student was shown a videotape of the lesson in which he or she participated to "stimulate recall" of the person's thought processes during the teaching-learning situation. After viewing a short segment of the videotape, the person was then interviewed regarding his/her thought processes during that segment of the videotape. Recently, Winne and Marx (Note 1) began a three-year project to identify cognitive processes needed to learn from teaching and to identify teacher behaviors that can signal students to use these processes. The ultimate goal of their project is to match students' cognitive processes and teacher's skills to enhance learning from teaching.

Unfortunately, the research by Bloom (1954) and Winne and Marx (Note 1) does not address the issue of differences in students' aptitudes. Clearly, students differ in their cognitive processes during a teaching-learning situation as they do in the aptitudes they bring into a classroom situation. These differences in cognitive processes may then ultimately affect their learning during instruction and their scores on an achievement test at the end of a lesson, at the end of a week, or even at the end of a school year. Furthermore, differences in cognitive processes may also be related to students' attitudes toward school, the teacher, the subject matter, and toward themselves as learners.

The present research addressed the following questions:

1. What cognitive processes do students use during direct instruction?

2. How are students' aptitudes, including ability and attitudes, related to their reported cognitive processes during direct instruction?

3. How are students' cognitive processes during direct instruction related to later achievement and attitudes?

Method

Subjects

The participants were 72 male and female students from a fifth/sixth-grade unit of an elementary school in a small city in Wisconsin. These students were selected from a pool of 294 students from an earlier study. Parent permission slips were sent home to all the students who had participated in the original study. The 72 subjects for this study were selected from these students who returned parent permission forms. Subjects actually chosen from the pool of students who returned permission slips were required to meet additional selection criteria.

In the earlier study, a principal-components analysis had been performed which yielded factors for ability and attitude. The math concepts subtest from Sequential Tests of Educational Progress (STEP) (Educational Testing Service, 1969) and the Raven's Progressive Matrices (Raven, 1958) loaded .55 and .55, respectively, on the ability factor. Attitude toward mathematics, measured with a scale developed by Peterson and Janicki (1979), and locus of control, as measured by the Academic Achievement Accountability Questionnaire (AAA) (Clifford, 1976), loaded .66 and .56, respectively, on the attitude factor. For the present study, 24 students were selected who were in the upper quartile on the ability factor, 24 students were selected who were in the second or third quartile on the ability factor, and 24 students were selected who were in the bottom quartile on the ability factor. In addition, within each ability group, students were selected from the initial pool such that half of the students within each ability group were above the median on attitude factor, and half of the students were below the median on the attitude factor. In a few cases where an insufficient number of students were available to satisfy the stratification criterion, students who did not originally volunteer were solicited by phone calls to their parents. If the parents agreed and signed the written permission form, then these students were also included in the study. Because the study was conducted over a two-day period during the summer, students were paid $10 for their participation in the two half-day teaching sessions.

The teacher in the study was one of the regular teachers in the classroom unit. Thus, all the children in the study knew him. The teacher volunteered to participate in the study and was paid for his participation.

Instrumentation

In the earlier study, the students had completed the Mathematics Basic Concepts (Form 4a) subtest from STEP (Cronbach's α = .84), Raven's Progressive Matrices (α = .82), the AAA (α = .80), and the attitude toward mathematics scale (α = .90).

The curriculum unit for the study consisted of a probability unit taught in two one-hour sessions. Practice problems were developed for the students to work on during the seatwork phase of each lesson. Each set of seatwork problems was scored and included as an outcome measure in the analyses. The 53 problems for lesson one (α = .95) provided practice on the objective of that day's lesson--finding the probability of a single outcome from among several possibilities. The objective of the second one-hour lesson was to teach students to find the probability of events that had two parts, such as "When flipping a coin twice, what is the probability of a head followed by a tail?" Students completed 45 problems (α = .94) designed to provide practice on this objective.

Student behavior during the lesson was coded by three coders using an adaptation of the observation system developed by Peterson and Janicki (1979). Each coder watched four students and checked the categories of behavior engaged in by each student during a 20-second interval. The generalizability of the observations was estimated by having two coders code twelve students. (See Cronbach, Gleser, Nanda, & Rajaratnam, 1972.) The generalizability of students' off-task behavior was .42. The low frequency of occurrence of off-task behavior probably contributed to the low generalizability.

Following each lesson and after the students had completed the seatwork for the lesson, students were interviewed using a stimulated-recall procedure. The interview form used during this procedure is shown in Figure 1.

Students' responses to the stimulated-recall interview were audiotaped and later transcribed. Each interview protocol was then coded by two coders. To check the validity of the transcription, each coder listened to the audiotape while coding the protocol. Students' responses were coded into the following major categories:

1. Attending: to what extent did the students' responses indicate that he or she was attending during this segment of the lesson.

2. Understanding: to what extent did the student report that he or she was understanding that portion of the lesson.

3. Students' Reasons for Not Understanding: a student's reported reasons for why he or she did not understand the lesson.

4. Students' Cognitive Strategies: the general and specific thought processes the student reported engaging in during that segment of the lesson, that helped him/her understand that portion of the lesson.

5. Teaching Processes: the student's perception of teacher behaviors and teaching strategies that helped him or her understand.

The generalizability of the codings of the stimulated-recall interview

Instructions for videotape viewing: In a few minutes I am going to ask you some questions about what you were doing or thinking at different times during the math lesson. But, first, you will look at different parts of the videotape we just made. Try to remember what you were doing and thinking during the part of the lesson you will see on the videotape.

Instructions for student interview: Now I am going to ask you some questions. There are no right or wrong answers. Answer each question as completely and honestly as you can. Remember, tell me what you were thinking or doing when Mr. Knickerbocker was first teaching you the lesson.

1. What were you thinking about during the part of the math lesson that you just saw on the videotape? If you were thinking about several different things, tell me about all of them.

ATTENDING TO THE LESSON

NO RESPONSE or "I DON'T KNOW"

Prompt: Try to remember what you were thinking about? What were you thinking about?

NO RESPONSE or "I DON'T KNOW"

Prompt: Were you paying attention?

"YES," "I DON'T KNOW," or NO RESPONSE

"NO"

NOT ATTENDING TO THE LESSON

Why were you thinking about ______?

UNSATISFACTORY RESPONSE

Prompt: What are some (other) reasons why you weren't paying attention?

2. During the time Mr. Knickerbocker was teaching, were you understanding the part of the math lesson that you just saw?

"YES," NO RESPONSE or "I DON'T KNOW"

What things did the teacher do to help you understand? Prompt: Tell me more about it or explain what you mean.

What things were you doing or thinking that helped you understand? Prompt: Tell me more about it or explain what you mean.

"NO"

What did you have trouble understanding? Prompt: Tell me more about it or explain what you mean.

Why were you having trouble understanding?

NO RESPONSE, "I DON'T KNOW," INCOMPLETE or UNSATISFACTORY RESPONSE

Prompt: Did the teacher do things that made it difficult for you to understand the math lesson? What were they?

What are some (other) reasons why you had trouble understanding the math lesson?

What things did you do or think about that should have helped you to understand? Prompt: Tell me more about it or explain what you mean.

Note: Use each prompt only once.

Figure 1. Stimulated-recall interview.

protocols was assessed using the procedure described by Cronbach, Gleser, Nanda, and Rajaratnam (1972). An estimate of the generalizability of the codings across coders was obtained by having two coders code the interview protocols of ten students. The estimated generalizability coefficients (ρ) for the actual study in which two coders coded all protocols were as follows: always attending (ρ = .92); sometimes attending (ρ = .92); understood everything (ρ = .98); eventually understood everything (ρ = .97); understood some (ρ = .97); understood none (ρ = .96); total specific student processes (ρ = .92); relating to prior knowledge (ρ = .92); motivating self (ρ = .87); no response to "What/Why did you have trouble understanding?" (ρ = .79); minimal rather than maximal response to the preceding question (ρ = .73); teacher's overview (ρ = 1.00); and no response to "What did the teacher do that helped you understand?" (ρ = .95). The following three categories were coded an insufficient number of times on the selected interview protocols to allow the calculation of generalizability coefficients: not sure whether attending, not sure whether understanding, and trying to understand teacher or problem--level 2.

As an additional measure of students' thought processes during the teaching-learning situation, a cognitive process questionnaire was developed. This questionnaire was designed as an objective measure of some of the same cognitive processes which the students were expected to report during the interview. The questionnaire consisted of 23 items to which the students responded on the following six-point scale: "usually," "often," "sometimes," "almost," "never," or "don't know." In responding to the items, the students were directed to think about things they thought about or did to learn the probability lessons as well as to think about how they learned math during the school year. The questionnaire included an "attending" subscale (α = .65), a "monitoring understanding" subscale (α = .22), and "specific cognitive strategies" subscale (α = .65). The 4-item attention subscale included such questions as "Do you miss important things your math teacher says because you aren't paying attention?" The 6-item monitoring understanding scale included such questions as "If you don't understand something the teacher says, do you figure out why you don't understand?" The specific cognitive strategies subscale included such questions as "When the teacher asks questions during the lecture, do you figure out the answers?"; "During the math lecture, do you think about things the teacher has said at different times during the lecture and try to put them all together so that the lesson makes sense?" and "When you do seatwork problems, do you think about how you should work the problem before you actually start to work it?" This subscale included 13 items. The internal consistency of students' responses to the total 23-item questionnaire was estimated to be .71 using Cronbach's alpha.

A 36-item achievement test was developed to assess the students' achievement of the basic concepts and skills taught in the probability unit. Cronbach's alpha for students' total scores on the achievement test was .90. In addition, the attitude towards mathematics scale was administered again as a posttest (α = .90).

<u>Procedure</u>

Before the study began, students were randomly assigned to one of six classes using a two-way factorial assignment of ability level (high, medium, and low) crossed with attitude (high or low). Thus, each class contained two students of each ability level by attitude level factor.

The classes were then randomly assigned to either mornings or afternoons over a consecutive two-day period. The study itself was conducted over a six-day period in the summer. Thus, class 1 met on Monday and Tuesday morning in week 1; class 2 met on Monday and Tuesday afternoon in week 1; class 3 met on Wednesday and Thursday morning; class 4 met on Wednesday and Thursday afternoon; class 5 met on Monday and Tuesday morning in week 2; and class 6 met on Monday and Tuesday afternoon in week 2. All class sessions were conducted in the students' regular classroom at the school.

The teacher taught the same two-day lesson to each class using lesson plans developed by the teacher and a graduate assistant. The detailed plan developed for each lesson listed the major points to be covered by the teacher, the specific examples to be used, the specific questions that the teacher would ask in his teaching, and the practice problems to be given to the students. The teaching followed the direct instruction model described by Good, Grouws, Beckerman, Ebmeier, & Flatt (Note 2). Thus, the teaching in each lesson had the following four segments: review, development, controlled practice, and seatwork. Review consisted of the teacher reviewing prerequisite skills that were necessary for the lesson. During the development portion of the lesson, the teacher elaborated the concepts and skills for the given lesson using lively explanations, demonstrations, and questions (active interaction with the class). Following the development portion of the lesson, the teacher engaged in controlled practice, which consisted of giving the students several problems one at a time to work at their seats. The teacher then gave immediate feedback to the students on the answers to the problem. The last twenty to thirty minutes of the lesson consisted of seatwork. During the seatwork portion of the lesson, students worked individually at their desks on the practice problems that they were given. The teacher monitored the individual seatwork and provided help to individual students as needed.

During each lesson, the students and the teacher were videotaped and also were observed. Two videotape cameras were used, each focused on one set of six students and, occasionally, on the teacher and the blackboard.

At the end of each lesson, students were interviewed using the stimulated-recall interview procedure. Six trained graduate assistants and the principal investigator served as the interviewers in this study. One of the graduate students served as a substitute for the principal investigator during the time she was not present. Six students were interviewed simultaneously while the other students engaged in other activities. The six students viewed a selected videotaped segment as a group, and then each student was interviewed individually using the interview shown in Figure 1. After being interviewed privately about segment one, students returned to the group of six students and viewed segment two. They were then interviewed privately about their thought processes during segment two. This procedure was followed until all five videotaped segments had been viewed and discussed. The videotaped segments were selected to represent critical incidents during the lesson. On day 1, students viewed three selected segments from the "development" portion of the lesson, one segment from "controlled practice," and one segment from the beginning of the seatwork portion of the lesson. On day 2, students viewed one segment of the "review" portion of the lesson, two segments from "development," one segment showing "controlled practice," and one segment from the beginning of the seatwork phase of the lesson. Because the content of the lesson closely followed the scripted lesson plans, these segments were selected so that all students saw segments containing the same content.

After the stimulated-recall interview on day 2, each student was given the cognitive processes questionnaire orally by the interviewer. On day 2, while half the students were being interviewed using the stimulated-recall procedure, the other half of the students completed the achievement test and the attitude towards mathematics posttest. The students then reversed roles and the students who had been tested were interviewed while the interviewees then completed the achievement test and attitude questionnaire. This procedure was followed due to practical time constraints. Student ability level and attitude level were counterbalanced across the order of testing so that the effects of ability and attitude would not be confounded with order of testing.

The interviews were coded by four graduate students following training and practice using the coding procedure. Two coders independently coded each protocol and then conferred and reached consensus on discrepant codings. Only student responses to the specific questions provided on the interview forms were coded. Student responses elicited by invalid prompts or leading questions were disregarded.

Results

Descriptive Statistics on Aptitudes, Outcomes and Cognitive Processes

The means and standard deviations of students' scores on the aptitude and outcome measures are presented in Table 1. Students' scores on the seatwork problems for day 1 and day 2 were scored in two ways. First, we

Table 1

Means and Standard Deviations of Students'

Scores on the Aptitude and Outcome Measures

Student Aptitudes	N	Mean	S. D.
STEP Test	72	31.37	8.52
Raven's Progressive Matrices	72	36.69	8.50
Attitude Toward Math Pretest	72	52.07	9.36
Student Outcomes			
Seatwork Day 1 Raw Score	72	32.55	11.70
Seatwork Day 1 Percent Correct of Total Attempted	72	75.50	19.20
Seatwork Day 2 Raw Score	72	28.83	10.86
Seatwork Day 2 Percent Correct of Total Attempted	72	71.80	17.70
Achievement Test	72	28.17	8.24
Attitude Toward Math Posttest	72	51.90	8.61

computed a raw score representing the total number of problems correct each day. Second, we computed a percent score representing the number of problems correct of the total problems attempted.

Analysis of the achievement test scores showed no significant effect for class, F (5,66) = .383, $p > .05$. This finding supported our informal observations that the teacher taught the lesson similarly and with equal effectiveness across classes.

Table 2 presents the means and standard deviations of students' scores on the cognitive processes variables. Students' responses to the stimulated-recall interview were coded in the following manner: If a given category occurred during a videotaped segment, then that category received a "1;" if the category did not occur, then it was given a "0." If a given category occurred more than once during a segment, it was not counted again but simply received a score of "1." Scores for each category were then totaled across the five videotaped segments on day 1 and the five videotaped segments on day 2. Thus, for most of the categories the maximum possible score for a given student was 10 and the minimum possible score was 0.

The categories of "attending" and "understanding" were scored in a slightly different fashion. For each videotaped segment, the coder made a judgement as to whether the student was attending all the time; attending sometimes; or not attending. Similarly, the coder made a judgement as to

Table 2

Means, Medians, Standard Deviations, and Possible Range of Students' Scores on the Cognitive Processes Variables

Cognitive Processes	N	Mean	Median	S.D.	Possible Range
Attending	67	27.76	28.15	2.36	10-30
Understanding	61	54.70	55.88	7.84	17-68
Minimal rather than maximal response to "Why/What did you have trouble understanding?"	45	2.90	2.07	2.36	0-18
Students' Cognitive Strategies					
Total General	66	7.64	7.00	3.50	0-50
Total Specific	66	16.05	16.00	6.36	0-120
Relating to prior knowledge	66	3.65	3.06	2.61	0-20
Trying to understand the teacher or problem--level 1	66	5.14	5.05	2.85	0-10
Trying to understand the teacher or problem--level 2	66	1.43	1.92	1.91	0-10
Repeating	66	0.20	0.02	0.57	0-10
Anticipating	66	0.38	0.04	0.90	0-10
Checking answer with teacher	66	0.33	0.15	0.75	0-10
Reworking problem	66	0.26	0.14	0.56	0-10
Reading/rereading directions	66	0.76	0.60	0.82	0-2
Asking for help	66	0.62	0.50	0.72	0-10
Motivating self	66	1.09	0.94	1.39	0-10

(continued)

Table 2 (cont.)

Means, Medians, Standard Deviations, and Possible Range of Students' Scores on the Cognitive Processes Variables

Cognitive Processes (cont.)	N	Mean	Median	S.D.	Possible Range
Teaching Processes					
Teaching	66	0.18	0.06	0.78	0-10
Explaining	66	3.03	2.31	2.33	0-10
Asking questions	66	0.64	0.19	1.25	0-10
Providing examples/using board	66	4.97	2.94	5.02	0-30
Providing help/feedback	66	2.10	2.00	1.26	0-20
Providing an overview	66	0.71	0.55	0.78	0-2
Reviewing	66	0.39	0.96	0.07	0-10
Monitoring understanding	66	0.38	0.14	1.00	0-10
Appropriate pacing	66	0.05	0.02	0.31	0-10
Stimulating cognitive processing	66	1.39	1.02	1.40	0-10
Creating a positive learning environment	66	0.55	1.14	0.09	0-10
No response to "What did the teacher do that helped you understand?"	66	1.27	0.92	1.57	0-10
Cognitive Process Questionnaire					
Total Score	72	82.78	83.17	10.35	23-115
Attending Subscale	72	17.29	18.00	2.63	4-20
Monitoring Understanding Subscale	72	21.47	21.59	3.13	6-30
Specific Cognitive Strategies Subscale	72	44.01	43.75	7.54	13-65

whether the student understood all the material in that segment; understood only some of the material in the beginning but eventually understood all the material; understood only some of the material during the whole segment; or understood none of the material. These responses were then scaled from 3 (attending all the time) to 1 (attending none of the time) for the attending category, and from 4 (understood all) to 1 (understood none) for the understanding category. Thus, across days, each student could receive a maximum score of 30 on attending and a minimum score of 10 on attending. On each of the days students were asked to report the extent of their understanding of each section of the seatwork problems during the fifth stimulated-recall segment. Thus, a total of nine judgements of understanding were made on day 1, and eight judgements of understanding were made on day 2. Student's scores on the understanding variable could therefore range from 68 to 17.

The category "total specific cognitive strategies" represents the total number of times any given specific cognitive strategy was coded across the ten videotaped segments. Specific cognitive strategies included the following categories: repeating and reviewing information to oneself; relating information to prior knowledge; anticipating an answer to a teacher's question; trying to understand the teacher or figure out a problem, checking one's answer with the teacher or a student; reworking a problem in one's head or on paper if the answer were incorrect; reading or rereading directions or problems; and motivating oneself with thoughts.

Some students were missing data from the stimulated-recall interview because sections of their audiotaped interview were inaudible or because of technical failures in audiotaping the interview. A student missing three or more of the five videotaped segments on a given day was eliminated from the analysis. In addition, certain questions such as "What/Why did you have trouble understanding?" were asked only if the student indicated that he or she was having trouble understanding. Thus, the N for this category was lower than the N for the other categories.

The Relationship of Cognitive Processes to Aptitudes and Outcomes

Students' cognitive processes scores from the stimulated-recall interview and the Cognitive Processes Questionnaire were correlated with students' scores on the aptitude measures and the outcome measures. Kendall correlations (tau, τ) were computed because students' scores on the stimulated-recall categories were not normally distributed. Table 3 presents Kendall correlations between students' aptitude scores and their cognitive processes scores. Table 4 presents Kendall correlations between students' cognitive processes scores and their scores on the outcome measures. Table 5 presents Kendall correlations between students' cognitive processes scores on the stimulated-recall interview variables and on the Cognitive Processes Questionnaire.

Discussion

We will discuss the results of the study according to each cognitive processes category.

Attending

The attending category represented the degree to which the student appeared to be attending to the lesson based on his/her responses to the stimulated-recall interview questions. Students' scores on the attending variable were significantly positively related to their scores

Table 3

Kendall Correlations of Students' Aptitude

Scores with Students' Cognitive Processes Scores

		Student Aptitudes		
Cognitive Processes	N	STEP Test	Raven's	Attitude Toward Math Pretest
Attending	67	.17*	.08	.00
Understanding	61	.27***	.19*	.04
Minimal rather than maximal response to "Why/What did you have trouble understanding?"	45	.01	-.06	.08
Total General Cognitive Strategies	66	-.14	-.20**	-.06
Total Specific Cognitive Strategies	66	.23**	.17*	.19*
Relating to prior knowledge	66	.23**	.12	.26**
Trying to understand the teacher or problem--Level 2	66	.38***	.25**	.08
Motivating self	66	-.16*	-.04	.17*
Teacher's overview helped understanding	66	.16	.02	.03
No response to "What did the teacher do that helped you understand?"	66	-.19*	-.09	-.01
Total Score on Cognitive Processes Questionnaire	72	.23**	.24**	.16*
Attending Subscale	72	.18*	.16*	.16*
Monitoring Understanding Subscale	72	.15*	.09	.08
Specific Cognitive Strategies Subscale	72	.20**	.27***	.16*

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 4

Kendall Correlations of Students' Cognitive Processes Scores with Students' Scores on the Outcome Measures

Cognitive Processes	N	Seatwork Day 1 Raw Score	Seatwork Day 1 Percent	Seatwork Day 2 Raw Score	Seatwork Day 2 Percent	Achievement Test	Attitude Posttest
Attending	67	.09	.19**	.24**	.20**	.12	-.04
Understanding	61	.39***	.20**	.42***	.23**	.37***	.08
Minimal rather than maximal response to "Why/What did you have trouble understanding?"	43	-.16	-.16	-.27**	-.20*	-.31**	-.09
Total General Cognitive Strategies	66	-.07	-.08	-.18*	-.13	-.18*	-.09
Total Specific Cognitive Strategies	66	.24**	.25**	.26***	.23*	.18*	.15*
Relating to prior knowledge	66	.17*	.22**	.18*	.20**	.09	.00
Trying to understand teacher or problem--level 2	66	.33***	.38***	.36***	.35***	.37***	.03
Motivating self	66	.06	.05	.03	-.02	-.05	.26**
Teacher's overview helped understanding	66	.29**	.20*	.34***	.23**	.21*	.11
No response to "What did the teacher do that helped you understand?"	66	-.20**	-.13	-.16	-.02	-.14	-.06
Total Score on Cognitive Process Questionnaire	72	.21**	.26***	.20**	.23**	.18**	.19**
Attending Subscale	72	.11	.13	.29***	.28***	.24**	.23**
Monitoring Understanding Subscale	72	.12	.11	.10	.08	.09	.11
Specific Cognitive Strategies Subscale	72	.21**	.28**	.18*	.23**	.13	.16*

*$p < .05$; **$p < .01$; ***$p < .001$.

Table 5

Kendall Correlations of Students' Scores on the Cognitive Processes Interview Variables with Students' Scores on the Cognitive Process Questionnaire

Cognitive Processes	N	Total Score on Cognitive Process Questionnaire	Attending Subscale	Monitoring Understanding Subscale	Specific Cognitive Strategies Subscale
Attending	66	.25**	.13	.25**	.26**
Understanding	60	.14	.23**	.23**	.07
Minimal rather than maximal response to "Why/What did you have trouble understanding?"	45	-.20*	-.27**	-.19*	-.14
Total General Cognitive Strategies	66	-.11	.07	-.04	-.13
Total Specific Cognitive Strategies	66	.17*	.11	.11	.19*
Relating to prior knowledge	66	.06	.13	.03	.06
Trying to understand teacher or problem--level 2	66	.37***	.15	.34***	.33***
Motivating self	66	.05	-.12	.01	.07
Teacher's overview helped understanding	66	.05	.22*	.14	.03
No response to "What did the teacher do that helped you understand?"	66	-.08	.02	-.02	-.09

*p < .05; **p < .01; ***p < .001.

on the STEP test but were not related to their scores on the Raven's test or the attitude toward mathematics pretest (see Table 3). Thus, students who were higher on initial mathematics achievement tended to pay more attention during the lesson. Furthermore, attending was positively and significantly related to students' scores on the seatwork problems on days 1 and 2, but was unrelated to their scores on the achievement test (see Table 4).

These correlations suggest that attending may be more related to a proximal measure of achievement than to a delayed measure of achievement. Recently, several researchers have suggested that the amount of time a student spends engaged in learning (i.e., attention to the learning task) is a significant predictor of achievement (see, for example, Fisher, Berliner, Filby, Marliave, Cahen, & Dishaw, 1980). The results of this study suggest that students' reports of attending do seem to be related to achievement, at least to achievement on the immediate task to which students must attend. Interestingly, observed off-task behavior was unrelated to students' reports of attending ($\tau = .09$) or to scores on the achievement test ($\tau = -.09$).

Correlations of attending with other variables in this study may be lower than one would normally find in a regular classroom situation. This may be due to a ceiling effect on the attending variable. As reported in Table 2, the average score on attending was 27.76 out of 30, which suggests that students were attending to the lesson nearly all the time. Our observations of students' behavior indicated that, in fact, students were off-task during only .1 percent of the 20-second intervals coded, thus corroborating students' reports of their attention. We think that students' level of attention might have been very high for several reasons. First, there were only twelve students in each class. Second, although the study was conducted in a regular school classroom, the study was very much like a laboratory study because the teaching was highly controlled, and the students were videotaped during their learning. Finally, students had volunteered to participate in this study and were paid for their participation.

Correlations between students' scores on the stimulated-recall cognitive process variables and their scores on the Cognitive Processes Questionnaire give some indication of the validity of the cognitive processes constructs that we are investigating. Students' stimulated-recall scores on attending were related to their total scores on the Cognitive Process Questionnaire and to their scores on the Monitoring Understanding subscale and the Specific Cognitive Processes subscale, but they were not related to students' scores on the Attending subscale of the questionnaire. Thus, it appears that the Attending subscale of the Cognitive Processes Questionnaire was measuring something different from the attending category on the stimulated-recall interview. The Attending subscale of the Cognitive Processes Questionnaire may be measuring general attentional habits while the attending category on the interview may provide a measure of situation-specific attention. Moreover, the significant positive correlations between students' scores on the Attending subscale and students' achievement scores suggest that students' general attentional habits may be importantly related to achievement. (See Table 4.)

Understanding

Students' reports of their understanding of the lesson were moderately related to their achievement. As indicated in Table 4, students' scores on understanding were significantly and positively correlated with their scores on the seatwork problems on both days and with their scores on the achievement test. Thus, students who reported during the stimulated-recall interview that they understood all of the material tended to be those students who also did well on the seatwork problems and on the achievement test. However, students' reported understanding was also significantly positively related to their scores on the STEP test and the Raven's Progressive Matrices. Thus, students who were high on mathematics ability as measured by these two tests tended to be those students who reported that they understood the material during the lesson. When mathematical ability as measured by the STEP test was partialed out, students' scores on the understanding variable were still postitively and significantly related to achievement (τ .31 for the raw score on day 1 seatwork; $\tau = .36$ for the raw score on day 2 seatwork; and $\tau = .28$ for the achievement test). Therefore, independent of student ability, students' reports of their understanding of the lesson were still related to their achievement at the end of the lesson.

Our findings on students' reports of their understanding support the proponents of metacognitive research such as Brown (1978) who have argued that the ability to monitor one's own understanding of instruction is an essential prerequisite for learning. Brown (1978) cites the following quote by Holt from his book, <u>How Children Fail</u> (1964):

> Part of being a good student is learning to be aware of one's own mind and the degree of one's own understanding. The good student may be one who often says he does not understand, simply because he keeps a constant check on his understanding. The poor student who does not, so to speak, watch himself trying to understand, does not know much of the time whether he understands or not. Thus, the problem is not to get students to ask us what they don't know; the problem is to make them aware of the difference between what they know and what they don't. (pp. 28-29)

Our data support Holt's notion that knowing what and/or why one does not understand is important. As indicated in Table 4, students who did not provide detailed explanations of what/why they had trouble understanding tended to do poorly on the seatwork problems on day 2 and on the achievement test. Surprisingly, students' scores on this variable were unrelated to their ability.

Students' scores on the understanding variables on the stimulated-recall interview were positively correlated with students' scores on the monitoring understanding subscale of the Cognitive Processes Questionnaire. Understanding scores were also correlated with scores on the attending subscale of the Cognitive Processes Questionnaire (see Table 5). Thus, these correlations provided some indication of construct validity for the understanding category but also suggest some overlap between the understanding category on the stimulated-recall interview and the attending category of the Cognitive Processes Questionnaire (see Table 5).

Students' Cognitive Strategies

During the stimulated-recall interview, students were asked to describe what things they were doing or thinking about that helped them understand. Students' responses to this question were categorized according to the strategy that was used and according to whether the strategy was a general strategy such as "thinking," "listening," or "working," or whether the strategy was a more specific cognitive strategy as described above.

Type and frequency of specific strategies reported. As shown in Table 2, students mentioned, on the average, a total of 7.64 general cognitive strategies across all segments of the stimulated-recall interviews. In contrast, students mentioned an average of 16.05 specific cognitive strategies The most frequently mentioned specific strategy was "trying to understand the teacher or a problem--level 1." Examples of this category include the following:

Student: "I was thinking about how I was going to do the problems."

Student: "Well, I thought about it in my brain--how I could get the answer, you know, like I was adding and dividing . . ."

Student: "I was just sort of following along in my brain what he (the teacher) was writing on the board and trying to sort of match 'em up and everything."

Another specific strategy that was frequently mentioned by students was relating the information being taught to prior knowledge or to prior information presented by the teacher. (See Table 2.) The following is an example of this category:

Student: "Well, I was thinking about, you know, I was trying to remember stuff from last year that I was taught and, you know, numerator and denominator, which was which and stuff like that."

Student: "As I was working out the problems, I looked at the chart on the board that he made for us and that made the problems go easier 'cause as he wrote down the chart he explained how it was supposed to work for the problems."

Specific cognitive strategies that were not mentioned frequently included "repeating," "anticipating," "checking one's answer with the teacher," and "reworking the problem." Repeating involved repeating the information to oneself. Anticipating included trying to anticipate what the teacher would say or what information would be presented. Checking one's answer included statements like the following:

Student: "Well, I'd do the problems in my head and I saw if I came up with the same answer as the person he called on did."

Relationship of specific strategies to aptitudes and outcomes. The total number of specific cognitive strategies mentioned by a student was positively related to students' scores on the seatwork problems on days 1 and 2 and to the students' scores on the achievement test. Thus, students who articulated specific cognitive strategies that they used during the teaching-learning situation tended to have higher scores on the achievement measures than students who did not articulate such cognitive strategies. In contrast, the total number of general cognitive strategies mentioned by a student was negatively related to students' scores on the achievement test. Taken together with the findings for attending, these findings suggest that it is not simply attending but rather what the student does while attending that is important.

Students' scores on the total specific cognitive strategies were also significantly related to ability scores as measured by the STEP test and the Raven's test. When students' scores on the STEP test were partialed out, students' scores on specific cognitive strategies were no longer significantly related to achievement scores. Thus, one might conclude that the correlation between students' use of specific cognitive strategies and student achievement is trivial because the effect appears to be due to ability. On the other hand, one might argue that employing such specific cognitive strategies are, in fact, the very essence of ability. For example, Brown (1978) has argued that cognitive processes such as predicting, planning, checking, and monitoring are the essence of intelligent activities. The latter interpretation of the correlational finding also agrees with the approaches of other investigators who define ability in terms of a variety of constituent cognitive processes (see, for example, Carroll, 1976; Guilford, 1956).

Students' reported use of two specific cognitive strategies appeared to be importantly related to student achievement. One strategy was relating the information being taught to prior knowledge or prior information. As indicated in Table 4, students who reported that they attempted to relate the information to their prior knowledge tended to do better on the seatwork problems on days 1 and 2. However, these students also tended to be higher in prior achievement as measured by the STEP test (see Table 3). When students' scores on the STEP test were partialed out, the relationship between students' scores on relating to prior knowledge and their seatwork scores was no longer significant. Thus, employing a strategy such as relating new information to prior knowledge seems to be highly related to one's learning and achievement of new knowledge, but is also highly related to one's learning and achievement of previous knowledge.

A second cognitive strategy that was highly related to students' achievement was students' reports of trying to understand the teacher or a problem--level 2. The "level 2" distinction indicated that the student reported employing a relatively sophisticated approach in attempting to understand the lesson. This category was coded whenever a student's response included information about (a) a sequence of specific or general problem solving steps which were used; (b) strategies required to work the problem; or (c) insights about the nature of the material. Examples of this category are the following:

Student: "I was figuring out how many, like how many there were, how many chances there were to get 'em and then I thought how many chances were there to get anything."

Student: "I added up how many possibilities there were to get those numbers, and then I added up the total possibilities."

Students' responses in this category were significantly positively related to students' scores on the achievement measures (see Table 4). Students' scores in this category also tended to be positively related to student ability as measured by the STEP test and the Raven's (see Table 3). However, when students' scores on the STEP test were partialed out, the relationship between "trying to understand the teacher or problem--level 2" and student achievement was still significant (τ = .27 for percent correct on lesson 1 seatwork; τ = .24 for percent correct on lesson 2 seatwork; and τ = .21 for the achievement test). Thus, students who indicated an awareness of attempting to try to figure out a problem or material being presented, as well as showing some awareness of the necessary steps involved to solve the problem, did better on the achievement test than the student who did not show such an awareness.

Of all the categories on a stimulated-recall interview, the category of "trying to understand teacher or a problem--level 2" was most highly related to students' scores on the Cognitive Processes Questionnaire. Scores in this category were positively significantly related to students' total scores on the Cognitive Processes Questionnaire as well as to thei: subscale scores on the monitoring understanding subscale and their s cognitive strategies subscale.

A third category, "motivating self," was the only cognitive strategy category that pertained to affective thought processes by the student. An example of such motivating self-statements would be:

Student: "Work 'em out good! Try my best to get it right."

Not surprisingly, students' reports of making such motivating statements were significantly positively related to both their attitudes on the mathematics pretest and their attitudes toward mathematics on the posttest. In contrast, such motivating statements were unrelated to students' achievement on the seatwork or the achievement test. It appears that thinking thoughts to motivate oneself is related to one's motivation at the beginning and at the end of a curriculum unit. Students who tended to think motivating thoughts were those students who also tended to have positive attitudes towards mathematics at the beginning and at the end of the unit.

Teaching Processes

During the stimulated-recall interview, students were asked to respond to the question "What things did the teacher do to help you understand?" One teaching strategy mentioned by students was that the teacher provided an overview which helped them understand. This category of teaching processes was mentioned with the greatest frequency relative to the number of times it could have been mentioned (see Table 2). An example of this category is the following:

Student: "Right before we started 'em [the seatwork problems] he kind of went over it, the directions, and went over a couple problems that might be harder for us."

In this study, the teacher provided an overview before students began to work on the seatwork problems. Students who in the stimulated-recall interview indicated an awareness of the overview and indicated that it helped them understand were also those students who tended to do well on the seatwork problems and the achievement test. Moreover, students' mention of the teacher's use of an overview was unrelated to students' scores on the STEP test and the Raven's Progressive Matrices.

Provision of an overview or an "advance organizer" is a teaching strategy that has been highly recommended by educational psychologists as an effective strategy for facilitating students' learning (see, for example, Ausubel, 1968; Gagné, 1974.) It appears from this study that students who were aware of the overview provided by the teacher tended to achieve at a higher level than those students who were unaware of the teacher's overview.

Summary and Conclusions

The present findings show that ability is positively related to achievement but that a number of cognitive processes are related to both ability and achievement. Although the results of this study are only correlational, we would interpret them as suggesting cognitive processes which define ability and produce achievement. According to student responses to the stimulated-recall interview, the picture that emerges is that higher ability students are more inclined to attend to the lesson; to employ either a variety of specific cognitive strategies or to engage in these processes more frequently; to use the specific strategy of relating to prior knowledge; to report problem-solving steps and insights about the material; and to acknowledge the teacher-provided overview as a technique which promotes understanding. In addition, higher ability students are more likely to report that they understand the lesson. On the other hand, lower ability students are more likely to provide only general or imprecise reasons for what/why they do not understand.

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ASSOCIATED FACULTY

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Professor
Curriculum and Instruction

W. Patrick Dickson
Assistant Professor
Child and Family Studies

Fred N. Finley
Assistant Professor
Curriculum and Instruction

Lloyd E. Fronreich
Professor
Educational Administration

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Sociology

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Curriculum and Instruction

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English and Linguistics

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Assistant Professor
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Barbara J. Shade
Assistant Professor
Afro-American Studies

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Center Director and Professor
Educational Policy Studies and Educational Psychology

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Sociology

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Educational Psychology

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Professor
Educational Psychology