LEARNING THROUGH FEEDBACK

A Systematic Approach for Improving Academic Performance

Ron Van Houten, Ph.D.

Mount Saint Vincent University, Halifax, Nova Scotia

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To
Children

Rate Measures

The rate at which a behavior occurs is how often it happens in a given amount of time. Hence a second-grade student who works 150 basic multiplication facts, of the form 5 X 6 = _____, in three minutes, is working at a rate of 50 problems per minute. By dividing the total number of problems completed (150) by the total amount of time (three minutes) we have calculated the rate in problems per minute, at which this student works simple multiplication facts. In order to compute any rate we need to know two things, the number of problems completed and the time that the student took to complete them.

However, this calculation only tells us how rapidly the student works, it tells little about how accurately he or she works.

Another way to measure student performance would be to calculate both correct and error rates, with correct rate defined as the number of problems worked correctly in a unit time, and error rate defined as the number of problems worked incorrectly in a unit time. When both measures are viewed together, the student's work rate and accuracy are both readily apparent. Why be so concerned with a student's work rate? For one thing, correct rate is a good indicator of proficiency. Merely being capable of performing a task such as multiplying two one-digit numbers does not demonstrate that the student is proficient at single-digit multiplication. For example, one student may be able to do 70 or 80 of these problems correctly in a minute with no errors, while another can only do 15 or 20 without errors. Since both students are capable of doing the task without errors, should we consider that they are both equally proficient? In order to answer this question we must first ask ourselves what proficiency really means. Proficiency seems to be correlated with speed. A sailor is proficient at tying knots when he can do it rapidly and without errors. It is not enough merely to be able to tie the knot given enough time. Typists are proficient only when they can type at a high enough rate for their services to be useful. Most people could type a perfect page given enough time, but that does not make them proficient typists. A guitarist is not proficient at playing a particular piece until it can be played at a comfortable speed. Why place so much emphasis on speed? The above examples suggest that the answer to this question is tied to the concept of utility. The task must be performed at a useful speed. But useful for what? The answer to this question involves the interrelationship betwen tasks. In order to learn long division we must first master many skills, including basic addition, subtraction, and multiplication. If a student can only multiply slowly, long division is not likely to be mastered very easily. Basic skills are not likely to be effectively utilized until they can first be performed at a useful

or automatic rate. The repeated use of practice, drill, and exercises shows that teachers are vaguely aware of this relationship. Watching a student build proficiency is an exciting way to observe pupil growth. Haughton (1972) has reported numerous examples of rates on basic skills being correlated with rates on more complex tasks. The potential of most students cannot help but be dependent on how well basics are mastered. Increasing the rate and automaticity of basics should increase the potential for success in more complex activities. Therefore, it is not surprising that without exception, better students tend to work at a more rapid sustained clip than poorer students.

Doing a long division problem is a breeze if you can do basic addition, subtraction, multiplication, and division facts automatically. However, it is not likely to be much fun for students laboring on their fingers. In addition, it is quite likely that a rapid pace will decrease the likelihood of the student loosing track of an operation and thereby making an error.

An example of the relationship between basic skills and more complex skills is illustrated in an unpublished study by Van Houten and Sharma. Mr. Sharma taught math to two small classes in an Intermediate Industrial Program located in a rural community. The students' ages ranged between 12 and 16. Being able to do long multiplication and division was an important part of their program. However, they generally worked these problems very slowly, making a considerable number of errors. It was noted that they were not particularly competent at basic multiplication facts. This was obvious for two reasons. First, many of them used their fingers; and second, they often asked the teacher questions like, "How much is seven times nine?" Therefore, it was decided that their competency in basic multiplication facts should be enhanced in order to improve performance on the more complex tasks dependent on this skill.

Each day all the students were given a different ten-minute test containing various long multiplication and division problems, which served as a measure of student success. These problems were arranged on the worksheet according to increas-

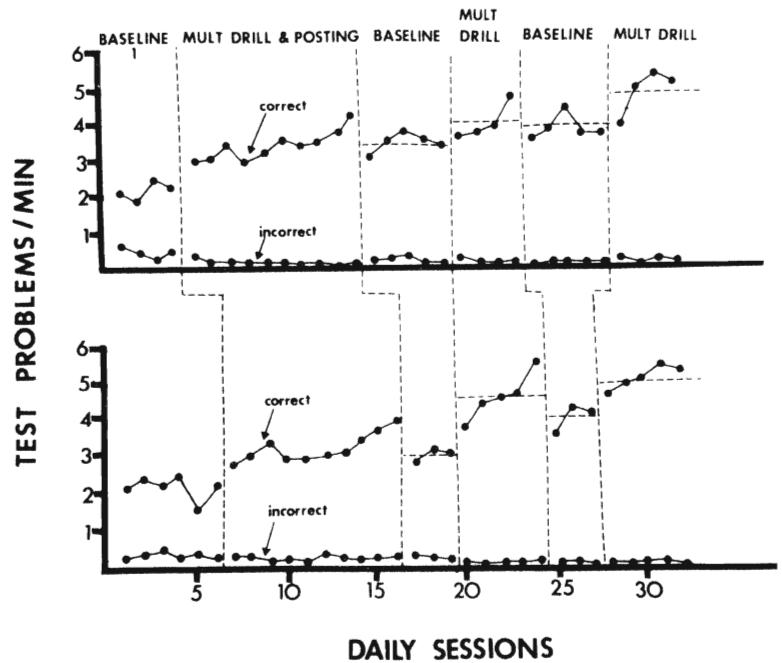

Figure 1–1 The mean number of test problems junior high school students in two classrooms worked correctly during each session.

ing difficulty. The same general types of problems were given each day in order to control for the difficulty of the work, but the numbers were changed to prevent them from memorizing the answers to specific problems. On some days, termed baseline sessions, the tests were administered to the class at the end of the math period; but on other days, termed multiplication drill sessions, the class was drilled on multiplication facts at the beginning of the period and tested at the conclusion of the period. A feedback system was employed to ensure that the performance on multiplication facts would improve. However, the success of the program was judged by whether or not the performance on the long multiplication and division tests improved as a result of the students' learning to work their multiplication facts more rapidly. Figure 1–1 shows both the average

number of test items worked correctly and incorrectly per minute during baseline and when multiplication drill was in effect for both classes. As indicated by the figure, correct rate increased, and error rate decreased whenever the students were given multiplication drill. However, when the multiplication drill was removed, performance neither improved nor deteriorated but rather, remained stable. Further, following the first period of multiplication drill for Class 1 and the second period of multiplication drill for Class 2, accuracy stabilized at close to 100 percent.

An additional fringe benefit of the multiplication drill was the gradual decline in the number of questions asked about number facts during tests. It should be noted that students rarely made errors during multiplication drill from the onset of the study. Therefore, a teacher who only considered accuracy on basic multiplication facts would have concluded that these students had learned all the multiplication facts and therefore required no further training. However, a teacher who also looked at their work rate would have noted that they could only work between 30 and 40 problems per minute prior to exposure to the feedback program. This rate is low compared to the number that a competent student or teacher can complete in a minute. Following training, students could work between 60 and 70 multiplication problems in a minute. Although accuracy on multiplication facts did not improve, rate did. Further, improvement in the rate at which students worked multiplication facts was correlated with improvement in rate and accuracy on more complex math tests involving basic multiplication.

These findings can be partly understood in terms of the concept of overlearning. In overlearning studies tasks are learned to a criterion of 100 percent correct. Once the task is learned to "perfection," or 100 percent accuracy, some students are given further training on the task for a period of time while other students are not. When tested on the task again at a later date, the results show that the task is better retained when it is learned beyond "perfection." However, if a rate measure is

used instead of a percentage measure, one would see that as the error rate declines to zero, correct rate often continues to increase. In other words, the student becomes less hesitant and more self-assured. Therefore, correct rate is a quantitative index of further learning as the student becomes more proficient at the task, and the student is not really overlearning at all. The impression that he or she is overlearning is merely an illusion resulting from the choice of a less sensitive measure (percentage), which loses some important aspects of the original performance.

Relationships have also been reported between reading rate and reading comprehension as measured by the accuracy of answers to questions about a story. Colavecchia (1975) found that students answered fewer questions correctly when they were forced to read material at their instructional level at rates of 15 to 30 words per minute than when the material was presented at a rate that enabled them to read at 60 to 100 words per minute. In another study, Carnine (1976) varied the rate of item presentation for two children on the Level 1 Distar reading program (Engelmann and Bruner, 1974). During the slow presentation rate condition, the teacher paused for five seconds before presenting the next item; and during the fast presentation rate condition, the teacher proceeded immediately to the next item after each response. The results showed that student accuracy (percent items answered correctly) increased from an average of 28.1 percent and 65.1 percent respectively during the slow presentation condition to 80.5 percent and 89.8 percent respectively during the fast presentation rate condition. Hence, not only did a fast presentation rate lead to faster progress but also to improved accuracy. Similarly Van Houten, Morrison, Jarvis, and McDonald (1974) found that story quality as judged by independent raters improved as student story writing rate was increased through the introduction of a feedback system.

Until now we have examined the rate at which a student can perform a particular task. It is also possible to look at the rate at which students master new tasks. Since students who

work more quickly can move through the curriculum in less time, the rate that students master tasks can be employed to predict the adequacy of a student's progress. For example, a student who masters twice as many reading lessons to criterion per day than a peer should learn to read twice as rapidly. So it is not only important to determine how quickly a student reads or completes a reading exercise; it is also important how many lessons or pages are completed per day. Fortunately, this measure can easily be obtained.

The value in taking such an approach is best illustrated by an example provided by Kandel, Ayllon, and Roberts (1976), in which prisoners were given incentives for learning math and English in one of two ways. During a standard incentives condition, a specified number of points were earned by passing each skill unit test in math and English. During a second condition, termed an enriched incentives condition, inmates earned more points the faster they passed the tests. Hence, an individual who passed twelve tests in a week would earn considerably more points for his work than someone who completed twelve tests in four weeks. As shown in Figure 1–2, the rate of progress was up to nine times as great when incentives were made contingent on moving through the material at an accelerated rate. These results clearly demonstrate the value of examining the rate at which a student progresses through the material rather than just the number of units mastered.

To calculate this measure all one has to do is divide the number of lessons or units mastered by the time taken to complete them.

Getting the Measures

Timing Behavior

In order to obtain data on the rate at which a task occurs, it is first necessary to present the task for a fixed period of time. How long? The answer to this question yields some interesting

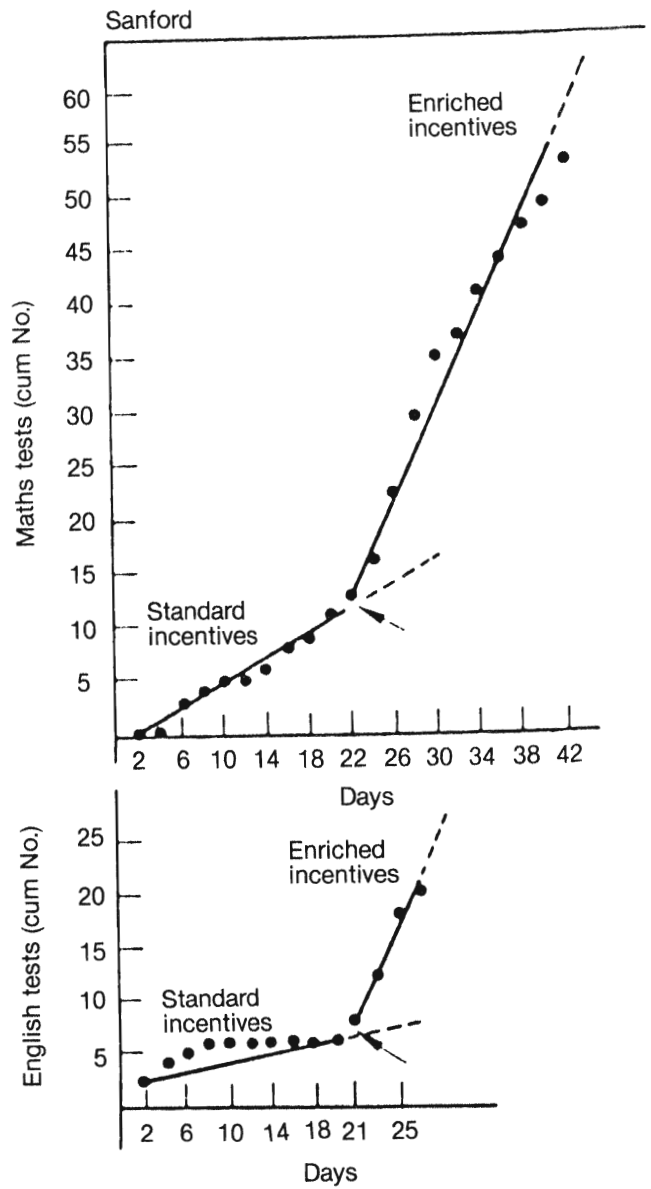

Figure 1–2 The number of math and English units mastered by one subject during the standard and enriched incentives condition (from Kandel, Ayllon, and Roberts, 1976).

information. Teachers often rely on the clock to start and stop academic assignments; thus periods, or portions of periods, are usually allotted for completion of a set amount of work. This contingency is much like a fixed-interval schedule of reinforcement, in which the student has a fixed amount of time either to finish an assignment or complete as much work as possible. Although such timing is present in most classrooms, children are rarely aware of it, and teachers often extend or reduce the length of an activity period as a function of student performance.

However, the results of recent research have demonstrated that the simple operation of explicitly timing a behavior has an effect on the rate at which children work so that the shorter the timing interval the more rapidly the students work. Hence, an interesting fringe benefit resulting from measuring the rate of behavior will often be an increase in performance.

Of course these results fly in the face of current advice, which suggests that teachers give children all the time they "require" to finish an assignment. It is often argued that if less time is given than is "needed," students will become frustrated. However, this analysis does not recognize that the amount of time needed is dependent on the amount of time allotted. Economists have a law stating that work expands to fill the time available. Behaviorally speaking, this means that rate declines in order to fill the time available.

Let's look at some of the research examining the relationship between rate and time limits. Van Houten, Hill, and Parsons (1975) showed that timing and self-scoring increased the rate of story writing of two entire classes of students. The students wrote almost twice as much during the brief writing period when they were informed that they were being explicitly timed with a stopwatch. Unfortunately, timing and self-scoring were introduced together, and it was not possible to conclude definitively that explicitly timing the students produced the increase in performance.

However, in another experiment, Rainwater and Ayllon (1976) timed the reading and math workbook activities of several first graders who were working below standard. Initially, assignment lengths and time allotted to complete an assignment varied. Next, the teacher explicitly timed the period with a kitchen timer. The number of problems assigned and the time limit were kept constant during this condition, and these values were determined by calculating the average number of problems completed and time taken during the previous condition. If a student did not complete his or her assignment before the timer went off, the number of problems completed was noted and the student was allowed to complete the assignment. The data in Figure 1–3 show that both math and reading workbook performance increased following the introduction of explicit timing. It appears that simply informing students that they are being timed increases their rate. The authors also reported that children made comments such as, "I beat the clock." The fre-

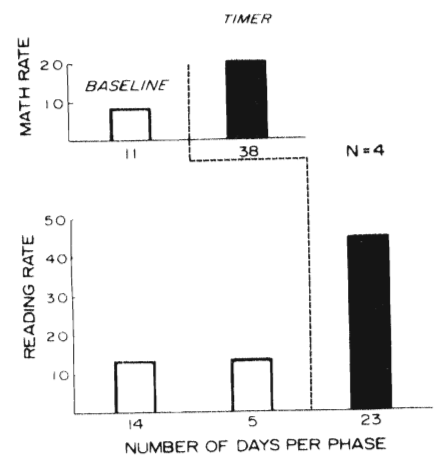

Figure 1–3 Mean math and reading rates during the baseline and timing conditions (from Rainwater and Ayllon, 1976).

quency of this type of comment suggests that we do not challenge students sufficiently by just presenting them with work to complete. Students require a yardstick for improvement, and timing helps them to measure their growth. Interestingly enough, performance improved in the Van Houten, Hill, and Parsons (1975) and Rainwater and Allyon (1976) studies even though the amount of time to complete an assignment did not change from the baseline condition. However, these results do not tell us the effects of varying timing duration.

In another experiment, Van Houten and Thompson (1976) examined the effects of timing alone on the math performance of a class of second-grade students who were academically behind their peers. Each day, the children worked for 30 minutes on addition and subtraction worksheets containing problems of the following type: 3 + 5, 7 + 8, 9 – 3, etc. These worksheets were stapled together to form math booklets. When a student completed one sheet he or she turned it back and began the next sheet. Under these standard conditions students tended to work at a very low rate (from three to four problems per minute). However, accuracy was reasonably high. In addition, the teacher noted that children frequently counted on their fingers or used scrap paper to make and count slash marks.

Next, the teacher instructed the class that the math period was being timed by a spring-wound timer. They were further instructed that they would be timed for one-minute periods with a stopwatch. At the beginning of each timing the teacher would say "Pencils up, ready, begin." The children would then work until the one-minute timing was up. The teacher then told the students to stop and draw a line after the last problem answered, and the next minute timing would begin. This procedure was repeated until the 30-minute math period was up.

The results produced by timing students for brief intervals is presented in Figure 1–4. Several things are apparent from the data. First, student accuracy remained quite high throughout, showing improvement with repeated drill. Second, accuracy during the last portion of this study averaged 98 percent. Fi-

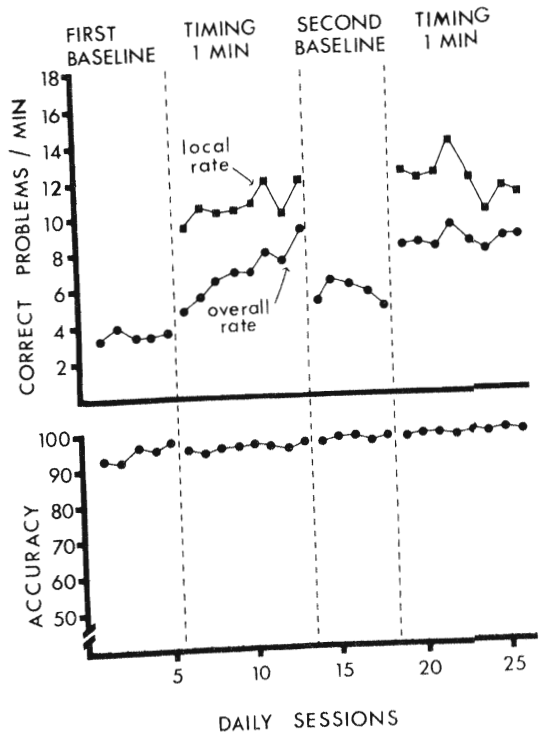

Figure 1–4 The top graph depicts the mean number of problems worked correctly per minute, whereas the bottom graph depicts the mean accuracy of student performance on basic addition and subtraction problems (from Van Houten and Thompson, 1976).

nally, both overall and local rate increased following the introduction of brief successive timings. (Overall rate was the number of problems worked correctly during the 30-minute period divided by 30 minutes, while the local rate was the number of problems worked correctly divided by the actual time the students had to work. Local rate was always higher than overall rate, because students could not work between timings.) The figure also shows that the removal of brief timings led to a decline in rate during the second baseline condition and an

increase in rate during the second timing condition. The authors also noted an increase in the frequency of student comments such as: "I did more problems this time."; "I finished three lines."; etc., during the timing conditions.

These results show that explicitly timing students' math performance for brief periods of time increased the work rate, i.e., the number of problems worked correctly per minute, while maintaining high levels of accuracy. It is interesting to note that the teacher's reason for drilling students on addition and subtraction facts was to reduce their reliance on such aids as number lines, counters, marking slashes on scrap paper, or finger-counting. In other words the purpose of the drill was to help them memorize the number facts and thereby become more proficient in using them. As the project progressed, the teacher noted that the children counted on their fingers less often and that the use of scrap paper declined markedly. Timing students for brief periods led to a more efficient use of drill times because students attempted more problems in a set period of time. The results of an unpublished follow-up study further demonstrates that breaking a period down into brief one-minute timings leads to higher rates than longer intervals such as three or eight minutes. However, the reader should be cautioned that the performance rates reported here should not be considered optimal, since the author has designed feedback programs that have resulted in rate increases to 70 or 80 problems per minute in first- and second-grade students. These rates compare favorably with those of adults.

One reason that timing children for short intervals may be effective is that it tends to make performance changes more salient, thereby focusing attention on performance. Further, it is also well known that most people enjoy racing against the clock. Trying to "beat the clock" can be an interesting game.

Researchers have also studied the effects of varying the total time available for students to complete their work. Allyon, Garber, and Pisor (1976) examined the relationship between time limits and work rate. Three students from a school for the educable retarded were given incentives for working on daily

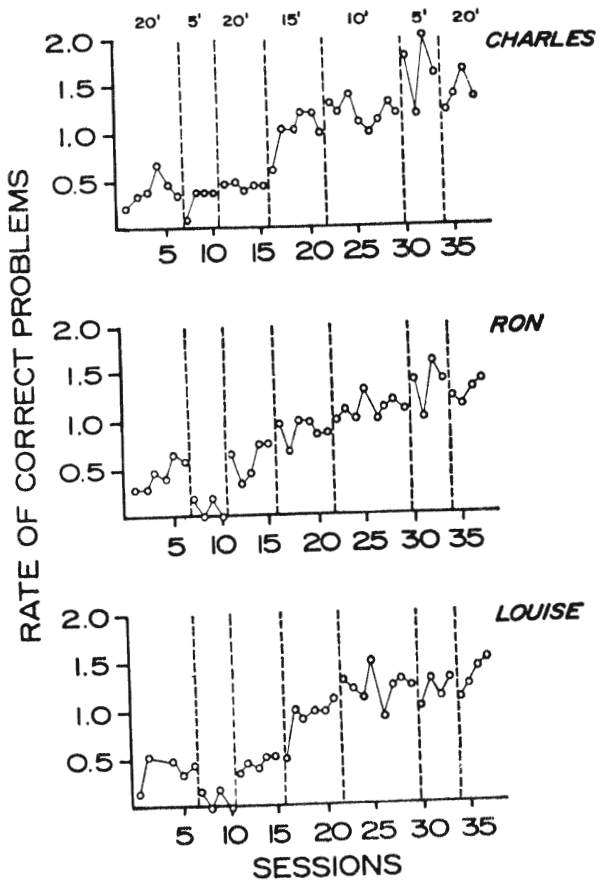

Figure 1–5 The number of correct problems completed per minute by three children in a special education classroom (from Ayllon, Garber, and Pisor, 1976).

math assignments. Initially all students had 20 minutes to complete their math assignments. A stopwatch was used to measure how long each student required to finish his or her assignment. When the time limit was up all students had to stop working and the teachers went to the students' desks, scored their assignments, and gave incentives. Figure 1–5 reveals that the work rate during the first 20-minute condition was quite low.

The abrupt introduction of a five-minute time limit led to a decline in work rate. However, the gradual reduction of time limits from 20 to 15 to five minutes led to a substantial increase in work rate. Further, once high work rates had been reached with short time limits, these rates were maintained when students were again given a 20-minute time limit. Ayllon, et al., also noted that the students relied less on finger-counting as the time limit was gradually decreased. One reason why these students did not increase their rate following an abrupt shift in the time limit may have involved the use of incentives. Following the abrupt decrease in time limit, students may have thought it difficult to continue to earn as many rewards as they did during the previous condition. As a result they may have decided to work at a lower rate in protest. Paradoxically, rate may have shown an increase if incentives had not been provided, since reducing time limits would not have generated as much frustration.

Indeed, Van Houten and Little, in an unpublished experiment, attempted to replicate the results reported by Allyon, Garber, and Pisor (1976) using a similar group of students. However, in the Van Houten and Little experiment a token economy was not employed. Interestingly, work rate increased following an abrupt transition from a 20-minute to a 5-minute time limit. This result clearly supports the position that the failure to obtain an increase in work rate following an abrupt decrease in time limit in the Allyon, et al., experiment was the result of emotional behavior generated by the interaction of the token economy and the abrupt reduction in time limit.

It is also interesting to note that performance in the Van Houten and Little study declined somewhat after the time limit was again increased to 20 minutes. This result also differs from that obtained by Allyon, et al., who found that increased response rate was sustained when the time limit was increased to 20 minutes. Again, it is possible that the token economy helped sustain high rates once the time limit was again increased.

Lastly, the results of the Van Houten and Little study

indicated that accuracy improved for two students following the abrupt reduction in time limit, while the third student, whose baseline performance was already high, showed no change following treatment. These data support the assertion that faster performance need not lead to a decline in quality.

These results imply that if more and more time is set aside because students are working at slower rates, their rates will become even slower. These findings can be contrasted with the advice of educators who advise that students be given lots of time to do each assigned task without heavy pressure from deadlines.

One question that would interest most teachers is how do the children react to timing? Aside from working harder, children seem to enjoy thoroughly racing against the clock. The best evidence for this is the numerous times I have seen students timed on one activity request that they be timed on additional activities. Further, it is also not uncommon to see children timing each others' performance on additional activities without prior prompting from the teacher. At this point if the reader is not convinced of the results produced by timing student performance for brief periods, they can dispel their doubts by taking out a stopwatch and suggesting to poorly motivated students that they would like to see how much work they can complete in a brief period. The results can be startling. The most remarkable thing about the results obtained is not only the magnitude of the effects, but their durability. Students never seem to tire of being timed.

Although the evidence cited clearly shows that timing student performance usually leads to increases in productivity, it should be remembered that this improvement is only a fringe benefit of the timing procedure. The primary purpose of explicitly timing students' work is to assess productivity levels and to yield a basis for providing feedback. How much difference feedback can make is only foreshadowed by the effects of timing on student performance. It seems clear that the increase in performance produced by timing behavior partially results from chil-

drens' attempts to compare their present performance with past performance. Timing activities for brief intervals allows students to make such comparisons easily.

Finally, what is the optimal timing duration? There is no single answer to this question because optimal values may vary with tasks and student experience as well as important pragmatic considerations, such as ease of grading. For example, when teaching basic addition facts, one-minute timed samples may be quite adequate, since many facts (80 to 100) can be done by a competent student in this period of time. However, if the task is more complex, such as a daily math test containing more complex work, such as four row, six column addition, longer periods of time will be required. Generally, it is better to provide less time than is needed so that student work rate can show growth. However, an alternate strategy is to start off with longer intervals and gradually decrease the period length.

When working in areas that require direct teacher assessment, such as reading rate and accuracy, one-minute timed reading tests are quite adequate. However, when working on comprehension at their seats, a series of items can be presented, and hence timing duration can be increased proportionately. Further examples are provided in Chapter 5.