Preteaching Versus Concurrent Teaching of the Component Skills of a Multiplication Algorithm

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Teaching the component skills that comprise a more complex skill increases the probability that the complex skill will be learned (Gagné, Mayor, Garstens, & Paradise, 1962; Gollin, Moody, & Schadler, 1974; Mayer, Stiehl, & Greeno, 1975) or that transfer will occur (Carnine, 1977; Houser & Trueblood, 1975; Jeffrey & Samuels, 1967). Case (1975) explains the benefits of teaching component skills as follows:

> In the early stages of skill acquisition, subjects normally have to monitor several external stimuli, and coordinate a number of discrete responses. With overlearning, however, these responses become integrated into one unit. Since the skill is now much "simpler" from the subject's point of view, it consequently requires very little attention for execution. The result is (or should be) that a good deal of coordinating capacity is "left over," and that it can be used for integrating the newly consolidated basic skill with other basic skills. (p. 75)

In these studies, a teaching component skills treatment was compared with a treatment in which component skills were not taught. The purpose of the present study was to determine whether the time at which component skills are taught is a significant instructional variable. The hypothesis was that preteaching component skills results in more rapid learning of a complex skill than teaching the components at the same time as the complex skill. Preteaching components was expected to be more efficient because, according to Case, integrating recently mastered units or components would be easier than simultaneously mastering the components and integrating them to form a more complex skill.

Method

Subjects and Setting

The study was conducted during the last three months of the school year. Fifteen below-average (as defined by the Metropolitan Readiness Test) first graders judged by the teacher as able to benefit from the multiplication instruction were selected as subjects. The 8 girls and 7 boys were randomly assigned to either the preteaching group (4 boys and 4 girls) or the concurrent group (3 boys and 4 girls). Daily 10-minute sessions were conducted in the afternoon. The experimenter, a graduate student in education, met with each student in a corner of the classroom that was screened off by a 6-foot divider.

Materials

Twenty-four single-digit multiplication fact cards were generated by using all the possible combinations with multipliers of 2, 3, 7, and 9 and multiplicands of 1, 2, 3, 4, 5, and 6. Two facts with each multiplier were randomly selected as transfer problems and were not presented during training. The remaining 16 facts were used for training.

Procedure

In the preteaching treatment students received instruction in the three component skills—counting by various numbers, decoding facts, and applying a count-by strategy—before encountering the 16 flash cards. Each 10-minute session devoted to the component skills was divided into three intervals: a 4-minute block devoted to counting by various numbers, a 2-minute block for decoding facts and applying the count-by strategy, and finally a second 4-minute block for counting by various numbers.

The counting-by skill was taught with eight sets of examples: 2 to 8, 2 to 12, 3 to 12, 3 to 18, 7 to 28, 7 to 42, 9 to 36, and 9 to 54. The procedure was the same for each set. The experimenter said, "We're going to count by two. My turn. 2, 4, 6, 8. Say it with me. Two, four, six, eight. Your turn." The experimenter repeated the "your turn" instruction until the child correctly repeated the counting series on three consecutive trials. The experimenter corrected errors by modeling the answer and repeating the instruction. After the child responded without a correction on three consecutive trials, the experimenter initiated the next set of count-by examples, following the same procedure.

The second component skill, decoding, was taught with randomly selected training examples that were written on a chalkboard. The experimenter taught the decoding skill by writing a fact such as 2×3 on the board and saying, "This problem says count by two, three times. What does this problem say?" For subsequent examples, the experimenter just asked, "What does this problem say?" The experimenter corrected errors by modeling the answer and repeating the task. Decoding training continued until the child correctly decoded three consecutive problems. For the third component skill, the count-by strategy, the experimenter wrote a problem on the board (e.g., 2×3) and said, "We count by two three times, so I hold up three fingers. Now I count by two for each finger." The experimenter then counted each extended finger: "Two, four, six. When I count by two, three times, I end up with six. Your turn. Hold up three fingers. Now count by two each time you touch a finger." Note that this counting procedure differs from common practice that would translate 2×3 as $3 + 3$ rather than $2 + 2 + 2$.

After modeling and testing the count-by strategy, the experimenter led the child through the entire procedure for working multiplication problems by presenting a series of questions and instructions. The child responded to each instruction. "What does this problem say to do? . . . We count by two, three times. So how many fingers are you going to hold up? . . . Do it. Hold up three fingers . . . What are you going to count by? . . . Count . . . When you count by two, three times, what do you end with?"

After a child responded without a mistake to all the instructions in the procedure for three different problems, the component skill training was completed and the first of seven sets of flash cards was presented. The experimenter said, "Tell me the answer to these problems." If the answer was incorrect, she decoded the fact; for example, "The problem says to count by two, three times. Do it." If the child still did not give the correct answer, she (a) modeled the correct answer, (b) repeated the instructions for working a multiplication fact, and finally (c) asked the child to give the answer for the flash card.

The set of cards was shuffled after each presentation. After a child correctly responded to three consecutive problems, the next set of facts was introduced. Training was terminated after a child responded correctly to 15 of the 16 facts in Set 7, the last set. The 8 transfer facts were then immediately presented. Child responses to the transfer facts were neither confirmed nor corrected.

Children in the concurrent group began with the seventh set of facts, which contained all 16 facts. They received instruction in the component skills at the same time that they were presented a multiplication fact to solve. The experimenter presented a flash card such as 2×3 and modeled decoding the fact, the count-by strategy, and counting two, four, six. After modeling, the experimenter had the children respond to the same instructions as presented to the preteaching group. The experimenter corrected mistakes by giving the instruction that preceded the error, modeling the response, repeating the instruction, continuing with the remaining instructions, and finally asking for the answer to the fact on the card. Since a child in the concurrent group did not receive pretraining on the components, the experimenter often had to model and repeat an instruction several times before the child responded correctly. Training was terminated after a child responded correctly to 15 of the 16 training facts. The 8 transfer facts were then presented.

A time-to-criterion measure was determined for each child by timing every training session. Also, correct responses to transfer facts were recorded for each child.

Results

Children in the preteaching group reached criterion in significantly less time than children in the concurrent group, $t(13) = 1.99, p < .05$. The mean for the preteaching group was 105 minutes and 29 seconds, $SD = 20:11$. The mean for the concurrent group was 137 minutes and 35 seconds, $SD = 37:50$. On the eight transfer facts the mean of correct responses was 6.5 ($SD = 1.0$) for the preteaching group and 4.9 ($SD = 1.5$) for the concurrent group, $t(13) = 2.23, p < .05$.

Discussion

Research cited earlier found that teaching the component skills of a complex skill enhanced learning and transfer of that skill. The present results extend those findings by showing that the time at which the component skills were presented was a relevant variable. When the component skills of the procedure for working multiplication problems were pretaught, children learned to solve a set of multiplication facts in less time than when the components and the procedure were learned at the same time. More rapid learning in the preteaching group was also accompanied by more correct responses to transfer facts. The relative efficiency in terms of time and transfer scores for the preteaching treatment may have resulted from a "chunking" procedure (Case, 1975), in which skills were mastered and then integrated into a more encompassing framework. Analogous results in paired-associate learning tasks were reported by Carnine (1976), in which a stimulus was introduced and integrated with previously introduced stimuli before a new stimulus was introduced.

The generalizability of the present findings to different populations and skills requires further research. The students in the present study were below-average-achieving first graders. The applicability of preteaching component skills to children of differing ages and of differing abilities is open to investigation. Also, the procedure for working multiplication facts was amenable to an analysis of component skills and to preteaching them. The range of problem-solving procedures with identifiable component skills that are suitable for preteaching needs to be specified, and research is needed to determine whether preteaching those skills is more efficient than concurrently teaching the components and the procedure.

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Using Games to Maintain Multiplication Basic Facts

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Bright, Harvey, and Wheeler (1979) examined whether a game treatment was an effective way to retrain skills with multiplication basic facts for children who had previously had an opportunity to master those facts. They concluded the game treatment was effective. The present study examined whether the effects of games on mathematics skills are stable over time. Two research questions were developed.

1. Can games be used effectively to help students maintain skills with multiplication basic facts over a school year?
2. If games are effective, how often must they be used?

Procedures

Games

The games used were MULTIG and DIVTIG as found in *Developing Mathematical Processes* (Romberg, Harvey, Moser, & Montgomery, 1974, 1975, 1976). These games were described previously (Bright et al., 1979).

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