The Search for Methods of Group Instruction as Effective as One-to-One Tutoring

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Schools cannot provide tutoring for every student, but the use of mastery learning in combination with other practical methods may enable students to learn almost as well.

For several years, my doctoral students and I have been searching for solutions to what we call the "2 sigma problem": can researchers and teachers devise teaching-learning conditions that will enable the majority of students under *group instruction* to attain levels of achievement that can, at present, be reached only under good tutoring conditions?

Two University of Chicago doctoral students in education, Anania and Burke, began in 1980 to compare student learning under one-to-one tutoring, mastery learning, and conventional group instruction. As the results of these separate studies at different grade levels and in differing school subjects began to unfold, we were astonished at the consistency of the findings and at the great differences in student cognitive achievement, attitudes, and self-concept under tutoring as compared with group methods of instruction.

Anania (1981) and Burke (1983) defined the three methods of instruction as follows:

- *Conventional*: Students learn the subject matter in a class with about 30 students per teacher. Tests are given periodically only for purposes of determining students' marks.
- *Mastery Learning*: Students learn the subject matter in a class with about 30 students per teacher. The instruction is the same as in the conventional class and is usually with the same teacher. Formative tests (the same tests used with the conventional group) are given for purposes of feedback followed by corrective procedures and by parallel formative tests to determine the extent to which the students have mastered the subject matter.
- *Tutoring*: Students learn the subject matter with a good tutor for each student, or for two or three students simultaneously. This tutoring instruction is followed periodically by formative tests, feedback-corrective procedures, and parallel formative tests as in the mastery learning classes. The need for corrective work under tutoring is very small.

The students were randomly assigned to these three learning conditions, and their initial aptitude test scores, previous

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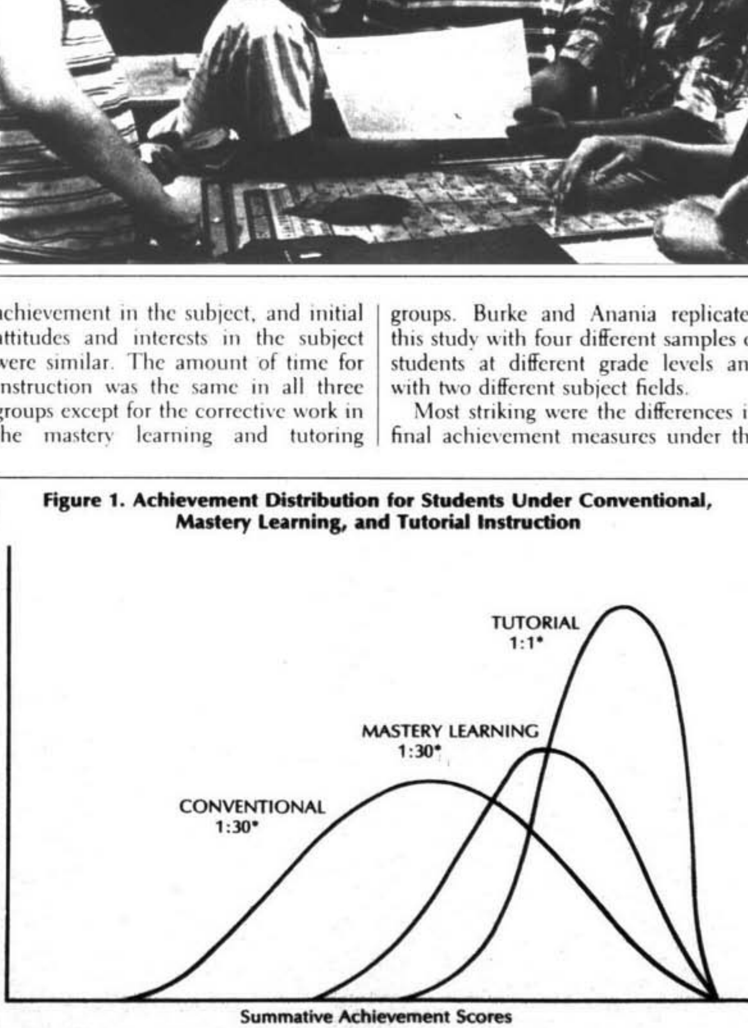
achievement in the subject, and initial attitudes and interests in the subject were similar. The amount of time for instruction was the same in all three groups except for the corrective work in the mastery learning and tutoring groups. Burke and Anania replicated this study with four different samples of students at different grade levels and with two different subject fields.

Most striking were the differences in final achievement measures under the three conditions. Using the standard deviation (sigma) of the control class, which was taught under conventional conditions, it was found that the average student under tutoring was about two standard deviations above the average of the control class. Put another way, the average tutored student outperformed 98 percent of the students in the control class. The average student under mastery learning was above one standard deviation above the average of the control class, or above 84 percent of the students in the control class.

Figure 1. Achievement Distribution for Students Under Conventional, Mastery Learning, and Tutorial Instruction



*Teacher: Student Ratio

The variation of the students' achievement also changed under these learning conditions such that about 90 percent of the tutored students and 70 percent of the mastery learning students attained the level of summative achievement reached by only the highest 20 percent of the students under conventional instructional conditions (Figure 1).

There were corresponding changes in students' time-on-task in the classroom (65 percent under conventional instruction, 75 percent under mastery learning, and 90+ percent under tutoring) and students' attitudes and interests (least positive under conventional instruction and most positive under tutoring). There were great reductions in the relations between prior measures of aptitude or achievement and the summative achievement measures. Typically, the aptitude-achievement correlations changed from +.60 under conventional instruction, to +.35 under mastery learning, and +.25 under tutoring.

However, the most striking of the findings is that under the best learning conditions we can devise—(tutoring)—the average student is 2 sigmas above the average control student taught under conventional group methods of instruction.

The tutoring process demonstrates that *most of the students* do have the potential to reach this high level of learning. An important task of research and instruction is to seek ways of accomplishing this under more practical and realistic conditions than one-to-one tutoring, which is too costly for most societies to bear on a large scale. This, then, is the "2 sigma" problem.

It has taken almost a decade and a half to develop the mastery learning strategy to a point where large numbers of teachers at every level of instruction and in many countries can use the feedback-corrective procedures to get the 1 sigma effect. (That is, the average mastery learning student is above 84 percent of the students under conventional instruction, even with the same teacher teaching both the mastery learning and the conventional classes.) If the research on the 2 sigma problem yields *practical methods*—which the average teacher or school faculty can learn in a brief period of time and use with little more cost or time than conventional instruction—it would be an educational contribution of the greatest magnitude. It would change popular notions about human potential and would have significant effects on what the schools can and should do with the educational years each society requires of its young people.

Figure 2. Effect of Selected Alterable Variables on Student Achievement

	Variable		*Effect size*	*Percentile equivalent*
D	Tutorial instruction	....	2.00	98
D	Reinforcement	....	1.20	
A	Feedback-corrective (ML)	....	1.00	84
D	Cues & explanations	....	1.00	
(A) D	Student classroom participation	....	1.00	
A	Student time-on-task	....	1.00+	
A	Improved reading/study skills	....	1.00	
(D) C	Cooperative learning	....	.80	79
D	Homework (graded)	....	.80	
D	Classroom morale	......	.60+	73
A	Initial cognitive prerequisites	......	.60	
C	Home environment intervention	.....	.50+	69
D	Peer and cross-age remedial tutoring	....	.40	66
D	Homework (assigned)	...	.30	62
D	Higher order questions	...	.30	
(D) B	New science & math curricula	...	.30+	
D	Teacher expectancy	...	.30	
C	Peer group influence	..	.20	58
B	Advance organizers	..	.20	
	Socioeconomic status (for contrast)	...	.25	60

+ = Averaged or estimated from correlational data or from several effect sizes

Object of change process: A- Learner
B- Instructional Material
C- Home environment or peer group
D- Teacher

Adapted from Walberg (1984)

The Search

In a number of articles my graduate students and I have attempted to contrast alterable educational variables with more stable or static variables (Bloom, 1980). In our treatment of this topic we summarized the literature on such alterable variables as the *quality of teaching*, the *use of time* by teachers and students, *cognitive* and *affective* entry characteristics of students, *formative* testing, *rate of learning*, and the *home environment*. In each case we contrasted these alterable variables with the more stable variables, such as personal characteristics of teachers, intelligence measures, achievement tests for grading purposes, socioeconomic status of the family, and so on. We also indicated some of the ways in which the alterable variables influence learning, and the processes by which these variables have been altered.

But not all alterable variables are likely to have equal effects on learning. Our research summaries were intended to emphasize those alterable variables that have had the strongest effects on school learning. Within the last three years, this search has been aided by the rapid growth of the meta analysis literature. In this literature, each writer has summarized the research on a particular set of alterable variables to indicate the effect size between control and experimental groups of students. They have standardized the results in terms of the *difference* between the experimental and control groups divided by the standard deviation of the control group.[1] In each study, the reviewer also analyzed the effect size under different conditions, level of school, sex of student, school subject, size of sample, and so on. Such reviews are very useful in selecting alterable variables which are most likely to contribute significantly to the 2 sigma solution.

Figure 2 is adapted from Walberg's (1984) summary of effect sizes of key variables. Walberg listed the selected variables in order of magnitude. We

have added additional variables and indicated the equivalent percentile for each effect size. Thus, in the first entry, *tutorial instruction*, we have indicated the effect size, 2 sigma, and the finding that under tutorial instruction, the average student is above 98 percent of the students under the control teaching conditions. The average student under the control conditions would be above 50 percent of the students under these teaching conditions.

In our own attempts to solve the 2 sigma problem, we assume that two or three alterable variables *used together* contribute more to learning than any one of them alone. Having used mastery learning for more than 15 years at different levels of education and in different countries, we have come to rely on mastery learning as one of the possible variables to be combined with selected other variables. Under good conditions, the feedback-corrective process of mastery learning yields approximately a 1 sigma effect. We have systematically tried other variables, which, combined with mastery learning, might approach the 2 sigma effect size. So far, we have *not* found any two-variable combination that has exceeded the 2 sigma effect. Thus, our present research approaches the 2 sigma effect but does not go beyond it.

We have classified the variables in Figure 2 in terms of the direct object of the change process:

A. The learner

B. The instructional material

C. The home environment or peer group

D. The teacher and the teaching process

We believe that two variables involving different objects of the change process are likely to be additive, while two variables involving the same object of the change process are less likely to be additive—unless they occur at different times in the teaching-learning process. Thus the mastery learning process, which affects the learner most directly, when combined with changes in the teaching process, which affects the teacher most directly, yield additive results (Tenenbaum, 1982; Mevarech, 1980). While we do not believe these rules are more than suggestive at present, future research on this problem will undoubtedly yield a stronger set of generalizations about how the effects of separate alterable variables may be best combined.

Improve Student Processing of Conventional Instruction

In this section we are concerned with ways students can learn more effectively without basically changing the teaching. If students develop good study habits, devote more time to the learning, improve their reading skills, and so on, they will be better able to learn from a particular teacher and course even though neither the course nor the teaching has been changed.

For example, the mastery learning feedback-corrective approach, is primarily addressed to providing students with the cognitive and affective prerequisites for each new learning task. When the mastery learning procedures are done systematically and well, the school achievement of the average student under mastery learning is approximately 1 sigma (84th percentile) above the average student in the control class even when both classes are taught by the *same teacher* with much the same *instruction* and *instructional material*. We view the mastery learning process as a method of improving the students' learning from the same teaching over a series of learning tasks.

The more students possess the cognitive prerequisites for each new learning task, the more positive they are about their ability to learn the subject; and they put in more active learning time than do control students. As we observe the students' learning and the test results in both the mastery learning and the conventional class, we note the im-

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provements in student learning under mastery learning and the lack of such improvement in the conventional classes. The main point is that the mastery learning students improve their *processing of the instruction*, although the instruction is much the same in both types of classes.

Leyton (1983) suggested that one approach to the 2 sigma problem would be to use mastery learning during an advanced course in a sequence, but in addition attempt to *enhance the students' initial cognitive entry prerequisites* at the beginning of the course. He worked with high school teachers in Algebra 2 and French 2 to develop an initial test of the prerequisites for each of these courses. The procedure in developing the initial test was to take the final examination in the prior course (Algebra 1 or French 1) and have a committee of four to six teachers in the subject independently check each test item they believed measured an idea or skill that was a necessary prerequisite for the next course in the subject. There was very high agreement on most of the selected items, and discussion among the teachers led to consensus about some of the remaining items.

Two of the classes were helped to review and relearn the specific prerequisites they lacked. This was not done for the students in the other two classes. The method of enhancing the prerequisites was much like the mastery learning feedback-corrective process in which the teacher retaught the items the majority of students had missed; small groups of students helped each other over items that had been missed; and the students reviewed items they were not sure about by referring to the designated pages in the instructional material. The corrective process involved about three to four hours of time during the first week of the course. After the students completed the corrective process, they were given a parallel test. As a result of the corrective process most of the students reached the mastery standard (80 percent) on the parallel test given at the end of the first week of the course. In a few cases, students who didn't reach this standard were given further help.

More important was the improved performance of the enhanced classes over the other two classes on the first *formative* test in the advanced course (French 2 or Algebra 2). The enhanced classes, which had been helped on the initial prerequisites, were approximately .7 sigma higher than the other two classes on the first formative test given at the end of a two-week period of learning in the advanced course.

When one of the enhanced classes was also provided with mastery learning feedback-corrective procedures over a series of learning tasks, the final result after a ten- to 12-week period of instruction was that this experimental group was approximately 1.6 sigmas above the control group on the summative examination. In other words, the average experimental student was above 95 percent of the control students on this examination. There were also attitudinal and other affective differences in students related to these achievement differences. These included positive academic self-concept, interest in the subject, and desire to learn more in the subject field.

Leyton found that the average effect of initial enhancement of prerequisites alone is about .6 sigma. (See Figure 3 for differences between conventional and conventional plus enhanced prerequisites and between mastery learning and mastery learning plus enhanced prerequisite.) That is, we have two processes, *mastery learning* and *initial enhancement of cognitive prerequisites*, which have sizable but separate effects. When they are combined, their separate effects tend to be additive. We believe these two variables are additive because they occur at different times. The enhancement of the initial prerequisites is completed during the first week of the new course, while the mastery learning feedback-corrective process takes place every two or three weeks during the course, and after the initial enhancement.

This solution to the 2 sigma problem is likely to be applicable to sequential courses in most school subjects. (In the United States over two-thirds of the academic courses in elementary-secondary schools are sequential.) This solution, of course, applies most clearly to the second course in a sequence. It probably will not work as well with third, fourth, or later courses in a sequence if there has been no earlier use of initial enhancement of prerequisites or mastery learning procedures. We hope these ideas will be further explored in the United States as well as in other countries. We believe this solution is relevant at all levels of education including elementary-secondary, college, and even at the graduate and professional school level.

We also regard this approach as widely applicable within a country because the prerequisites for a particular sequential subject or course are likely to be very similar even though different textbooks and teachers may be involved. Thus, a well-made test of the initial prerequisites for a particular sequential course, such as 5th grade arithmetic, French 2, and so on, may with only minor changes apply to other versions of the same course within a particular country. Also, the procedures that work well in enhancing these prerequisites in one school should work equally well in other schools. Much further research is needed to establish which sequential courses for this approach are most effective.

Finally, the time cost of the initial enhancement procedures is limited to the class hours of the course during the first week of the sequential course, while the time or other costs of the mastery learning procedures have usually been very small. We hope that this approach to the 2 sigma problem will be found to be a widely applicable and economical solution for teachers who wish to improve student learning, student academic self-concept, and student attitudes and interest in the subject matter.

Our graduate students have proposed several other approaches for improving student processing of conventional instruction.

1. Help students develop a student support system in which groups of two or three students study together, help each other when they encounter difficulties in the course, review in advance of taking tests, and review their learning periodically. A student support system that provides support, encouragement, and even help when needed can do much to raise the level of learning of the participants. There is evidence that these and other cooperative learning efforts are almost as effective as mastery learning procedures. (The effect size of cooperative learning [Slavin, 1980] is estimated at .80 or the 79th percentile. See Figure 2.)

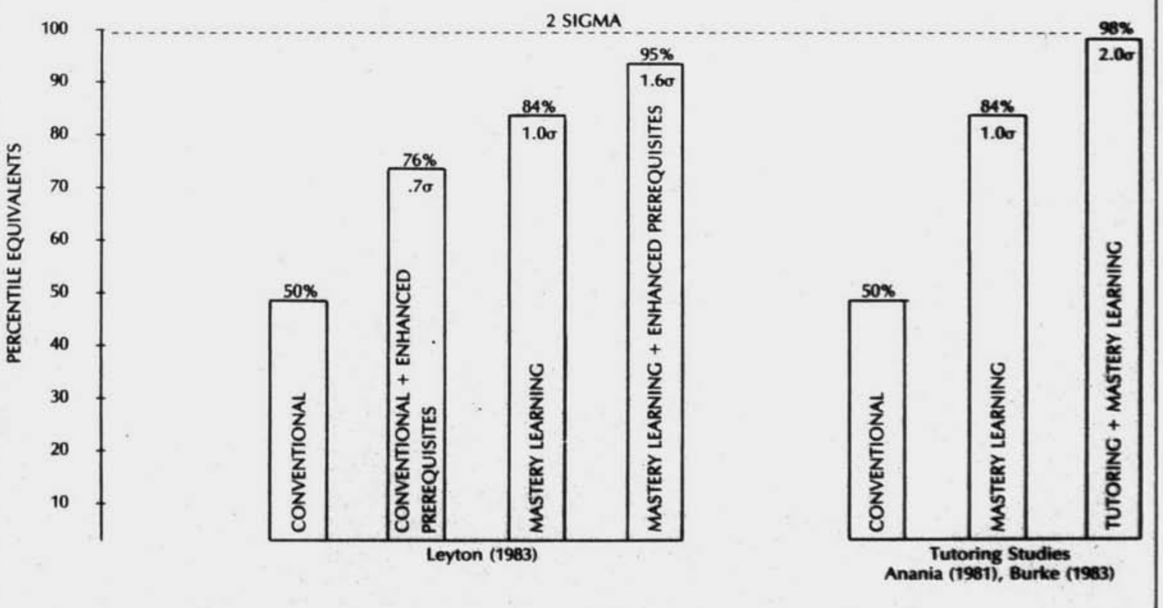
2. There is evidence that students who take special programs to improve their reading and/or their study and learning methods tend to learn more effectively. Ideally, such special programs should be available at the beginning of each new school level; that is, junior high school, high school. One would hope that the special programs would be closely related to the academic courses the student is taking currently. (The effect size of improved reading/study [Pflaum and others, 1980] is estimated at 1.00 or 84th percentile.)

Improve Instructional Materials and Educational Technology

The textbook in the United States and in most advanced countries in the world is an almost universal part of school instruction. Authors and publishers have worked very hard to improve textbooks for reading and to some extent arithmetic, mathematics, and science by changing the sequential nature of topics, attempting to find important ideas or schema that interrelate different parts of the subject, and improving illustrations and exercises. However, as far as we can find these have not had very significant effects on student achievement unless teachers were provided with much inservice education for the new curricula or the new textbooks.

Our graduate students have been intrigued by the possibility that the organization of a particular section (or chapter) of the textbook might be better integrated or the parts of the section more clearly related to each other. They have found that pre-organizers or advance organizers (Ausubel, 1960) have been moderately effective when provided in the textbook or provided by the teacher at the beginning of each new unit of the course. These may be provided in the form of objectives, some ideas about what will be learned in the unit, or a

Figure 3. Average Summative Achievement Scores Under Different Learning Conditions. Comparison of tutoring studies, mastery learning, and enhanced prerequisites.



brief discussion of the relation between what has already been learned and what will be learned in the unit. Such advance organizers (Luiten and others, 1980) appear to have an average effect size on achievement of about .2 sigma.[2] While this effect is rather consistent, by itself it is not enough to contribute significantly to the 2 sigma effect. However, the students have suggested that a *combination* of advance organizers at the beginning of a new topic, further organizational aids during the chapter or unit, and appropriate questions, summaries, or other organizational aids at the end of the unit are likely to have a substantial effect on the student's learning of that chapter.

In Process

One of our students, Avalos, is working on a study of the effect of *organizational aids* in the instructional material combined with the *initial enhancement of cognitive prerequisites* and the mastery learning *feedback-corrective* procedures. Avalos is planning a research design that will enable him to determine the separate effects of each of the three processes, the effect of any two of the processes, and the combined effect of all three processes. At least, it is anticipated that the combination of any two of the processes will be greater than the effects of any one of the same processes. Hopefully, the effect of any two will be above 1.3 sigmas (90th percentile). If this is found, it will provide several new solutions to the 2 sigma problem, some of which can be done with very little cost or effort by the teachers or the school system.

Avalos expects the results noted above because the organizational aids can be built into new textbooks and can be used by students with a minimum of emphasis from teachers. The initial enhancement of the prerequisites is completed before students begin to study new course subject matter, while the mastery learning feedback-corrective procedures take place every two or three weeks during the course. We believe that each of these processes is somewhat independent of the other processes.

My students have suggested ways to improve instructional materials and educational technology.

1. Some computer learning courses, such as the Plato system, appear to work very well for highly motivated students. It should be possible to determine which computer courses enable sizable proportions of students to attain the 2 sigma achievement effect. The effectiveness of computer courses can be determined in terms of the time required, completion rates, student performance on achievement tests, and student retention of the learned material. Hopefully, the more effective computer courses will also have positive effects on such affective characteristics as academic self-concept, interest in the subject, and desire to learn further with computer learning methods.

2. While the average effect size for new science and math curricula is only .3 sigma, some of the new curricula in these and other subjects may be much more effective than others. A careful search of new curricula may determine which ones are more effective and what it is about these new curricula that makes them more effective than the others.

3. Many countries have developed new science and math curricula. Some have permanent curriculum centers that are responsible for the planning and development of new curricula, teacher training, and use of the new curricula. The students have proposed that cross-national studies be made to determine where new curricula in other countries have been far more effective than others and what made them more effective. Hopefully, some of the new curricula may also show the 2 sigma effect in these other countries.

Home Environment and the Peer Group

In this section, we are primarily concerned with out-of-school support from the home or peer group—specifically the ways in which the student's achievement, academic aspirations and goals, and progress in learning are influenced by this support. We know that the home environment has a great influence on the pupil's school learning and that this influence is especially effective at the elementary level or earlier. The peer group's influence is likely to be strongest (both positively and negatively) at the secondary level.

Home Environment Processes. Many studies have focused on the home environment processes that affect learning. These studies involve interviews and observations to determine the relevant interactions between parents and their children. The studies find correlations of +.70 to +.80[3] between an index of the home environment processes and the children's school achievement. Some of the home environment processes that appear to have high relationships with school achievement include:

1. *Work habits of the family*: the degree of routine in the home, the emphasis on regularity in the use of space and time, and the priority given to schoolwork over other activities.

2. *Academic guidance and support*: the availability and quality of the help and encouragement parents give the child for his or her schoolwork and the conditions they provide to support the child's schoolwork.

"Parent encouragement and support throughout the elementary years would have very great consequences for children over the many years they attend schools and colleges."

3. *Stimulation*: the opportunity provided by the home to explore ideas, events, and the larger environment.

4. *Language development*: opportunities in the home for developing correct and effective use of language.

5. *Academic aspirations and expectations*: the parents' aspirations for the child, the standards they set for the child's school achievement, and their interests in and knowledge of the child's school experiences.

These studies of the home environment processes began with the work of Dave (1963) and Wolf (1964, 1966), and have since been replicated in other studies done in the U.S. and other countries (Marjoribanks, 1974; Kalinowski and Sloane, 1980).

While these previous studies suggest a strong effect of home environments on school learning of children, they do not provide evidence on the extent to which home environments can be *altered* and the effect of such alteration on changes in children's school achievement.

A recent study done in Thailand by Janhom (1983) involved a control group and three experimental groups of parents and their children. In this study, the most effective treatment of the parents was for the group of parents to meet with a parent educator for about two hours twice a month for six months. In these meetings the parents discussed ways in which they could support their children's learning in the school. Usually, the parent educator made an initial presentation on one of the topics listed above (work habits of the family, and so on) and then the parents discussed what they did as well as what they hoped to do to support their children's school learning.

Another approach included visits to each home separately by a parent educator twice a month for six months. A third approach was one in which newsletters about the same topics were sent to the home twice a month for six months.

The parents of all four groups were observed and interviewed at the beginning and end of the six-month period using the Dave interview and observational methods. While the three experimental approaches show significantly greater changes in the parents' home environment index than the control group, the most effective method was the series of meetings between groups of parents and the parent educator. The changes in the home environment of this group were highly significant when compared with the changes in the other three groups of parents.

The 4th grade children of all these parents were given a national standardized test on reading and mother tongue as well as arithmetic at the beginning and end of the six-month period. Here, it was found that the children of the meeting group of parents had changed by 1 sigma in achievement, as contrasted with the change in the control group of children. In contrast, the parent educators' visits to each of the homes every other week had only a .5 sigma effect on the children's school achievement.

Other methods of changing the home environment have been reported by Dolan (1980), Bronfenbrenner (1974), and Kalinowski and Sloane (1980). Here again, the most effective approaches to changing the home environment processes result in changes in the children's school achievement. (The effect size of home environment [Iverson and Walberg, 1979] is estimated at .50 or 69th percentile.)

While methods for changing the home environment are relatively costly in terms of parent educators meeting with groups of parents over a series of semi-monthly meetings, the payoff of this approach is likely to be very great. Parent encouragement and support throughout the elementary years would have very great consequences for children over the many years they attend schools and colleges.

While such research has not been done as yet, our graduate students have suggested an approach to the 2 sigma problem of combining effective parent education with mastery learning. Since parent support takes place in the home and mastery learning takes place in the school, we expect that these two effects

John Murphy

"The average student in the enhanced group was above 93 percent of the students in the control classes."

will be additive. The result should be close to a 2 sigma improvement in student learning.

Ideally, if both methods began with 1st or 2nd grade children, the combination should result in consistently good learning at least through the elementary school years with less and less effort expended by the parents or by the use of mastery learning procedures in the school.

Peer Group. During the adolescent years it is likely that the peer group will have considerable influence on the student's activities, behavior, attitudes, and academic expectations. The peer group to which the individual "belongs" also has some effect on the student's high school achievement level as well as further academic aspirations. These effects appear to be greatest in urban settings. While it is difficult to influence the student's choice of friends and peer groups, the availability of a variety of extracurricular activities and clubs in the school enables students to be more selective in their peer choices. (The effect size of peer group influence [Walberg, 1984] is estimated at .20 or 58th percentile.)

Improvement of Teaching

Approximately 20 percent of the students learning under conventional instruction do about as well as the tutored students (Figure 1). That is, tutoring probably would not enable these top students to perform any better than under conventional instruction. In contrast, about 80 percent of the students do relatively poorly under conventional instruction as compared with what they might do under tutoring. We believe this results in part from the unequal treatment of students in most classrooms.

Observations of teacher interaction with students in the classroom reveal that teachers frequently direct their teaching and explanations to some students and ignore others. They give much positive reinforcement and encouragement to some students but not to others, and they encourage active participation in the classroom interaction from some students and discourage it from others. The studies find that typically the students in the top third of the class are given the greatest attention by teachers, while the students in the bottom third of the class receive the least attention and support. These differences in the interaction between teachers and students provide some students with much greater opportunity and encouragement for learning than is provided other students in the same classroom (Brophy and Good, 1970).

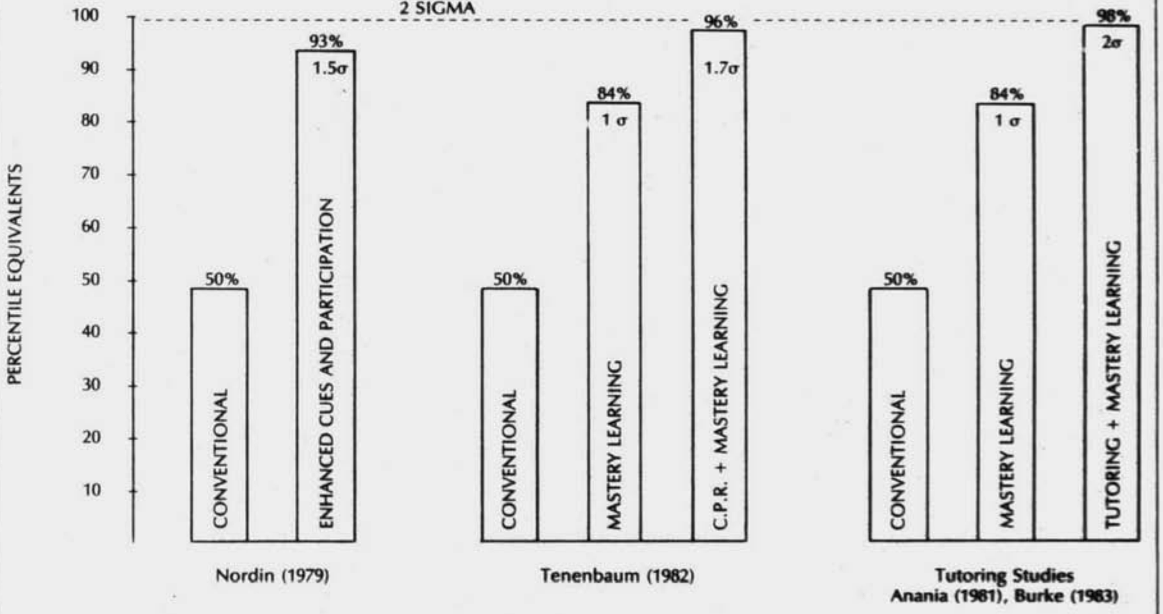
It is very different in a one-to-one tutoring situation where there is constant feedback and correction between the tutor and tutee. If the explanation is not understood by the tutee, the tutor soon becomes aware of it and explains further. There is much reinforcement and encouragement in the tutoring situation, and the tutee must be actively participating in the learning if the tutoring process is to continue. In contrast, there is less feedback from each student in the group situation. Frequently the teacher gets most of the feedback on the clarity of his or her explanations, the effect of reinforcements, and the degree of active involvement in learning from a *small* number of high achieving students in the typical class of 30 students.

Teachers are often unaware of the fact that they provide more favorable conditions of learning for some students than others. Generally, they are under the impression that all students in their classes are given equal opportunity to learn. One basic assumption of our work on teaching is that teachers who are helped to secure a more accurate picture of their own teaching methods and styles of interaction with their students are increasingly able to provide more favorable learning conditions for more of their students, rather than just for the top fraction of the class.

In some of our research on the 2 sigma problem we have viewed the task of teaching as providing more equal treatment of students, and have therefore been trying to give teachers feedback on their differential treatment of students. We attempt to provide teachers with a mirror of what they are now doing and have them develop techniques for equalizing their interactions with students. These include such techniques as calling on students in random order, finding something positive and encouraging in each student's response, involving more students in active engagement in the learning process, securing feedback from a small random sample of students to determine when they comprehend the explanations and illustrations, and supplying additional clarification and illustrations as needed. The major emphasis in this work has *not* been to change the teachers' *methods* of instruction, but to have teachers become more aware of ways they could more directly teach to a cross section of the students during each class session.

The first of our studies on improving instruction was done by Nordin (1979), who found ways of improving the cues and explanations for students as well as increasing active participation. Nordin found it helpful to meet frequently with teachers to explain these ideas and to observe the teachers and help them determine when they still needed to improve these qualities of the instruction. He also had independent observers noting the frequency with which the experimental teachers were using these ideas well or poorly. Similarly, he had the students note the frequency with which they were actively participating in the learning and any problems they had

Figure 4. Average Summative Achievement Scores Under Different Learning Conditions. Comparison of tutoring studies, mastery learning, and enhanced instructional methods.



with understanding the ideas or explanations.

Nordin also compared student learning under conventional instruction, under mastery learning, and under enhanced cues (explanations), and participation conditions. During the experiment, observers noted that student participation and the explanations and directions were positive in about 57 percent of the observations in the control class as compared with about 67 percent in the enhanced cues plus participation classes. The students in the control classes noted that the cues and participation were positive for them about 50 percent of the time as compared with about 80 percent of the time for students in the enhanced participation classes.

In terms of final achievement, the average student in the enhanced cue and participation group was 1.5 sigmas higher than the average student in the control classes. (The average student in the enhanced group was above 93 percent of the students in the control classes. See Figure 4.) Nordin also used the mastery learning procedures in other classes and found that they worked even better than the enhanced cues plus participation procedures. Unfortunately, he did not use mastery learning in combination with the enhanced cues plus participation methods.

In any case, Nordin did demonstrate that teachers could be taught to be more responsive to most of the students in the class, to increase student participation, and to ensure that most of the students understood the explanations and illustrations provided. He found that the students in the enhanced participation and cues classes were actively engaged in learning about 75 percent of the classroom time while the control students were actively learning only about 57 percent of the time.

In a later study, Tenenbaum (1982) compared control groups, mastery learning groups, and *enhanced cues, participation, and reinforcement in combination with mastery learning (CPR+ML)*. Tenenbaum studied these three methods of teaching with randomly assigned students in two different courses, 6th grade science and 9th grade algebra.

Tenenbaum also used students' observations of their own classroom processes on cues, participation, and reinforcement. He found that under CPR+ML students responded positively about their own participation about 86 percent of the time as contrasted with 67 percent in the control classes. He also had the classes monitored by an observer who found large differences in these teaching processes in the CPR+ML classes as contrasted with the control classes.

The results of this study demonstrated large differences between the three methods of instruction with the final achievement scores of the CPR+ML

> "Our teaching methods, instructional materials, and testing methods rarely rise above the lowest category of the taxonomy: knowledge."

group about 1.7 sigmas above the control students. (The average student in this group was above 96 percent of the students in the control group.) The average student in the mastery learning groups was the usual 1 sigma above the control students. (See Figure 4.)

This research makes it clear that teachers in both the Nordin and Tenenbaum studies could, at least temporarily, change their teaching methods to provide more equal treatment of the students in their classes. When this more equal treatment is provided and supplemented with the mastery learning feedback and corrective procedures, the average student approaches the level of learning found under tutoring methods of instruction.

There are several methods for giving feedback to teachers on the extent to which they provide equality of interaction with their students. The tactic of providing a "mirror" to the teacher seems to be an excellent approach. This may be in the form of an observer's notes on what the teacher and students did, or may come from student observations of their own interactions with the teaching (preferably anonymous, but coded as to whether the students are in the top third, middle third, or the bottom third of the class in achievement)—such as their understanding of the cues and explanations, the extent of their overt and covert participation, and the amount of reinforcement they receive. A videotape or audiotape recording of the class could serve the same purpose if the teacher is trained in ways of summarizing the classroom interaction between the teacher and students.

We hope that when teachers are helped to secure a more accurate picture of their own teaching methods and styles of interaction with their students, they will be better able to provide favorable learning conditions for most of their students.

Improve the Teaching of Higher Mental Processes

While there is much of rote learning in schools throughout the world, in some of the national curriculum centers in different countries I find great emphasis on problem solving, application of principles, analytical skills, and creativity. Such higher mental processes are emphasized because these centers believe they enable students to relate their learning to the many problems encountered in day-to-day living. These abilities, which are retained and used long after the individual has forgotten the detailed specifics of the subject matter taught in schools, are regarded as essential characteristics needed to continue learning and to cope with a rapidly changing world. Some curriculum centers also believe that higher mental processes are important because they make learning exciting and constantly new and playful.

In these countries, subjects are taught as methods of inquiry into the nature of science, mathematics, the arts, and the social studies. The subjects are taught as much for the ways of thinking they represent as for their traditional content. Much of this learning makes use of observations, reflections on observations, experimentation with phenomena, and the use of firsthand data and daily experiences as well as primary printed sources. All of this is reflected in the materials of instruction, the learning and teaching processes used, the questions and problems used in quizzes, formative testing, and final summative examinations.

In sharp contrast with some of these other countries, teachers in the U.S. typically use textbooks that rarely pose real problems. Instead, U.S. textbooks emphasize specific content to be remembered and give students little opportunity to discover underlying concepts and principles and even less opportunity to attack real problems in the environments in which they live. Both teacher-made and standardized tests are largely tests of remembered information. Even after the sale of over one million copies of the *Taxonomy of Educational Objectives—Cognitive Domain* (Bloom and others, 1956) and over a quarter of a century of using this domain in preservice and inservice teacher training, still over 95 percent of test questions that U.S. students are *now* expected to answer deal with little more than information. Our instructional materials, our classroom teaching methods, and our testing methods rarely rise above the lowest category of the taxonomy: knowledge.

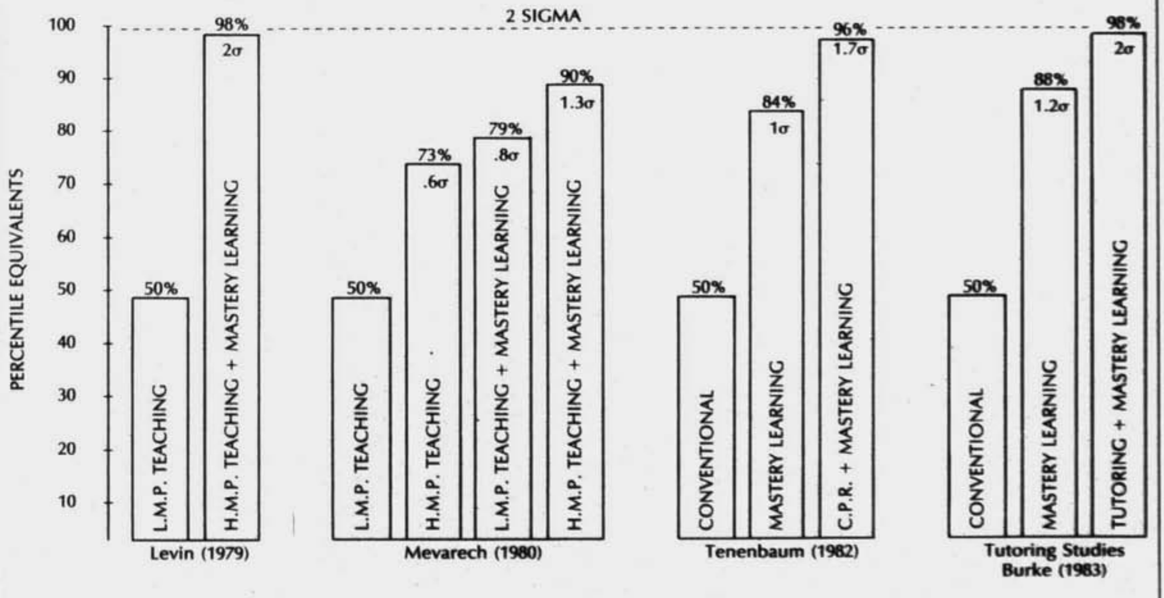
Many years ago, when I was the College Examiner of the University of Chicago, the college faculty was very much concerned that the students were only learning to remember information in the different courses in science, social science, and the humanities—in spite of the fact that their stated objectives emphasized problem solving and the higher mental processes. After much observation and data collection it became clear that lectures to large groups of students (300 to 400), supplemented by textbooks that included facts but not problems, and quizzes and final examinations that included only questions of remembered information, could not enable students to learn the higher mental processes emphasized in the faculty's educational objectives.

After much debate and further study, the faculty and administration decided to replace lecture classes with small discussion classes (28 students per class). They discarded the textbooks (which some of the faculty had authored) and made greater use of primary source readings, firsthand experiences, and laboratory situations. They developed tests and quizzes that included higher mental process questions. The final comprehensive examinations for the different subjects largely became open-book examinations during which students could refer to their notes or other materials because most of the questions dealt with new problems that required students to do more than remember detailed information. After several years of intensive work on these matters, the improvements in students' higher mental process learning and achievement became very pronounced. These and other appro[illegible]es made it clear that most students *could* learn the higher mental processes if they became more central in the teaching-learning process.

In the tutoring studies reported at the beginning of this article, it was found that the tutored students' higher mental process achievement was 2 sigmas above the control students (Figure 5). (The average tutored student was above 98 percent of the control students on the higher mental processes part of the summative examination.) In these studies,

"After several years of intensive work . . . the improvements in students' higher mental process learning and achievement became very pronounced."

Figure 5. Average Higher Mental Process Achievement Under Different Learning Conditions. Comparison of tutoring studies, mastery learning, and higher mental process instructional methods.



lower mental processes as well as higher mental process questions were included in the formative tests used in the feedback-corrective processes for both the mastery learning and tutored groups. Once again, the point is that most students can learn the higher mental processes if they become more central in the teaching-learning process.

Several studies have sought to improve higher as well as lower mental processes. In the Tenenbaum (1982) study, which emphasized changing teacher-student interaction, the cue-participation-reinforcement + mastery learning student group was 1.7 sigmas higher than the control students on the higher mental process part of the summative examination. (The average CPR + ML student was above 96 percent of the control students on the higher mental processes. See Figure 5.) Thus, this approach to the 2 sigma problem improved both the students' lower and higher mental processes.

Levin (1979) focused on improving higher mental processes by emphasizing the mastery of lower mental processes and providing learning experiences in which the students applied principles in a variety of different problem situations. On the summative examinations, students scored very high on both the knowledge of principles and facts and in their ability to apply the principles to new problems. These experimental students were compared with a control group that was taught only the principles and not their application. On the higher mental processes, the experimental group was 2 sigmas above the control students (the average experimental student was above 98 percent of the control students) in the ability to apply the principles to new problem situations.

A third study by Mevarech (1980) was directed to improving higher mental processes by emphasizing heuristic problem solving and including higher and lower mental process questions in the formative testing and in the feedback-corrective processes. On the higher mental process part of the summative tests, the group using the heuristic methods plus mastery learning was 1.3 sigmas above the control group taught primarily by learning algorithms—a set of rules and procedures for solving particular math problems. (The average experimental group student was above 90 percent of the control students.)

In all of these studies, whether group instruction or tutoring, both the instruction and the feedback-correctives emphasized higher mental processes. It was evident in all of the studies that in the formative feedback and corrective processes the students needed and received more corrective help on the higher mental processes questions and problems than they did on the lower mental process questions.

In Process

One of the studies currently being conducted by Wegner-Soled compares control and experimental groups on higher and lower mental process achievement in mathematics and social sciences. In the maximum experimental group, the teachers will be trained to use as much as 33 percent of classroom questions emphasizing higher mental processes; the formative tests will include at least 33 percent higher mental process questions; and the instructional material will emphasize both higher and lower mental processes. Wegner-Soled believes that the combination of all three—*classroom higher mental process questions, formative tests with feedback and correctives on higher mental process questions,* and *instructional material including higher mental process emphasis*—should lead to something approaching the 2 sigma solutions as compared with conventional instruction and materials where higher mental process is almost completely lacking. This study will attempt to determine the separate contributions of each of these three elements as they affect both higher and lower mental processes.

In Summary

While all of us at first thought that solving the 2 sigma problem would be an impossible task, we agreed that if we succeeded in finding *one* solution there would soon be a great many solutions. In this article, I have reported on six solutions to the 2 sigma problem. In spite of the difficulties, our graduate students found the problem to be most intriguing because the goal was so clear and specific—find methods of group instruction as effective as one-to-one tutoring.

It soon became evident that more than group instruction had to be considered. We also needed to find ways of improving students' learning processes, the curriculum and instructional materials, and the home environmental support of the students' school learning. While this article is only a preliminary report on what has been accomplished to date, it should be evident that much can now be done to improve student learning in the school. However, the search is far from complete. We look for additional solutions to the 2 sigma problem to be reported in the next few years.

In the meantime, I hope that teachers and the schools will make use of the findings reported here. Each teacher might find one of the solutions more useful and practical than the others. Each school or school system might try some combination of the following:

1. Improve the student processing of instruction by using the mastery learning feedback-corrective process and/or the enhancement of the initial cognitive prerequisites for sequential courses.

2. Improve the tools of instruction by selecting a curriculum, textbook, or other instructional material that has proven to be very effective.

3. Improve the home environmental support of student learning by beginning a dialogue between the school and the home.

4. Improve instruction in the school by providing favorable conditions of learning for all the students in each classroom as well as by increasing the emphasis on higher mental process learning for all the students. □

[1] $\frac{\text{Mean experimental–Mean control}}{\text{Standard Deviation of the control}} = \frac{\text{Mex-Mc}}{\text{Sigma of control}} = \text{Effect Size}$

[2] Incidentally, such advance organizers have about a .4 sigma effect on retention of the learning.

[3] When questionnaires rather than interviews and observations have been used, the correlations are somewhat lower, with the average being between +.45 and +.55.

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