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The Effects of a Student-Centered Thinking Strategies Approach to Learning
Basic Facts

Presidential Scholar Thesis
University of Northern Iowa

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Spring 1998

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Children receive a wealth of education at school. They learn things to help them contribute to society. They learn things to help them function in society, things they will use on a daily basis. One such thing is their knowledge of basic arithmetic facts. Learning basic arithmetic facts is an important part of a child's education. They are the building blocks for further mathematical applications, mental math, and estimation. It is essential that children understand basic facts.

There is, however, an inconsistency between current practice and current recommendation for teaching basic facts of arithmetic. Nearly all teachers use activities with concrete objects, or direct modeling activities, to begin teaching children basic facts. They have students count the objects to determine the answer. The objects give student "proof" of the result (Rathmell, 16). These counting activities are soon followed by drill and practice, such as flashcards and timed tests.

In contrast, several responsible professional organizations, such as the National Council of Teachers of Mathematics, and leading math educators, suggest that direct modeling activities should be used to help children develop thinking skills, and that drill and practice be delayed. They believe learning and practicing thinking strategies develop the children's concept of the operation, develop appropriate language, encourage thinking beyond counting, and help children memorize the facts, rather than answers (Rathmell, 16). This can often happen with little or no drill. In fact, some teachers and math educators believe that no drill is needed.

These recommendations are not ideas without support. Research of teacher-directed approaches to helping kids learn thinking strategies provide evidence that this approach is more effective in helping kids master basic facts. They memorize the facts sooner, and retain them longer.
Now the question becomes, “Can children learn basic facts even better by using a student-centered approach to helping them learn thinking strategies?” This study is an examination of a thinking strategies approach to teaching basic addition facts.

**Background:**

Thinking strategies help children derive basic facts, which encourages an understanding of the fact and not just the answer. These thinking strategies for addition include count all, count up, doubles, and make ten.

A. **Count All:** To solve the problem $4 + 5 = 9$, the child would count, “1, 2, 3, 4, ..., 5, 6, 7, 8, 9.”

B. **Count Up:** When solving a problem the child will count up from one of the addends. When beginning this strategy, the child will start counting from the first addend. To solve $2 + 7 = 9$, the child will start at 2 counting, “2, ..., 3, 4, 5, 6, 7, 8, 9.” As this strategy develops, the student will choose the greatest addend, increasing efficiency, instead of always choosing the first addend. Now, to solve $2 + 7 = 9$, the child will start with 7 counting, “7, ..., 8, 9.”

C. **Doubles:** Children are often taught doubles, and can use this knowledge to solve basic fact problems. They may realize that many of their basic fact problems are one or two more or less than a doubles fact they know. For example, to solve $4 + 5 = 9$, the child may think, “$4 + 4 = 8$, so $4 + 5$ is one more, or 9.” The child may also think, “$5 + 5 = 10$, and $4 + 5$ is one less, or 9.”

D. **Make Ten:** Ten is often considered to be a landmark number. It is easy to add, and students know this. When children have a problem to solve, they may make the problem into one where they can add a number to 10. For example, $9 + 5$ is like $10 + 4$, or 14. This strategy is most effective when one of the addends is 8 or 9.
Where do these strategies fit into the learning of basic facts? How reliable is the method of children developing thinking strategies? The answers to these questions can be found in past research concerning the teaching and learning of basic facts.

Research Studies:

One influential study was conducted by William Brownell and Charolette Chazal in 1932. Brownell and Chazal studied and wrote about, “The Effects of Premature Drill in Third-Grade Arithmetic.” They developed three conclusions about the use of drill:

1. Drill does not guarantee that children will be able to immediately recall basic fact combinations,

2. In spite of long-continued drill, children tend to maintain the use of whatever procedures they have found to satisfy their number needs, and

3. Drill makes little, if any, contribution to growth in quantitative thinking by supplying more mature ways of dealing with numbers (Brownell and Chazal, 26).

These three conclusions can best be demonstrated by considering the learning of Johnie and George.

"Suppose that Johnie is required to give the sum of 5 and 4. Suppose further that he obtains his answer by thinking, ‘5, 6, 7, 8, 9.’ In the typical experiment, records are made of his time (let us say .6 second) and the correctness of his answer. The fact the he counted to get the sum is disregarded. Suppose now that George secures the same answer of 9 for the combination in the same length of time (.6 second), but that he does so by thinking, ‘5 and 5 are 10, so this is 9.’ The experimental records for George are identical with those for Johnie. It is true that Johnie and George are equal in efficiency,
but they are in no means equal in level of performance. Johnie is a counter; George is capable of a much more advanced type of quantitative thinking” (Brownell and Chazal, 19).

Drill may increase the speed at which a child answers a basic fact problem, because it speeds up the thinking that the child is using. It does not, however, change the child’s thinking, or encourage more advanced thinking (Rathmell, 17). For example, if a student’s strategy is to solve each addition fact by counting, drill only tends to speed up the child’s counting. “To be more effective, drill must be preceded by sound instruction” (Brownell and Chazal, 26).

William Brownell also conducted a study which focused on the types and levels of mature thinking that are involved in learning. “Learning is characterized by a continuous series of changes from lower or less mature and effective organizations of behavior to steadily higher or more mature and effective types of response” (Brownell, 334). In the hierarchy of mature thinking used in this study, guessing and rote memorization are placed at the bottom. The next stage is when a child has some way to figure out the basic fact problems. There are different levels of this category depending on the maturity of the thinking strategy. The highest stage in the study is when a child can immediately respond to the problem and give an explanation for their answer. At this stage of the hierarchy, the students have learned the basic facts by using meaningful relationships (Brownell, 334).

In his study, Brownell studied how children progressed towards mature thinking based on the way they learned the problem. Fewer than 3% of the children in Brownell’s study started at the highest stage, immediate response with explanation. Approximately 40% of the children started at
the lowest stage of the hierarchy, guessing or memorizing, at the beginning of the study. By the end of the study, only about 3% of these children advanced to the highest stage, approximately 35% moved to the second stage, and an overwhelming 60% of those who started out guessing and/or memorizing were still guessing and/or memorizing at the end of the study. The rest of the students began the study with a way to solve the problem that involved more mature thinking than memorization, an overwhelming 75% moved up the hierarchy to the highest stage. They developed more mature ways of thinking (Brownell, 332). See Figure 1.

Figure 1
More mature ways of thinking lead to proficiency with skills, according to a research study conducted by Carol Thorton. She believes that thinking, not just memorization, bridges the gap between concrete materials and proficiency with skills. See Figure 2.

Figure 2

A study conducted by Thorton and her partner, Paula Smith, examined the difference in accuracy in basic facts between students taught in a traditional way and students taught using thinking strategies, but in a teacher-directed classroom.

According to the written post-test, there was an approximate 40% difference in accuracy between the two groups! When solving for doubles, the strategies group had an accuracy of 99.7%, compared to the 61.6% accuracy of the traditional group. The strategies group had an accuracy of 96.9% for count up problems, and the traditional group’s accuracy was 57.0%. A 75.7% accuracy rate was achieved by the strategies group for
harder basic fact problems, compared to only a 36.2% accuracy by the traditional group (Smith and Thorton, 11). These trends also held for basic subtraction facts. See Figure 3.

Figure 3

The spring interview revealed what thinking processes the students were using. Approximately 30% of the strategies group relied on counting to solve basic fact problems. Twice as many children from the traditional group relied on counting to solve the problems. Of the strategies group, nearly 60% had the basic facts memorized, compared with only 12% of the traditional group. Only 2.1% of the students in the strategies group gave a
wrong answer or did not attempt to answer, compared to 20.4% of the students in the traditional group. (Smith and Thorton, 12). See Figure 4.

**Figure 4**

![Comparison of Dominant Response to Nine Subtraction Facts: Strategies versus Traditional](image)

Using a student-directed environment:

Although the research studies discussed here support the use of thinking strategies in teaching basic facts, they all used teacher-directed methods. Yet, does the thinking strategies approach work in a student-directed environment?

To answer this question, Anthony Gabriele, Larry Leutzinger, and Edward Rathmell, three professors from the University of Northern Iowa
worked on a curriculum development and research project through a grant from the Iowa Space Consortium. There were also three student workers for the grant: Kristin Meyer, Kim Young, and Amber Grotjohn.

As student workers, we helped to develop a curriculum for teaching basic facts that combined the use of manipulatives and the teaching of thinking strategies. Throughout the summer of 1997, we wrote over 200, 5-minute basic fact lessons. These lessons focused on number relationships, addition, and subtraction, and were grouped according to the thinking strategies children might use to solve the problem (Gabriele, et al., 2).

Each lesson followed a similar format. A basic fact problem was posed to the class, and the students were given time to solve the problem. Then, the students invented the strategies that were discussed in class. The teacher only highlighted and discussed a strategy after the children had shared their thinking. Unlike traditional approaches the goal of this project was to help students derive the correct answer and the thinking strategies they used to achieve the answer. The teacher ended the lesson by emphasizing a more efficient strategy, that one of the students had shared, and gave the class a new problem where they could use the more efficient strategy. This new problem sometimes included larger two- and three-digit numbers and emphasized mental computation.

To test our materials, as well as the notion of a student-directed thinking strategies approach, we used 2nd grade classrooms in the Waterloo School District. The experimental group used our materials on a daily basis, and focused on thinking strategies. Our control group used our materials only once a week, and focused more on drill.

A 60 second basic fact test was given to students prior to the start of the study to collect baseline information. The same test was given again at
1 month intervals throughout the study. "In order to more precisely understand who might benefit from the 5 minute curriculum and by how much, students were subdivided into three skill levels (low - less than 8 problems correctly solved; middle - 8 to 10 problems correctly solved; and high - greater than 10 problems correctly solved)" (Gabriele, et al., 4). These tests provide results in both speed and accuracy of the experimental and control groups.

Between October and December, the experimental high group’s speed decreased approximately .5 second per attempted solution. It may seem odd that during the same time period the control high group’s speed decreased about 1 second per solution. The reason for this is twofold. First, during this time period the control group was studying addition in their math textbooks and completing worksheets similar to the time assessments they were given. Second, because there was a greater focus was on drill, their speed completing these facts was increasing, which is typical of drill. These results change if we look at the middle and low groups. The experimental middle group decreased their time per attempted solution by approximately 2.5 seconds. The control middle group decreased their time by about 2 seconds per solution. The most impressive results are found when we look at the results for the low groups. The decrease in time for the experimental low group was about 5.5 seconds per solution. With the control low group, the decrease was only approximately 4.5 seconds per solution. See Figure 5.
One Minute Timed Test Results
For Addition Facts
Mean Number Of Seconds Per Attempted Solution

<table>
<thead>
<tr>
<th>Group</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (9)</td>
<td>10.4</td>
<td>6.0</td>
<td>4.8</td>
</tr>
<tr>
<td>Middle (8)</td>
<td>6.9</td>
<td>4.9</td>
<td>4.3</td>
</tr>
<tr>
<td>High (4)</td>
<td>4.4</td>
<td>4.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Total (21)</td>
<td>7.9</td>
<td>5.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Con:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (9)</td>
<td>10.2</td>
<td>5.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Middle (8)</td>
<td>6.7</td>
<td>4.4</td>
<td>4.6</td>
</tr>
<tr>
<td>High (4)</td>
<td>4.7</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Total (21)</td>
<td>7.8</td>
<td>4.7</td>
<td>4.9</td>
</tr>
</tbody>
</table>

We find the same results when looking at the percentage of correct answers each group gave between October and December. In October, there was a remarkable difference in percentages between the high, middle, and low students of both the experimental group and the control group. In December, however, this difference disappears in the experimental group.
The percentage correct on the timed test for the experimental group were 96% for the high group, 97% for the middle group, and 97% for the low group. What an difference this could make in a child’s self-esteem! There is no difference in the ability of any child in the experimental group. Unfortunately, this difference remains in the control group. In December, the percentage correct for the control group was 100% for the high group, 93% for the middle group, and 84% for the low group. See figure 6.

Figure 6

One Minute Timed Test Results For Addition Facts
Mean Percent Correct

<table>
<thead>
<tr>
<th>Group</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (9)</td>
<td>90</td>
<td>94</td>
<td>97</td>
</tr>
<tr>
<td>Middle (8)</td>
<td>93</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td>High (4)</td>
<td>95</td>
<td>100</td>
<td>96</td>
</tr>
<tr>
<td>Total (21)</td>
<td>92</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td>Con:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Low (9)</td>
<td>89</td>
<td>87</td>
<td>84</td>
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<tr>
<td>Middle (8)</td>
<td>96</td>
<td>97</td>
<td>93</td>
</tr>
<tr>
<td>High (4)</td>
<td>98</td>
<td>92</td>
<td>100</td>
</tr>
<tr>
<td>Total (21)</td>
<td>93</td>
<td>92</td>
<td>90</td>
</tr>
</tbody>
</table>
The children were also assessed using a basic fact computer program developed by Edward Rathmell and Kris Pegah. The computer assessment included 5 different tests for the students to perform, of which each student completed two. There was a Count On test, a Doubles/Near Doubles test, a Make Ten test, an Easy Mental Math test (consisting of adding multiples of tens), and a Hard Mental Math test (consisting of adding any two-digit number). The children completed the computer assessment in October and in February, when we could measure the percentage correct between the control group and the experimental group.

Between October and February, the experimental group raised their mean percentage correct in the Count On test by 2%. The control group, however, lowered their mean percentage correct by 1% on the same test. Both groups raised their percentage correct in the Double/Near Doubles test by 15%. On the Make Ten test, the experimental group increased their mean percentage correct by 13%, and the control group increased theirs by 11%. On the Easy Mental Math test there appears to be a greater increase in percentage in the control group. This group increased their percentage by 71%, and the experimental group increased by 44%. Only after seeing the strategies of each particular teacher involved in the study do we see why this happens. The teacher of the control group practiced easy mental math problems with her class on a regular basis. Typical to a drill and practice format, this type of thinking increased in speed and in accuracy. Also typical of a drill and practice format, more advanced thinking of basic facts were not encouraged. This only happened in the experimental group. By looking at the results of the Hard Mental Math test, we see that the experimental group increased their average percentage correct by 55%. The
control group only increased their mean percentage correct by 32%. See figure 7.

Figure 7

Computer Assessment For Addition

Mean Percent Correct

<table>
<thead>
<tr>
<th></th>
<th>Count On</th>
<th>Near Doubles</th>
<th>Make Ten</th>
<th>Easy Mental</th>
<th>Hard Mental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp: Oct</td>
<td>96</td>
<td>78</td>
<td>82</td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td>Feb</td>
<td>98</td>
<td>93</td>
<td>95</td>
<td>73</td>
<td>71</td>
</tr>
<tr>
<td>Con: Oct</td>
<td>94</td>
<td>77</td>
<td>74</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Feb</td>
<td>93</td>
<td>92</td>
<td>85</td>
<td>85</td>
<td>46</td>
</tr>
</tbody>
</table>

Conclusion:

I have come to three conclusions as to how children learn basic facts for the maximum accuracy and retention.

1. When looking at the data for the experimental group and the control group, it can be concluded that children learn basic facts better by using a thinking strategies approach.

2. Although past research has focused on teacher-directed thinking strategies approaches, the student-directed thinking strategies approach that we used gave us similar results to past research. From this I conclude that student-directed approaches can also be used to help children learn basic facts effectively.

3. By the results of the timed test we collected in December, there was no difference in the achievement levels of the middle and low groups of students. For these students, using a student-directed thinking strategies approach to learning basic facts...
“leveled the playing field.” It also showed the students how they could use thinking strategies to understand and to learn their basic addition facts. Hopefully, this way of thinking will carry over into their other classes, allowing students to become better at problem solving, at critical thinking, and at solving mental math problems.

I enjoyed working on this project very much. It gave me the chance to see how children begin to learn arithmetic, which I feel gives me a better background for teaching 8th grade math. As a secondary mathematics major, I had had no idea how children learned their basic arithmetic facts. By working to develop this curriculum, I saw how involved teaching basic facts to children could be. It also gave me an opportunity to use a student-centered technique. This is something that I had been interested in using in my classroom, but it had not been focused on during my studies. Finally, I feel that I am going into teaching with a larger experience base. Now, I have had experiences with how high school students learn, how middle school students learn, and how elementary children learn.
Works Cited


