

# Teaching Behavior and Student Learning Outcomes in Dutch Mathematics Classrooms

Citation for published version (APA):

Tomic, W. (1989). Teaching Behavior and Student Learning Outcomes in Dutch Mathematics Classrooms. *Journal of Educational Research*, 82(6).

## Document status and date:

Published: 01/01/1989

## Document Version:

Peer reviewed version

## Please check the document version of this publication:

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# Teaching Behavior and Student Learning Outcomes in Dutch Mathematics Classrooms

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**ABSTRACT** In this article I described the means of identifying teaching behaviors that have cognitive and affective learning effects on students who are taking a course in mathematics. This study was conducted on 50 mathematics teachers who were teaching in the eighth grade. I obtained the data on teaching behaviors through direct systematic observation. Multiple regression was used as the method of analysis. For the cognitive domain, the results showed that effective teaching behaviors are (a) high-level questions put to a large group of students, (b) probing, followed by a correct student response, (c) teacher waiting after asking a question, (d) successful redirecting, and (e) all forms of positive acknowledgement. Effective teaching behaviors in the affective domain are (a) all forms of teacher lecture/explanations, (b) probing, followed by correct student response, and (c) all forms of positive acknowledgement. More teaching behaviors have a positive effect on mathematical knowledge than have a positive effect on students' attitude toward mathematics.

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In all educational activities, teachers try to realize specific learning objectives by applying more or less specific teaching behaviors. In this article I identified those teaching behaviors that have possible cognitive and affective learning effects on students taking a course in mathematics. By teaching behaviors, I mean alterable behaviors belonging to the following categories: teacher lecturing, explaining, and providing instructional cues, questioning, giving opportunities to respond, providing feedback, and nonacademic interactions.

I defined learning outcomes as cognitive, as well as affective, student outcomes. Cognitive outcomes are reflected by the students' scores on achievement tests. Affective student outcomes in this study represent scores on an attitude scale toward the subject of mathematics. I examined which combination of teaching behaviors within the five different categories best predicts student learning outcomes, as measured by the average class posttest

scores in the sample of 50 teachers. Using multiple regressions of mathematics achievements and attitudes of students toward mathematics for each category of teaching behaviors, I traced which linear combination of teaching behaviors explains most of the variance in student learning outcomes. Also, I distinguished between teaching behaviors affecting student learning outcomes both in the cognitive and affective domains.

This study is part of a wider research program that has the general objective of identifying teaching behaviors and the desired student learning outcomes in mathematics. Based on the results of this study, I described possible effective teaching behaviors that I would like to apply to the development of an experimental training course in which teachers will be given directions for organizing teaching learning processes in the classroom. I began this study by formulating this research question: Which combination of teaching behaviors within the five categories is possibly effective in relation to student learning outcomes in the cognitive and affective domain?

## Method

### *Research Design*

To answer the above-mentioned research question, I employed a pre/postcorrelational design and observed 50 mathematics teachers, during eight lessons each, for 8 months. In order to calculate statistical association measures between teaching behaviors on one side and student learning outcomes on the other, one is required to have available data about student learning outcomes at the end of the observation period. Evidence consistently suggests, however, that cognitive student entry behavior deter-

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mines to a great extent the results that students achieve after having taken a particular course (Bloom, 1976). Therefore, when investigating influences of teaching behaviors on student learning outcomes, one must adjust for cognitive entry behavior and affective entry characteristics of students. To make adjustments regarding influences of students' cognitive entry behavior and affective entry characteristics in mathematics, pretests are indispensable.

### *Population and Sample*

The study population was composed of mathematics teachers working in the eighth grade. All of the 17 selected schools used one of the following textbooks: *Getal en Ruimte* (Number and Space), *Moderne Wiskunde* (Modern Mathematics), or *Sigma*. The 17 schools, which could be reached by train, were drawn at random from schools throughout the Netherlands, within the above constraints. The sample involved 50 mathematics teachers.

### *Data Collection Regarding Teaching Behaviors*

I obtained the data on teaching behaviors or process variables by the direct systematic observation method and registered the student-teacher interactions using the Five-Minute Interactions Instrument (FMI). Five well-trained observers registered the applied teaching behaviors in each classroom during five periods of 5 min a lesson, totaling eight lessons of approximately 50 min. The length of an interaction was 5 s. The FMI instrument was based largely on instruments developed by the Stanford Research Institute (Stallings, 1977) and is widely used in other classroom studies (Goodlad, 1984).

Using the FMI instrument, I obtained a survey of the teaching behaviors during five different 5-min periods of eight lessons. Coding with the FMI instrument was teacher oriented. I coded student behavior only when the student interacted directly with the teacher. Each interaction was specified by means of three codes: content of the interaction, context within which the interaction occurred, and who was interacting with whom.

**Content.** The content area comprised five categories: instruction, teacher questioning, teacher giving opportunity to respond, teacher providing feedback, and non-academic interactions. Instruction included the presentation or explanation of academic content (teacher lecturing, explaining, providing instructional cues), with or without material aids.

Within the question category, a distinction was made between questions requiring short-term memory recall and those requiring more complex cognitive operations such as the manipulation of information previously acquired. I gave a separate code to those questions allowing the expression of personal ideas, feelings, or opinions. Questions that the teacher redirected to another student following an unsatisfactory response were similarly coded

separately. Student response codes differentiated between responses produced independently and those that involved reading from a text. Any explicit indication that the student did not know the answer was coded as *student does not know*.

Within the feedback category, codes specified whether the teacher gave positive or negative acknowledgement to a student response and noted how frequently the teacher repeated or gave answers. I also coded attempts to seek feedback about teacher effectiveness in explanations or clarifications. Absence of teacher-student interactions during academic tasks was coded as "silence." Nonacademic interactions were coded as "discipline," "procedure," or "social." Whenever background noise prevented the observer from hearing the content of an interaction, I used the code "cannot hear."

**Context.** One of six context codes recorded the setting for every interaction. The fact that teachers may interact with varying numbers of students was acknowledged by distinguishing among large group, small group, or private interactions. "Monitoring" was the context code when the teacher supervised students who were working independently. If the teacher was working at his or her desk and not supervising the students at their seat work or if the teacher was interacting with someone outside of the observed class, "noninvolved" was indicated. On those occasions when the teacher was observed to be directing the students from one academic activity to another, I used the "transition" context code.

**Who-to-whom interactions.** These codes identified who initiated the interaction and with whom the interaction occurred. I coded teaching behaviors as "teacher to group" and "teacher to student" in an on-going interaction or "teacher to others" not within the classroom. Student behaviors were coded as "group to teacher" and "student to teacher."

### *Training of Classroom Observers*

The five classroom observers were trained for 8 days, beginning with 6 consecutive days before the collection of classroom data and an additional 2 days of refresher training 3 months after the initial training during the period of classroom visits. The training consisted essentially of discussions familiarizing the observers with the FMI instrument, followed by extensive practice and homework in the use of the instruments. The observers had to learn the definitions of the codes and become sufficiently proficient so that a minimum of 60 interactions could be coded accurately within a 5-min period. The training also consisted of practical exercises using videotaped and audiotaped classroom situations. All observers visited classrooms for four practice sessions to allow them to practice in a realistic setting.

I began a formal check on observer agreement on the third day of training and repeated it on subsequent days.

Toward the end of each day, the trainer compared the observers' frequencies with his or her own. The research team had set the standard of comparison as a discrepancy no greater than 5%. By the end of the 6 days, the five observers had achieved an acceptable level of accuracy. I conducted another check on observer agreement two weeks after the training. These results also were satisfactory. Although 60 coded interactions per 5 min of classroom instruction initially seem high, this frequency could occur routinely in 5-min periods of classroom time.

#### *Interobserver Agreement and Reliability*

I examined whether the five observers displayed any differences in coding the teaching behaviors. First, from the data that they collected, I estimated the interobserver agreement between observer-pairs using the pairwise observation method (live observations). Two observers simultaneously performed observations in one classroom. I counted the number of codes in a specific category that each observer used and correlated these counts with one another for each category. Then I performed this calculation for each of the nine observer-pairs.

Second, I estimated the reliability of observation (audio observations) by determining the internal consistency coefficient alpha (Cronbach, 1951). To do this, I worked with an additional set of data obtained by having all observers simultaneously code five different 5-min fragments of an audiotaped lesson. A fixed interval of 5 s was set between two codes, which means that the observers were forced to code after each interval of 5 min. Using this interval method, I estimated the coding consistency of all five observers. The context of the teaching behaviors, however, could not be coded from the audiotapes because they lack the essential visual elements. (See Table 1.)

The results of the reliability checks can be summarized as follows. The mean correlation coefficients calculated on the basis of live observations of teaching behaviors varied from  $-.30$  (only one observer-pair) to  $.97$ . For context and who-to-whom interactions, the mean correlation coefficients varied from  $.72$  to  $.90$  and  $.75$  to  $.85$ , respectively. The internal consistency coefficients of teaching behaviors calculated on the basis of audio observations varied from  $-.91$  (once) to  $.99$ . The who-to-

whom interactions varied from  $-.178$  (once) to  $.99$ . Note that the coefficients for the context and the who-to-whom interactions were high. To a lesser extent this result also was true of teaching behaviors. The above-mentioned results did not deviate from results obtained by similar research (Sirotnik, 1984). (See Table 2.)

#### *Gathering Data on Student Learning Outcomes*

By student learning outcomes, I included cognitive as well as affective learning outcomes. Cognitive outcomes are reflected by the students' scores on an achievement test in mathematics. Affective student outcomes in this study represent the students' scores on a scale measuring attitude toward the subjects of mathematics. The pretest was composed of mathematical subject matter for transition-year students (seventh grade). The pretest consisted of test items provided by the Central Institute for Test Development (CITO). For the posttest, the chosen subject matter was treated in the aforementioned eighth-grade textbooks. CITO and I developed the items in the posttest. Data on the variable students attitudes toward mathematics were gathered by means of a Likert scale.

I provided information on the quality of the measurements for cognitive and affective student-learning outcomes and estimated the reliability of the variables in question by testing the internal consistency of the scale (the KR-20 formula) and applying Cronbach's internal consistency coefficient alpha. The KR-20 for the pretest on classroom level was  $.87$  and the KR-20 for the posttest on classroom level was  $.92$ . The internal coefficient alphas for the preattitude and postattitude scales in mathematics were  $.60$  and  $.63$ , respectively.

#### *Method of Analysis, Multicollinearity and Selection Procedures*

To address the problem of multicollinearity, I followed the suggestions made by Neter and Wasserman (1974). On theoretical grounds, I reduced the number of teaching behaviors, inspected the intercorrelation matrix of the teaching behaviors in a particular model, and then removed the independent variables that produced multicollinearity. To avoid multicollinearity, I did not submit several of the independent variables for analysis. Instead I selected the teaching behaviors to be analyzed on conceptual grounds and on their suitability for an experimental teacher training program. As a result of the two selection criteria, almost all of the reported teaching behaviors were composite variables.

To reduce the number of independent variables, I applied the backward procedure, entering the class mean scores on the cognitive, respectively affective pretest as covariables for all cases. Bloom (1976) has pointed out that entering behavior explains a large part of the variance in learning outcomes. One must adjust for this confounding variable. In this study, the cognitive pretest

**Table 1** — "Who-to-Whom" Interactions Internal Consistency of Five Observers

Variable	Mean correlation coefficient	Internal consistency coefficient alpha
Teacher to group	.96	.99
Teacher to student	.79	.94
Student to teacher	.90	.96
Group to teacher	-.22	

Table 2—Directly Observed Teaching Behaviors: Internal Consistency of Five Observers

Variable	Mean correlation coefficient	Internal consistency coefficient alpha
Teacher lecturing/explaining/ providing instructional cues		
Lecture/explanations	46	90
Lecture/explanations with materials	80	94
Lecture/explanations nonverbal	99	99
Instructional cue	30	70
Teacher questioning		
High-level question	48	70
Recall or recognition question	20	91
Opportunity to respond		
Student response	74	93
Student statement	05	75
Providing feedback		
Acknowledgment positive	67	89
Wrong	65	81
Probe	69	91
Teacher repeats student answer	87	94
Effectiveness of teaching question	29	58
Nonacademic interactions		
Silence	46	82
Discipline	10	04
Procedure	81	93
Observer cannot hear interaction	30	63
Social interaction	37	84

scores explained 43% of the variance in mathematics achievement and the affective pretest scores explained 13% of the variance in the affective posttest scores.

The results of the multiple regressions of the criterion variables on the independent variables are found in Tables 1 and 2. I excluded those cases where the teaching behaviors, in addition to scores on the cognitive pretest, explained less than 2% of the variance in mathematics achievement and student attitudes toward mathematics, respectively. The tables report the following information: regression coefficient ( $B$ ), standard error  $B$ ,  $t$  ratio, significance level, standardized regression coefficient (Beta), multiple correlation coefficient  $R$ , and the determination coefficient  $R^2$ .

In the following paragraphs I presented the results of the multiple regressions of mathematics achievement, respectively students' attitudes towards mathematics, for different teaching behaviors within the distinct categories. I did not, however, imply that the relationships found reflect cause and effect. Strictly controlled field experiments, therefore, are necessary. The operational definition of the variables is given in the Appendix.

## Results

### Results in the Cognitive Domain

After the multicollinearity check, the following three teaching behaviors remained that explain less than 2% of

the variance in mathematics achievement in addition to cognitive entering behavior: all forms of teacher lecture/explanations, lecture/explanations to individual students, and instructional cue after lecture/explanations. Table 1 shows no results for behaviors that fall within the category opportunity to respond, because they explained less than 1% of the variance in mathematics achievement. (See Table 3.)

*Cognitive level of questions.* Originally, the linear regression model consisted of the following variables: student cognitive entering behavior, recall/recognition question in large group. Together the four predictors explained 46% of the variance in mathematics achievement. After using the backward procedure, in addition to student cognitive entering behavior, only the teaching behavior, high-level question in large group, remained in the model. Combined with student cognitive entering behavior, this teaching behavior explained 45% of the variance in mathematics achievement. This result indicated that high-level questions in large groups describe 2% of the variance in mathematics achievement.

*Probing.* The model included seven predictor variables that taken together, explained 46% of the variance in mathematics achievement. In addition to student cognitive entry behavior, the model treated probing to group, high-level question followed by probing, recall/recognition question followed by probing, probing followed by student response, probing followed by correct student re-

response and probing followed by incorrect student response After analysis, two teaching behaviors remained, namely, probing followed by student response and probing followed by correct student response

*Difficulty level of questions* The analysis of this model involved two predictor variables, namely, student cognitive entering behavior and teacher waits after asking a question, indicating the difficulty level of the teacher's question In this model, this teaching behavior apparently explained 2% of the variance in mathematics achievement

*Redirecting* In addition to student cognitive entering behavior, this model included the predictors redirect question and successful redirecting After I applied the backward procedure, these two teaching behaviors remained in the model and explained 4% of the variance in mathematics achievement

*Student contribution* Originally the model was composed of the predictor variables student contribution, teacher response to student question, and student asks question, in addition to student cognitive entry behavior By applying the backward procedure, I eliminated two teaching behaviors and the variable student asks a question remained in the model The standardized regression coefficient of this predictor variable was negative

*Providing feedback* Teaching behaviors in the model belonging to the category providing feedback are teacher answer, all forms of positive acknowledgement, all forms of negative acknowledgement, and no acknowledgement after student response After analysis the behaviors, all forms of positive acknowledgement and all forms of negative acknowledgement, remained in the model and explained 4% of the variance in mathematics achievement

*Nonacademic interactions* In addition to student cognitive entry behavior, three teaching behaviors entered the analysis, namely, procedural interactions, discipline statement to individual student, and discipline statement to entire class After analysis, only the teaching behavior discipline statement to individual student remained in the model and explained 4% of the variance in mathematics achievement

*Results in the Affective Domain*

Table 2 does not report results on teaching behaviors belonging to three categories, namely the cognitive level of questions, the difficulty of questions, and, student contribution In addition to affective entering behavior, the explained variance in the affective posttest scores for these categories is less than 2% (See Table 4)

**Table 3 —Results of Backward Multiple Regression Analysis of Mathematics Achievement on Cognitive Entry Behavior and Teaching Behaviors**

Variables	Standard			Sig	Mult			
	B	Error B	t		Beta	R	R <sup>2</sup>	F
Model 1								
6 High-level question in large group	25	18	1.37	.17	.15	.67	.45	19.57*
Model 2								
14 Probing followed by student response	-4.86	4.23	-1.15	.25	-.1	.67	.45	12.82*
15 Probing followed by correct student response	1.30	1.01	1.29	.20	.17			
Model 3								
17 Teacher waits after asking a question	.61	.51	1.19	.23	.12	.67	.45	19.16*
Model 4								
10 Redirect question	-.98	1.06	-.92	.35	.10	.69	.47	13.67*
19 Successful redirecting	3.09	1.94	1.59	.11	.17			
Model 5								
26 Student asks question	.66	.38	-1.75	.08	-.18	.68	.47	20.61*
Model 6								
30 All forms of positive acknowledgment	.74	.39	1.86	.06	.25	.69	.47	13.73*
31 All forms of negative acknowledgment	-1.94	1.59	-1.22	.22	-.16			
Model 7								
34 Discipline statement to individual student	-.41	.22	-1.84	.07	.19	.69	.47	20.91*

\*p < .001

**Table 4 -- Results of Backward Multiple Regression Analysis of Mathematics Attitude on Affective Entry Characteristics and Teaching Behaviors**

Variables	Standard		t	Sig	Mult			
	B	Error B			Beta	R	R <sup>2</sup>	F
Model 1								
1 All forms of teacher lecture/explanations	.03	.03	.96	.33	.13			
Model 2								
16 Probing followed by incorrect student response	-.117	.105	-1.11	.26	.24	.48	.23	2.71*
10 Probing to group	-.299	.179	-1.67	.10	-.25			
12 High level question followed by probing	-.83	.95	-.87	.38	.18			
15 Probing followed by correct student response	.43	.93	1.52	.13	.39			
Model 3								
30 All forms of positive acknowledgment	.27	.17	1.50	.13	.19	.40	.24	4.85*
20 Teacher answer	-.137	.66	-2.06	.04	-.27			
Model 4								
34 Discipline statement to individual student	.13	.13	1.00	.32	-.13	.39	.15	4.25*

\* $p < .05$

*Lecturing/explaining/providing instructional cues* In the model, the teaching behaviors, all forms of teacher lecture/explanations, lecture/explanations to individual student, and instructional cue after lecture/explanations, entered the analysis. In combination with student affective entry characteristics, these predictor variables explained 16% of the variance in the affective posttest scores. After I applied the backward procedure, one teaching behavior, all forms of teacher lecture/explanations, remained in the model and explained 2% of the variance in the criterion variable.

*Probing* The model was composed of seven predictor variables. The six teaching behaviors are the same as those in the probing model in the cognitive domain. Four teaching behaviors remained in the model: Probing, followed by an incorrect student response, probing to group, and high-level question followed by probing had a negative relationship with students' attitudes toward mathematics. Probing followed by correct student response was positively related to attitudes toward mathematics in the model.

*Providing feedback* Five teaching behaviors related to feedback were included in the model, namely: acknowledgement positive, wrong teacher repeats student answer, teacher answer, and effectiveness of teaching question. After analysis, two teaching behaviors explaining 11% of the variance in students' attitudes toward mathematics remained in the model. Those teaching behaviors are all forms of positive acknowledgement and teacher answer. The regression coefficient of the latter variable was negative.

*Nonacademic interactions* This model included the same variables as the model in the cognitive domain. After analysis, only one teaching behavior, discipline statement to individual student, remained in the model and had a negative effect on students' attitudes toward mathematics.

## Discussion

In this article I investigated which combination of the different teaching behaviors was most effective in predicting student learning outcomes in the cognitive and affective domain. I determined the multiple regressions of mathematics achievements and the attitude of students toward mathematics for each category of teaching behaviors. In this way I traced which linear combination of teaching behaviors explains most of the variance in student learning outcomes. Statements about relationships between teaching behaviors on one hand and student learning outcomes on the other indicate to what extent teaching behaviors can predict learning outcomes.

Because student entering behavior is the most important predictor of student learning outcomes, I entered student cognitive entering behavior, respectively, student affective entry characteristics, as the first variable in all cases in the regression model. In this study, the scores on the cognitive pretest explain 43% of the variance in mathematics achievement and scores on the affective pretest explain 13% of the variance in scores on the affective posttest.

I have summarized the results concerning possible et-

fective teaching behaviors, comparing our outcomes, as far as possible, with results and/or theoretical views of other researchers. Because most researchers have reported about learning outcomes in the cognitive domain, I have restricted this comparison mainly to that domain. In this study I also indicated some implications for the design of an experimental teacher training program.

As mentioned previously in this article, I have primarily reported only composite teaching behaviors and have found that patterns of teacher-student interactions are more interesting and significant for designing teacher training programs than directly observed, discrete teaching behaviors.

In the category of teaching behaviors related to lecture, explanation, instructional cues, I observed no effect on mathematics achievement. Other researchers have reported positive effects on achievement (Anderson, Evertson, & Brophy, 1979, Bloom, 1976, Clark et al., 1979, Fisher et al., 1978, Levin, 1979, Lysakowski & Walberg, 1982). I found a positive effect in the affective domain, indicating that the more time teachers spent on lecture/explanation, the more positive the students' attitude toward mathematics will be. Taking into account that teaching behaviors related to lecture/explanation make up 36% of class time, the explained variance is small. Perhaps students find this passive activity of listening pleasant. Another explanation is that the variable enthusiasm, a predictor of learning outcomes (Rosenshine & Furst, 1971), leads to frequent lecturing and explaining.

Within the category questioning, high-level questions had a positive effect on mathematics achievement. The same effect was mentioned by Levin (1977) and Redfield and Rousseau (1980) among others. In this study, I observed that questions asked a large group of students are more effective than questions asked of a small group of students. Concerning the difficulty of questions, a positive effect appears to occur on mathematics achievement when a teacher waits after asking a question. Obviously, inserting a pause after asking a question contributes to learning outcomes. Maybe a correct response is more likely when students consider their answers carefully.

In general, the frequency of teaching behaviors related to probing and redirecting was low. Nevertheless, I found that redirecting a question had a positive effect on mathematics achievement. No positive effect on student learning outcomes was found for behaviors within the category opportunity to respond. In this study, student-initiated, task-related statements have a negative effect on learning outcomes, the same holds for the behavior student asks a question on mathematics achievement. This finding contradicts the results reported by Brophy and Evertson (1974) and Good and Grouws (1975).

Because of the strong theory and the amount of research that has been carried out to date (Bloom, 1976, Fisher et al., 1978, Lysakowski & Walberg, 1981, 1982), I was not surprised to find that all forms of positive ac-

knowledgement have a positive effect both on mathematics achievement and attitude toward mathematics. I naturally observed a negative effect for all forms of negative acknowledgement. Again, positive acknowledgement is apparently an effective teaching behavior, whereas negative acknowledgement does not contribute to learning outcomes.

I found that the learning outcomes were worse for nonacademic interactions when more time was spent on the monitoring and management of learners. One obvious explanation is that teachers manifesting inadequate management behavior spend a lot of time making discipline statements, consequently, students learn little.

Regarding the influence on the future entry behavior of students, I believe, on the basis of my results on the explained variance that, in principle, teachers can change more in students' attitudes toward mathematics than they can contribute to students' knowledge of mathematics. This conclusion seems important for teaching the subject, for one assumes that the more positive the attitude of students is toward mathematics, the higher they score on cognitive tests.

I agree with Evertson, Emmer, and Brophy (1980) that the large number of variables related to effective teaching behavior shows its multiple facets and cannot be reduced to a single behavior. Because I analyzed teaching behaviors within behavior categories, I cannot indicate which of all observed behaviors is most important in producing achievement or positive student attitudes. The applied analysis method was, therefore, inappropriate.

Although these results have been observed in other process-product research (Evertson, Emmer, & Brophy, 1980, Good & Grouws, 1977, Rosenshine & Furst, 1973) I found strikingly few effective behaviors. One should consider that, first, the student population had above-average achievement levels compared with other 12- to 13-year-olds in the Netherlands and, second, that this study was conducted in highly selective schools.

More teaching behaviors have a positive effect on mathematical knowledge than have a positive effect on students' attitude toward mathematics. To appreciate the different teaching behaviors in the cognitive and affective domain, one should recognize their similarities. One must not interpret these results causally, however. The effectiveness of the teaching behaviors can be identified only with further research (Fenstermacher, 1976). I cannot confine this study to the results of research linking teaching behavior and student outcomes, and I agree with Gilbert and Mosteller (1972) that strictly controlled, ecologically valid field experiments are necessary to determine effectiveness. Researchers must discover whether there is a causal connection between some teaching behaviors and a student's success at a given task. Only if the answer is positive, can researchers recommend teaching behaviors that positively affect learning outcomes and consti-



tute important implications for pre-and in-service teacher training

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#### APPENDIX

##### Operational Definition of Composite Teaching Behaviors

###### A. Lecturing/explanations/instructional cues

1. All forms of teacher lecture/explanations. All forms of teacher explanation, including nonverbal or materially aided, either to the entire class or an individual student.
2. Lecture/explain to individual student. All forms of teacher explanation including nonverbal or materially aided, to an individual student.
3. Instructional cue after lecture/explain. All forms of teacher explanation, to the entire class or an individual student, followed by an instructional cue.

###### B. Questioning

4. All forms of questions asked to entire class. All forms of teacher questions to the entire class: high-level and recall or recognition questions, questions related to the effectiveness of explanations or clarifications, redirected questions, probes, and assignments.
5. All forms of questions asked to individual student. All forms of teacher questions to individual student, identical to no. 4.
6. High-level question in large group. Teacher high-level question to group or individual student within a group of more than 8 students.
7. High-level question in small group. The same as no. 6, a group of 8 or fewer students.
8. Recall or recognition question in large group. Teacher recall or recognition question to group or individual student within a group of more than 8 students.
9. Recall or recognition question in small group. The same as no. 8 within a group of 8 or fewer students.
10. Probing group. Teacher probes a question in a large group.
11. Probing individual student. Teacher probes a question with an individual student.
12. High-level question followed by probing. Teacher high-level question to group or individual student, if followed by an incorrect student response, teacher subsequently provides feedback and probes the question.
13. Recall or recognition question followed by probing. Teacher recall or recognition question, etc., the same as no. 12.
14. Probing followed by student response. After an incorrect student response to a high-level or recall/recognition question, the teacher probes the question after which the same student responds.
15. Probing followed by correct student response. Teacher probing followed by student response, the subsequent interaction differs from redirecting, probing, negative acknowledgment, punishment, or teacher response, i.e., the student responds concisely.
16. Probing followed by incorrect student response. Teacher probing, if followed by an incorrect student response, teacher subsequently provides negative acknowledgment, redirects, or probes.
17. Teacher waits after asking a question. Teacher asks a question in a large or small group, followed by silence of at least 5 s.
18. Student cannot answer question. Teacher asks a high-level or recall/recognition question to a group or an individual student, followed by an incorrect student response or silence.
19. Successful redirecting. Teacher redirects question to another student whereupon the student responds. The subsequent interaction differs from redirecting, probing, negative acknowledgment, punishment, or teacher response. A correct student response is highly probable.
20. Redirecting more than once. Teacher redirects question to another student and receives an incorrect student response, the teacher negatively acknowledges this response, and once more redirects the same question.

###### C. Opportunity to respond

21. Student gives an extended response. Student response lasting at least 15 s.
22. Response in chorus. A group of students responds simultaneously.
23. Student response followed by a new question. Student or a group of students respond, followed by a teacher recall/recognition question or a high-level question.
24. Student contribution. An individual or class contribution in the form of explanation, reading from a book, or extended response.
25. Student asks teacher question after lecture/explanation. Teacher explains to individual student or class, followed by a student or class question to teacher.
26. Student asks question. Student high-level or recall/recognition question to a large or small group.
27. Student asks question or initiates task-related statement. A high-level or recall/recognition question or a task-related statement by an individual student or a group of students.
28. Teacher response to student question. A high-level or recall/recognition question by an individual student or a group of students, followed by teacher response.

###### D. Providing feedback

29. All forms of acknowledgment. The following forms of teacher

- feedback positive or negative acknowledgement, punishment, repetition of student answer
- 30 All forms of positive acknowledgement Student response followed by positive acknowledgement or teacher repetition of student response
- 31 All forms of negative acknowledgement Student response followed by negative acknowledgement or teacher response
- 32 Teacher criticizes student Teacher gives negative acknowledgement or punishes student
- 33 No acknowledgement after student response Student response, possibly incorrect, followed by a nonfeedback interaction
- E *Nonacademic interactions*
- 34 Discipline statement to individual student Teacher discipline statement to individual student
- 35 Discipline statement to entire class Teacher discipline statement to entire class

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