

Effectiveness of a Cognitive Strategy Intervention in Improving Arithmetic Computation Based on the PASS Theory

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Abstract

The purpose of this study was to determine if an instruction designed to facilitate planning, given by teachers to their class as a group, would have differential effects depending on the specific Planning, Attention, Simultaneous, Successive (PASS) cognitive characteristics of each child. A cognitive strategy instruction that encouraged planning was provided to the group of 19 students with learning disabilities and mild mental impairments. All students completed math worksheets during 7 baseline and 14 intervention sessions. During the intervention phase, students engaged in self-reflection and verbalization of strategies about how the arithmetic computation worksheets should be completed. The sample was sorted into one experimental and four contrast groups after the experiment was completed. There were four groups with a cognitive weakness in each PASS scale from the Cognitive Assessment System and one group with no cognitive weakness. The results showed that children with a cognitive weakness in Planning improved considerably (large effect size of 1.4), in contrast to those with a cognitive weakness in Attention (small effect size of 0.3), Simultaneous weakness (a slight deterioration and effect size of -0.2), Successive weakness (medium effect size of 0.4), and no cognitive weakness (small effect size of .2). These data showed that children with a Planning weakness benefitted from the instruction designed to help them be more playful. Those children who received the planning-based instruction who were not low in planning did not show the same level of improvement.

Cognitive strategy instruction has gained in acceptance in recent years, especially for children at risk for failure in mathematics (Montague, 1997). Many of the children who perform poorly in arithmetic computation, for example, are often deficit in both the knowledge of arithmetic facts as well the problem-solving skills that are important for success (Das, Naglieri, & Kirby, 1994). Direct instruction of the basic skills required to be successful is commonly available, but some children also perform poorly because they do not apply appropriate methods when problem solving (Kirby & Williams, 1991; Montague, 1997). Poor problem solving involves failure to organize the math, inadequate reflection on the best procedures used, difficulty analyzing the demands of the problem, and failure to carefully monitor and check the work. Good use of these mathematical problem-solving

activities is related to instruction as well as the child's cognitive characteristics (Naglieri & Ashman, 1999).

Das et al. (1994) and Naglieri and Das (1997a) presented a new conceptualization of cognitive processing based on the Planning, Attention, Simultaneous, and Successive (PASS) Theory. This theory takes a cognitive processing perspective of ability, proposing that IQ is better described as PASS cognitive processes. The theory assumes that PASS processes are the basic cognitive functions that allow children to perform in a variety of settings. These processes are defined as follows: *Planning* is a mental process that provides cognitive control and comprises development of strategies and plans, self-monitoring, self-regulation, and utilization of processes and knowledge to achieve a desired goal; *Attention* refers to the mental process that provides focused cognitive activity, resistance

to distraction, and selective attention over time; *Simultaneous* describes the mental process that allows the person to deal with many pieces of information at one time and arrange those data into interrelated groups; and *Successive* processing refers to the mental activity that allows a person to work with information in a specific order or series. Although all four of the PASS processes are statistically related to arithmetic computation (Naglieri & Das, 1997a), Planning is especially important for successful math performance and has been found to be related to cognitive strategy use in math computation (Das et al., 1994). More important, this process has been found to have important implications for intervention with children whose arithmetic computation is poor (Naglieri & Gottling, 1995, 1997).

Instruction designed to address the poor math problem-solving skills (e.g.,

poor use of planning) of some children has been successfully used by a number of researchers (see Pressley & Woloshyn [1995] and Scheid [1993] for a summary and Van Luit & Naglieri [1999] for an example). A series of studies has shown that cognitive strategy instruction designed to improve planning can influence children's performance on a variety of tasks. The researchers found that students who had poor scores in planning improved more than those who had high scores in planning when given the same instruction designed to facilitate, rather than directly teach, planfulness. This cognitive strategy method was initially used by Cormier, Carlson, and Das (1990) then replicated in two studies by Kar, Dash, Das, and Carlson (1992). Neither of those studies involved academic tasks, but Naglieri and Gottling (1995, 1997) extended this research to arithmetic computation taken directly from the curriculum. Their studies showed that there were differential effects of instruction designed to facilitate planfulness, and that these different effects were related to the Planning scores earned by the participants. These results suggested that the intervention helped those with low scores in planning considerably more than those with high planning scores and demonstrated the usefulness of training planning processes as part of mathematics instruction for students with learning disabilities. The results demonstrated that because students benefited differentially from the instruction depending on their cognitive abilities, matching the instruction to the cognitive weakness of the child was important. The purpose of the present study was to further test the results of these studies.

Method

Participants

This study involved a sample of 19 students (ranging in age from 12 to 14 years; 84% boys) who attended Grades 6 to 8 in two public schools in southern

California. The students attended a public school that served rural and suburban communities with low to lower-middle class levels of socioeconomic status. These students were previously identified and subsequently placed in special education settings for math instruction. Their handicapping conditions were listed primarily as learning handicapped, with a few students placed as mildly mentally impaired. Four of the 19 students were bilingual in Spanish and English but were instructed in English, and all were English-fluent.

Procedure

Baseline and intervention sessions designed to facilitate discussion of strategies were conducted over a 3-month period. These sessions were completed with the students as a group during their regular math instruction period. The sessions took place at the end of the school year, after math instruction in the types of problems included on the study worksheets had been completed using traditional instructional procedures. Students were informed that they had already been confronted with the types of problems on the worksheets and were asked to correctly complete as many problems on the page as they could during the 10-minute sessions of worksheet completion.

During the baseline phase, students simply completed a mathematics worksheet as instructed, engaged in unrelated activities for 10 minutes, then completed another worksheet using the same instructions. They were not given feedback on the number correctly completed. During the intervention phase, students completed worksheets, engaged in discussions about the strategies they believed were most effective, then were asked to complete a second worksheet. There was a 10-minute period for completing the mathematics page, a 10-minute period for the discussion intended to facilitate planning, and a second 10-minute period for completing another mathe-

matics page. The method of facilitating student planning was established in collaborative sessions between the school psychologist and the teacher, and guidelines for prompting were established following the method outlined by Naglieri (1999). All students were exposed to the intervention sessions that involved the three 10-minute segments of mathematics/discussion/mathematics in half-hour instructional periods.

The group discussion periods during Intervention were designed to encourage self-reflection and discussion in order to help the children gain an understanding of the need to plan and use efficient strategies when doing math. To achieve the general goal of improved use of planning and self-reflection, teachers encouraged the children to verbalize the methods they used and be self-evaluative. The teachers facilitated discussion with probes designed to encourage the children to consider various ways to be more successful. When a student provided a response, this often became the beginning point for discussion and further development of the idea. The following probes are illustrative of those used:

- Can anyone tell me anything about these problems?
- Let's talk about how you did the work sheet. What was the same or different about the problems?
- What could you do to make this seem easier?
- Why did you do it that way?
- How did you do the problems?
- What could you have done to get more correct?
- What did it teach you?
- What will you do next time?

Some of the strategies the students generated during this discussion were general, such as, "Check your answers to see if they are close," "Line up the numbers right," "Do the problems from right to left," "Search the page to find the shorter ones," "Skip the ones you completely forgot how to do," and

"Find the easy ones and do those first." Some of the more specific strategies the students mentioned included "Check to see if you have to borrow or carry," "Check your multiplication facts," and "Don't get top and bottom numbers mixed up" (for fractions). A list of strategies was generated and kept in the classrooms for reference during the remaining intervention sessions. Students were asked to describe how the strategies worked to their advantage. Even inappropriate strategies were listed but when discussed more in depth by the group, were rejected. For example, "I tried only the hardest problems" was determined by the students to be a poor strategy for completing the most problems correctly on the page.

During some of the discussion sessions, students volunteered to model the specific strategies they mentioned. The teacher provided clarification and feedback as to the usefulness of the strategies, and this was added to the ongoing list. However, the teachers were instructed not to make statements about specific items on the worksheets such as "That is correct" or "Remember to use that same strategy." They did not provide feedback on the number correct, and they did not give math instruction. The role of the teacher was to facilitate self-reflection and encourage the students to plan, so that they could correctly complete as many items as possible on the worksheets.

The school psychologist completed the first two sessions of the planning facilitation phase to model the method and help the teachers with their acquisition of it. The teachers then facilitated the subsequent discussions, consulted with the school psychologist during the time the experiment was under way, and made modifications as needed. For example, on occasion the students got off track and needed feedback to show that their method did not lead to correct answers. When the students worked through the problems on the board using the more specific strategies they came up with, errors either became evident to the students

themselves or were pointed out by the teacher, which also served as feedback to the others about how to proceed the next time. This allowed the teachers new ways to interact with the students about their methods of completing the page and thereby facilitated careful examination of the methods used to complete the math worksheets.

Instruments

Mathematics worksheets were prepared after careful analysis of the children's curriculum. The math content of the worksheets, which directly aligned with the curriculum, included 41 problems of varying types (see Figure 1). The worksheets were constructed in Microsoft Excel using several random number functions. Programming the random numbers to specific ranges controlled the requirements of the problems. This allowed for the generation of ample numbers of worksheets with approximately equivalent levels of difficulty.

Each child was individually administered the *Cognitive Assessment System* (CAS; Naglieri & Das, 1997a) by the second author during the course of the intervention. The CAS is an individually administered test of ability for children ages 5 through 17 years and is organized into four scales (Planning, Attention, Simultaneous, and Successive) according to the PASS theory, and a Full Scale standard score, each with a mean of 100 and *SD* of 15. The CAS comprises 12 subtests that have undergone extensive development and validation (see Das, Naglieri, & Kirby, 1994; Naglieri, 1999; Naglieri & Das, 1997b). The test is standardized on 2,200 persons ages 5 years 0 months to 17 years 11 months who closely match the United States population on the basis of gender, race, region, community setting, classroom placement, educational classification, and parental education. Extensive reliability and validity research is presented in the *CAS Interpretive Handbook* (Naglieri & Das, 1997b) and in Naglieri (1999).

Data Analysis. The entire sample of 19 children was divided into one experimental (low in Planning) and four comparison (low in Attention, Simultaneous, or Successive or not having any low PASS score) groups of children. Thus, groups of participants who had a significant cognitive weakness in one of the four PASS processes were identified. This means that, for example, a child in the low Planning group had to have a Planning score that was significantly lower than that child's mean PASS score and that the score had to be less than 85 (see Naglieri, in press). Using this criterion, 9 (47%) of the 19 students were identified as having a cognitive weakness, an amount similar to that found in classes of special education students (Naglieri, in press). The children with a Planning cognitive weakness formed the experimental group because the purpose of this study was to determine if those with a cognitive weakness in the CAS Planning Scale ($n = 3$) would show different rates of improvement. Students with a cognitive weakness in the Simultaneous ($n = 3$), Attention ($n = 2$), and Successive ($n = 1$) scales were identified to form comparison groups. Finally, those children without a cognitive weakness in any PASS scale ($n = 10$, a nonsignificant profile) were used to form a fourth comparison group.

The total number of math problems correct during the 7 baseline and 14 intervention sessions of the experiment were computed for every child and for the five groups of children as described above. The total number correct during the 14 intervention sessions was weighted by .5 so that the values would be comparable to the total number correct during the seven baseline sessions. Effect sizes were computed using the approach described by Weiner, Sheridan, and Jenson (1998). This method computes effect sizes without assumptions regarding the distribution in the populations or homogeneity of variance (see Busck & Serlin, 1992). The effect size is computed from the difference between the mean scores obtained during baseline and interven-

Name: _____	Page 1				
Date: _____					
- 988	- 98,923	- 7,344	+ $\frac{2}{2}$	+ $\frac{12}{12}$	+ $\frac{5}{14}$
- 335	- 287	- 3,740	+ $\frac{5}{5}$	+ $\frac{6}{13}$	+ $\frac{3}{3}$
- 15	- 50	- 154	- 5	- 18	- 24
× 1	× 2	× 68	- 8	- 1	- 3
+ 864	+ 99,979	+ 9,424	- 11	- 5	- 6
+ 192	+ 241	+ 6,430	- 9	- 9	- 7
- 83,052	- 71,085	- 81,747	- 3	- 10	- 4
- 44,247	- 24,408	- 12,688	- 5	- 14	- 9
× 1304	× 934	× 1918	- 7	- 12	- 5
× 39	× 533	× 767	- 8	- 10	- 9
+ 77,076	+ 13,212	+ 34,548	- 6	- 1	- 3
+ 65,444	+ 75,770	+ 51,434	- 8	- 3	- 8
+ 83,117	+ 15,293	+ 54,874	- 6	- 1	- 3
+ 55,597	+ 64,788	+ 31,614	- 8	- 3	- 8

FIGURE 1. Illustration of a math worksheet used in this study.

tion divided by the standard deviation obtained during the baseline phase.

Results

Each child's PASS scores as well as the total number correct during baseline and intervention are provided in Table 1. It is apparent from examination of the performance of the various groups of children that the intervention had

differential impact on the children. Those children with a cognitive weakness in Planning evidenced change scores of 63% to 338%, with effect sizes ranging from .6 to 2.6. These can be described using Cohen's (1988) guidelines of .2, .5, and .8 as small, medium, and large effect sizes, respectively. Overall, the group with a Planning cognitive weakness evidenced 167% improvement over baseline and an average effect size of 1.4. This amount of

improvement brought the children with Planning cognitive weaknesses to a level that was similar to that of the rest of the class. These findings are in contrast to those children with a cognitive weakness in Attention who showed a 46% increase (small effect size of 0.3) and a 39% increase in Successive (0.4 effect size). The performance of children with a cognitive weakness in Simultaneous processing deteriorated slightly, evidencing a -10% change and

TABLE 1
Individual Children's Baseline and Intervention Total Raw Scores, Percent of Change, and Effect Size

Participants	Plan	Sim	Att	Suc	Baseline		Intervention		% Change	Effect size
					mean	SD	mean	SD		
1	65	76	77	97	1.0	1.2	2.0	2.6	100	0.9
2	79	94	97	94	2.3	2.2	3.7	1.9	63	0.6
3	65	97	85	84	1.1	1.5	5.0	3.8	338	2.6
1-3	69.7	89	86.3	91.7	1.5	1.6	3.6	2.8	167	1.4
4	85	94	74	92	2.0	2.6	2.2	2.5	11	0.1
5	88	91	68	111	2.6	3.8	4.6	3.1	81	0.5
4-5	86.5	92.5	71.0	101.5	2.3	3.2	3.4	2.8	46	0.3
6	88	88	103	72	4.0	2.9	5.6	3.6	39	0.4
7	85	70	100	97	4.1	3.6	2.7	2.2	-34	-0.4
8	94	79	97	86	5.7	2.4	4.5	2.6	-21	-0.5
9	100	61	74	86	4.3	3.5	5.4	3.4	25	0.3
7-9	93.0	70.0	90.3	89.7	4.7	3.2	4.2	2.7	-10	-0.2
10	74	100	85	78	4.1	3.2	3.9	2.8	-7	-0.1
11	71	79	77	78	4.4	3.7	5.1	2.8	15	0.2
12	103	103	91	89	2.7	3.0	3.2	2.8	18	0.2
13	71	70	88	75	3.4	3.6	2.8	2.8	-19	-0.2
14	94	88	112	89	4.7	3.5	5.2	2.8	11	0.1
15	85	85	103	86	6.3	2.6	5.6	2.6	-10	-0.2
16	79	76	77	86	3.4	2.1	6.9	2.9	100	1.6
17	88	73	77	81	2.0	2.0	2.4	2.4	18	0.2
18	74	67	88	66	4.0	3.9	3.2	3.2	-20	-0.2
19	94	109	94	103	1.9	1.5	2.9	2.3	54	0.7
NCW	83.3	85.0	89.2	83.1	3.7	2.9	4.1	2.7	16	0.2

Note. $N = 19$. Plan = Planning, Sim = Simultaneous, Att = Attention, Suc = Successive. Percentage change was calculated using the formula: (mean number correct intervention - mean number correct baseline) / mean number correct baseline. Effect size was calculated using the formula: (intervention mean - baseline mean) / baseline SD. PCW = Planning Cognitive Weakness; SIMCW = Simultaneous Cognitive Weakness; ATTCW = Attention Cognitive Weakness; SUCCW = Successive Cognitive Weakness; NCW = No Cognitive Weakness. PASS scores that are Cognitive Weaknesses appear in boldface.

-0.2 effect size). Finally, children without a cognitive weakness improved 16% from baseline to intervention with a small 0.2 effect size. These data show that children with a Planning cognitive weakness benefited from the instruction designed to help them be more planful. Those who received the planning-based instruction who were not low in planning did not show the same pattern of improvement.

Discussion

In this study we have attempted to examine the importance of each child's PASS characteristics and the relation-

ship between a cognitive weakness and amount of benefit from instruction. The present results, like those reported by Naglieri and Gottling (1995, 1997), Cormier et al. (1990), and Kar et al. (1992), suggest that a cognitive strategy instruction that teaches children to better use planning processes is especially useful for those who need it the most. The results of the present study also illustrate that this technique, which does not use teacher scripts or rigidly formatted procedures, can be replicated. Additionally, these results are similar to other math studies involving special education children (e.g., Van Luit & Naglieri, 1999) but are especially relevant for

those who are poor in Planning, as measured by the CAS. This suggests that information about a child's ability, when defined by PASS, can have relevance for which intervention will be selected. Due to the fact that the present findings are consistent with previous research (Cormier et al., 1990; Kar et al., 1992; Naglieri & Gottling, 1995, 1997) as well as with findings by Van Luit and Naglieri (1999) and other cognitive strategy instruction researchers (e.g., Ashman & Conway, 1993; Pressley & Woloshyn, 1995), the utility of cognitive methods warrants careful consideration.

In combination with previous research, the present findings support

the suggestion made by Naglieri and Gottling (1997) that the PASS approach addresses the calls for a theoretical model of cognitive processing that influences learning (Geary, 1989). These studies support the view that PASS may meet the need for a "theory of the initial properties of the learner which interact with learning . . . [and] accounts for an individual's end state after a particular educational treatment" (Snow, 1989, p. 51). It seems that by changing the way aptitude is conceptualized (e.g., as PASS rather than traditional IQ) and measured (using CAS), the probability that aptitude-by-treatment interactions (ATIs) will be found has increased. It is important, however, that there be consistency between the aptitude (in this case, Planning) and the intervention (one that facilitates planning), and that the process be especially relevant to the academic area (planning is important to successful arithmetic computation; Das et al., 1994). It is also critical that aptitude is not measured in the traditional IQ manner defined as general ability.

The present results further suggest that past ATI research may have suffered from inadequate conceptualizations of aptitude, which may be why the approach based on PASS yielded different findings. Past researchers have found that students with low general ability improve little, whereas those with high general ability do well. In the present and previous investigations, researchers found that children who were low in planning improved the most. Moreover, children with different cognitive weaknesses have not benefited the same amount from the same intervention, suggesting, for example, that those with a Successive cognitive weakness need a different intervention than the planning facilitation. These findings also suggest that future research is needed to examine if ATIs can be found for different combinations of PASS cognitive weaknesses and specifically selected interventions.

It is reasonable to consider whether the results of the present or previous

studies (e.g., Naglieri & Gottling, 1995, 1997) were influenced by regression effects; however, the problem of regression toward the mean does not apply to these studies. Regression effects are found when participants are identified based on a low preintervention score on some measure and then tested after intervention on that same measure. In the present study and those that preceded it (Naglieri & Gottling, 1995, 1997), children were not grouped on the basis of low math scores and given the same or similar tests in math. Instead, the participants were organized into groups based on low PASS scores (or no low PASS score) after the intervention was completed, and then math scores were compared baseline to intervention. In addition, all groups could potentially benefit from the effects of repeated practice on the math worksheets. Finally, it is also important to recognize that the number of items that appeared on the math worksheets was large enough to ensure that ceiling effects would not influence the results. There were about 40 problems per page, and each child was given only 10 minutes to do them.

The present findings should also be viewed in conjunction with a larger body of research and instruction for general education students that promotes the concept of teaching children to be more strategic in a variety of subjects. For example, Ashman and Conway (1997) provided an excellent summary of a variety of cognitively based instructional methods, many of which focus on teaching children to be more strategic (i.e., planful). Perhaps the most illustrative of these is their Process Based Instruction (Ashman & Conway, 1993), which is a classroom-wide approach to teaching children to use plans and strategies when doing all types of academic tasks. Similarly, Pressley and Woloshyn (1995) advocated for the use of cognitive strategies to improve performance in a wide variety of academic areas for regular education students. Additionally, mnemonic strategies for remembering

facts have also been successfully used with general education students (Mastropieri and Scruggs, 1991). In fact, in a recent meta-analysis (Lloyd, Forness, & Kavale, 1998), mnemonic training was the most effective intervention (effect size of 1.6) in a group of methods including modality-based instruction, peer tutoring, behavior modification, and direct instruction. Thus, a growing body of research illustrates the potential benefits of cognitively based instructional methods, especially those that emphasize the utilization of strategies or plans.

In conclusion, this study provided information about an intervention teachers can apply to assist children who are poor in arithmetic computation. Based upon previous research and the current findings, we anticipate that many children will benefit from this instruction, but those with a cognitive weakness in Planning on the CAS are expected to improve the most. Thus, when the instruction is tailored to the need of the child, considerable improvement may result. When a child has a Planning weakness, the method described here should be provided, and additional work on the needed math skills could follow. If the child does not have a Planning weakness, then some other intervention that addresses his or her cognitive weakness (e.g., Simultaneous, Attention, or Successive) would be more appropriate (see Kirby & Williams [1991] or Naglieri & Ashman [1999] for illustrations).

More research is needed to examine the relationships between PASS cognitive weaknesses and mathematics performance. The planning facilitation method should be further examined using larger samples of children. Research is also needed to determine what methods will assist children with specific cognitive weaknesses in Simultaneous, Attention, and Successive processes. These studies should more fully explore the contributions cognitive instruction can have for students who perform poorly in math, especially when poor performance is related to a PASS cognitive weakness.

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