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An analysis of several recent drill services in arithmetic or an investigation into the amount of drill given to the various combinations - according to their relative difficulty

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Boston University

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An Analysis of Several Recent Drill Services in Arithmetic
or
An Investigation into the Amount of Drill Given to the Various Combinations - According to Their Relative Difficulty.

Submitted by

Albert Edwin Wing.

Pd B, Campbell, 1916
B S in Ed, Boston, 1924

In partial fulfilment of requirement
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1926.
An Analysis of Several Recent Drill Services in Arithmetic

or

An Investigation into the Amount of Drill Given to the Various Combinations - According to their Relative Difficulty.

There are one hundred primary or basic combinations each in addition, subtraction, and multiplication; and ninety in division. They are, in addition, the following direct combinations with their reverses:

\[
\begin{array}{cccccccccc}
0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 2 & 3 & 4 & 5 & 5 & 5 & 5 & 5 & 5 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 9 & 9 \\
2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 \\
3 & 4 & 5 & 6 & 7 & 8 & 9 & 9 & 9 & 9 \\
3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 \\
4 & 5 & 6 & 7 & 8 & 9 & 9 & 9 & 9 & 9 \\
4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\
5 & 6 & 7 & 8 & 9 & 9 & 9 & 9 & 9 & 9 \\
5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 \\
6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 \\
6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 \\
7 & 8 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 \\
7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 \\
8 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 \\
9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 & 9 \\
\end{array}
\]
In subtraction they are these:

<table>
<thead>
<tr>
<th>18-9</th>
<th>17-8</th>
<th>16-7</th>
<th>15-6</th>
<th>14-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-9</td>
<td>16-8</td>
<td>15-7</td>
<td>14-6</td>
<td>13-5</td>
</tr>
<tr>
<td>16-9</td>
<td>15-8</td>
<td>14-7</td>
<td>13-6</td>
<td>12-5</td>
</tr>
<tr>
<td>15-9</td>
<td>14-8</td>
<td>13-7</td>
<td>12-6</td>
<td>11-5</td>
</tr>
<tr>
<td>14-9</td>
<td>13-8</td>
<td>12-7</td>
<td>11-6</td>
<td>10-5</td>
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<tr>
<td>13-9</td>
<td>12-8</td>
<td>11-7</td>
<td>10-6</td>
<td>9-5</td>
</tr>
<tr>
<td>12-9</td>
<td>11-8</td>
<td>10-7</td>
<td>9-6</td>
<td>8-5</td>
</tr>
<tr>
<td>11-9</td>
<td>10-8</td>
<td>9-7</td>
<td>8-6</td>
<td>7-5</td>
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<tr>
<td>10-9</td>
<td>9-8</td>
<td>8-7</td>
<td>7-6</td>
<td>6-5</td>
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<tr>
<td>9-8</td>
<td>8-7</td>
<td>7-6</td>
<td>6-5</td>
<td>5-5</td>
</tr>
<tr>
<td>13-4</td>
<td>12-3</td>
<td>11-2</td>
<td>10-1</td>
<td>9-0</td>
</tr>
<tr>
<td>12-4</td>
<td>11-3</td>
<td>10-2</td>
<td>9-1</td>
<td>8-0</td>
</tr>
<tr>
<td>11-4</td>
<td>10-3</td>
<td>9-2</td>
<td>8-1</td>
<td>7-0</td>
</tr>
<tr>
<td>10-4</td>
<td>9-3</td>
<td>8-2</td>
<td>7-1</td>
<td>6-0</td>
</tr>
<tr>
<td>9-4</td>
<td>8-3</td>
<td>7-2</td>
<td>6-1</td>
<td>5-0</td>
</tr>
<tr>
<td>8-4</td>
<td>7-3</td>
<td>6-2</td>
<td>5-1</td>
<td>4-0</td>
</tr>
<tr>
<td>7-4</td>
<td>6-3</td>
<td>5-2</td>
<td>4-1</td>
<td>3-0</td>
</tr>
<tr>
<td>6-4</td>
<td>5-3</td>
<td>4-2</td>
<td>3-1</td>
<td>2-0</td>
</tr>
<tr>
<td>5-4</td>
<td>4-3</td>
<td>3-2</td>
<td>2-1</td>
<td>1-0</td>
</tr>
<tr>
<td>4-4</td>
<td>3-3</td>
<td>2-2</td>
<td>1-1</td>
<td>0-0</td>
</tr>
</tbody>
</table>

In multiplication, they are the following combinations with their reverses:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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</tr>
<tr>
<td>6</td>
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<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
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<tr>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
And in division:

<table>
<thead>
<tr>
<th>Dividend</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ÷ 1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 2</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 3</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ÷ 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0 ÷ 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Note that there are no "zero" divisors, hence there are ninety and NOT one hundred basic combinations in division as in the other three operations.

But besides these simple combinations, there are yet others; all told there are 1680 combinations which may be classified in this wise (1):

<table>
<thead>
<tr>
<th>Combination</th>
<th>Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple addition</td>
<td>100</td>
</tr>
<tr>
<td>Higher decade addition</td>
<td>755</td>
</tr>
<tr>
<td>(up to and including all cases where</td>
<td></td>
</tr>
<tr>
<td>9 is to be carried)</td>
<td></td>
</tr>
<tr>
<td>Simple subtraction</td>
<td>100</td>
</tr>
<tr>
<td>The subtraction involved in short division</td>
<td>175</td>
</tr>
<tr>
<td>Simple multiplication</td>
<td>100</td>
</tr>
<tr>
<td>Short division</td>
<td>450</td>
</tr>
<tr>
<td>Total</td>
<td>1680</td>
</tr>
</tbody>
</table>

(1) W. J. Osburn; Corrective Arithmetic, Pg. 11.
It may be noted here that these combinations must be absolutely mastered by the child before he has passed many years in school; Osburn, before quoted, would say by the end of the fourth year. The learning of this large number of facts— and simply as facts—is a very great task, indeed, but there is no alternative. Of course the child must know that the symbol 5 represents 5 objects of some kind; he must know and from a varied experience that the putting together, say, of 3 apples and 2 apples gives 5 apples; or 4 blocks and 1 block make a total of 5 blocks, and so on. But the combinations are not to be learned this way; instead, they are to be learned mechanically and as facts and incidentally let it be said, according to best thought today, not in table form. Tables are valuable in so far as they are used as means of remembering what has been learned; they are useless, perhaps even worse, as methods of learning.

In the past, we have gone entirely on the assumption that through the "transfer of training", learning for instance, that 6+5 is 11, the reverse combination 5+6 and the various corresponding decade combinations, as 26+5, 76+5, 86+5, etc, were all taken care of at the same stroke. This of course as we know now is not the case; each and every combination must be taken care of separately and learned independently.

Of the simple combinations in each of the four operations, given in full on pages 1, 2, and 3 herein, much study has been given recently pertaining to their relative difficulty. An early study of this sort was made by H. V. Holloway at the University of Pennsylvania. A more recent investigation made by Frank L. Clapp of the University of Wisconsin is per-
happens more thorough and reliable. It will be described briefly in the pages that follow; in fact the results of this Clapp Study have been made the basis in determining the conclusions of the present thesis.

This study of Prof. Clapp (2) which was possibly even more comprehensive, so it is said, than the original investigation of Ayres in the field of spelling, tested more than 10,000 school children in various and widely separated sections of the United States. We cannot go into detail but briefly it may be said that among other things discovered were these:

1.) That certain combinations are much more difficult than others. For instance in addition, it is shown that the following combinations caused 43% of all mistakes:

<table>
<thead>
<tr>
<th>5+5</th>
<th>6+5</th>
<th>7+5</th>
<th>8+5</th>
<th>9+5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5+6</td>
<td>6+6</td>
<td>7+6</td>
<td>8+6</td>
<td>9+6</td>
</tr>
<tr>
<td>5+7</td>
<td>6+7</td>
<td>7+7</td>
<td>8+7</td>
<td>9+7</td>
</tr>
<tr>
<td>5+8</td>
<td>6+8</td>
<td>7+8</td>
<td>8+8</td>
<td>9+8</td>
</tr>
<tr>
<td>5+9</td>
<td>6+9</td>
<td>7+9</td>
<td>8+9</td>
<td>9+9</td>
</tr>
</tbody>
</table>

and these are only twenty-five of the one hundred combinations in addition. In these tests it was shown that twenty times

(2) The best description of the Clapp Study is found in:
as many mistakes were made on some of the combinations as on others.

2.) Many more mistakes were made on certain combinations when they were presented in examples than when they were presented singly, while of others the reverse was true.

Based upon the results in these two regards, Clapp has prepared "Orders of Difficulty" of the combinations in each of the processes. The first Order of Difficulty that he gives us is termed Order A; the other Order B. In determining the former, pupils were tested on the combinations presented singly; while for the latter, the combinations were presented in examples. The A tests were timed and designed to measure the extent to which the associations represented by the various combinations are automatic in the minds of pupils. The B Tests involved no speed element and were designed to measure the difficulty of the combinations when pupils are free to determine the answers by any method they prefer. The results of the A Tests may be said to indicate the learning or teaching difficulty of the combinations while those of the B Tests represent their functional difficulty. Charts I, II, III, and IV on pages 9, 10, 11, & 12 of this work give in full both orders in all of the four processes.

The arrangement or line-up in the two Orders are quite different. One is surprised at noting so many combinations found in the first quartile of the one, appearing in the third or fourth quartile of the other. One very noticeable example is 2+2. Presented singly, it is rated as the most difficult of all the ninety combinations in division. That is, it is found as the first combination of the first quartile of Order A where the form is in decreasing order of
difficulty. But this same combination, 2+2, presented in examples, is one of the easiest; that is, it is found in Order E at nearly the end of the third quartile.

Not only is 2+2 found in the first quartile (the most difficult) of Order A, but so also are:

\[
\begin{array}{cccc}
9+9 & 1+1 & 8+8 & 3+3 \\
6+6 & 7+7 & 5+5 & 4+4
\end{array}
\]

That is to say, every digit divided by itself is among the twenty-five most difficult division combinations when presented singly. It seems that there is a marked tendency to respond "zero" to any number divided by itself. But these same combinations presented in examples do not give the same difficulty. None of them appear in either the first or second quartiles of the E Order.

In addition, the combination 2+9 in examples is one of the most difficult. It is found in Quartile I of Order B. But presented singly it is one of the less difficult and is found in Quartile IV of Order A. It is probable that if the child, having 2+9 presented singly, finds it bothering, he immediately and perhaps almost unconsciously reverses the order of the two addends thus having 9+2, which to many children would be easier. But in examples where one addend is most likely to be in decade form, as 32+9, reversing would not make the situation any easier.

It must be said, at least parenthetically at this point, that teachers often make the mistake of analyzing the work of pupils only when the combinations are presented singly and then giving attention to those combinations that cause
difficulty as indicated by such analysis. It is quite as
important, if not more so, to analyze the work of pupils when
the combinations are presented in examples and then give the
necessary attention to those combinations that are giving dif-
ficulty as revealed by this analysis. Giving drill only to
combinations which are proving troublesome singly will bring
but little if any improvement in written work which of course
makes up a large part of actual school and everyday arithmetic.
### Chart I

**Clapp Order of Difficulty**

<table>
<thead>
<tr>
<th>Order A</th>
<th>Addition</th>
<th>Order B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Difficulty</td>
<td>Functional Difficulty</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>8+5</td>
<td>9+0</td>
<td>0+7</td>
</tr>
<tr>
<td>7+9</td>
<td>2+6</td>
<td>0+1</td>
</tr>
<tr>
<td>5+8</td>
<td>9+3</td>
<td>7+2</td>
</tr>
<tr>
<td>9+7</td>
<td>0+6</td>
<td>1+9</td>
</tr>
<tr>
<td>6+6</td>
<td>6+5</td>
<td>0+9</td>
</tr>
<tr>
<td>6+9</td>
<td>3+8</td>
<td>8+1</td>
</tr>
<tr>
<td>5+7</td>
<td>3+4</td>
<td>6+2</td>
</tr>
<tr>
<td>7+8</td>
<td>3+9</td>
<td>0+4</td>
</tr>
<tr>
<td>8+7</td>
<td>2+3</td>
<td>3+6</td>
</tr>
<tr>
<td>9+6</td>
<td>3+5</td>
<td>0+2</td>
</tr>
<tr>
<td>5+9</td>
<td>6+3</td>
<td>2+4</td>
</tr>
<tr>
<td>8+9</td>
<td>7+3</td>
<td>3+0</td>
</tr>
<tr>
<td>8+6</td>
<td>2+7</td>
<td>4+5</td>
</tr>
<tr>
<td>4+7</td>
<td>8+4</td>
<td>0+8</td>
</tr>
<tr>
<td>7+5</td>
<td>4+8</td>
<td>6+0</td>
</tr>
<tr>
<td>4+9</td>
<td>8+0</td>
<td>8+3</td>
</tr>
<tr>
<td>9+5</td>
<td>1+0</td>
<td>8+2</td>
</tr>
<tr>
<td>9+4</td>
<td>5+2</td>
<td>6+4</td>
</tr>
<tr>
<td>6+7</td>
<td>4+2</td>
<td>1+4</td>
</tr>
<tr>
<td>5+6</td>
<td>1+2</td>
<td>9+1</td>
</tr>
<tr>
<td>4+6</td>
<td>5+3</td>
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# Chart II

## Clapp Order of Difficulty

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Clapp Order of Difficulty

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Chart IV

Clapp Order of Difficulty

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</table>
Having the Orders of Difficulty set up (See Charts I, II, III, and IV on pages 9, 10, 11, and 12), Prof. Clapp next proceeded to analyze two widely used arithmetic texts to determine whether or not the typical text book in use up to the time had not given most drill to the less difficult combinations and least drill to the more difficult combinations. Chart V on the next page shows graphically his findings which were quite as surmised. For instance, in one text, that he designates as Text B - in addition - the percentages of frequency of appearance of the combinations by quartiles were as follows:

<table>
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<th>Quartile</th>
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<th>4</th>
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<tr>
<td>IV</td>
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</tbody>
</table>

This means that in this particular text the twenty-five most difficult combinations appeared only fourteen times to every forty times that the twenty-five least difficult combinations appeared. This is typical, as shown in this same chart, of the other three operations of this same text and also of the other book analyzed and referred to as Text A. In every case in all of the four operations of both texts, a great deal less drill is given to the more difficult combinations.
<table>
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<th>Operation</th>
<th>Clapp Study Text A</th>
<th>Clapp Study Text B</th>
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<tbody>
<tr>
<td></td>
<td>Quartile</td>
<td>Percentages of Frequency of Appearance of Combinations by Quartiles as found by Clapp in Texts A and B. First quartile, the most difficult.</td>
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</table>

Most difficult comb's given this much drill.

Least difficult comb's given this much drill.
Having the findings of these analyses of typical texts widely used in this country, it has been thought desirable and worthwhile to analyze in the same manner several of the drill services in arithmetic recently offered by leading publishers. Such is the undertaking of the present study. Drill services by Hillegas, Osburn, and a series by Clapp, himself, are the objects; all of them bearing "copyrights" of either 1925 or 1926. These latest Services are coming to us with many claims made by their makers as meeting the demands of modern pedagogical and psychological research. Are these texts really giving most practice and drill to the more difficult combinations, or do they fail in this respect as did so grossly those analyzed by Clapp? This is the question to which we seek an answer.

It is of course the contention of the present study that the work of Clapp, Holloway, and others makes it quite certain that there is a real intrinsic difference in difficulty in the combinations both as to learning or teaching, and functionally. And it is with the Clapp Order of Difficulty of the Combinations that we are making the comparisons which are so fundamental to our conclusions.

In analyzing a text every combination in the entire book must be "rounded-up", so to speak, and tabulated. In an example in multiplication, as will be shown in detail presently, not only are there the several multiplication combinations, but also numerous combinations in addition coming from the "carrying", and from the adding of the partial products - if the multiplier is of two or more places. One example in long division will give combinations in addition, subtraction,
and multiplication, as well as division. Thus they soon reach up into the thousands; in fact the present study has involved the tabulating, checking, plotting, etc. of a grand total of 57,730 combinations. Of these the Hillegas Book furnished 9,069, the three books of the Osburn Series 11,484, and the two books of the Clapp Series 37,177.

Further on, but as an illustration only, a complete set of the combinations in one of the operations and from one of the Services, will be included. See Chart VI.
Procedure of Analyzing Examples into Their Various Combinations.

In this example in addition the following combinations are obtained:

\[
\begin{array}{ccc}
27 & 9 + 5 & 8 + 4 \\
45 & 14 + 7 & 12 + 2 \\
162 & 2 + 6 & 1 + 1 \\
241 & & \\
\end{array}
\]

This example in subtraction gives the combinations:

\[
\begin{array}{ccc}
9025 & 15 - 8 & 10 - 6 \\
5618 & 1 - 1 & 8 - 5 \\
3407 & & \\
\end{array}
\]

We have the following combinations from this example in multiplication:

\[
\begin{array}{ccc}
3709 & 5 \times 9 & 0 + 4 & 1 + 3 \\
45 & 5 \times 0 & 15 + 3 & 4 + 5 \\
18545 & 5 \times 7 & 0 + 3 & 8 + 8 \\
14836 & 5 \times 3 & 12 + 2 & 1 + 4 \\
166905 & 4 \times 9 & 6 + 4 & 5 + 1 \\
& 4 \times 0 & & \\
& 4 \times 7 & & \\
& 4 \times 3 & & \\
\end{array}
\]

In analyzing this example in long division, we obtain combinations as follows:

\[
\begin{array}{c}
41 ) 19896 \\
164 \\
349 \\
216 \\
205 \\
11 \\
\end{array}
\begin{array}{c}
19 + 4; 4 \times 1 \text{ and } 4 \times 4; 8 - 4 \text{ and } 9 - 6 \\
34 + 4; 5 \times 1 \text{ and } 8 \times 4; 8 - 3 \text{ and } 4 - 2 \\
20 + 4; 5 \times 1 \text{ and } 5 \times 4; 6 - 5 \text{ and } 1 - 0 \\
\end{array}
\]

Note that subtraction combinations giving "zero" in long division are not included. This is following the Clapp procedure in his analyses.
As said before, in this study we are attempting to determine whether or not certain of the latest Drill Services in Arithmetic are giving more drill and practice to the most difficult combinations and less to the least difficult combinations. It has been shown already that the typical textbook even up to the present has been notoriously deficient in this respect. The drill Services being considered in these pages are the following and in this order:

1. Osburn Grade II
2. Osburn Grade III
3. Osburn Grade IV
4. Osburn Grades II, III, and IV (combined)
   Published by Houghton Mifflin Co.
5. Clapp Grade IV
6. Clapp Grade V
7. Clapp Grades IV and V (combined)
   Published by Silver Burdett & Co.
8. Hillegas (Horace Mann Supplementary Arithmetic)
   Published by J. B. Lippincott Co.

In the results tabulated and graphed in Charts LXXI, LXXII, LXXIII, and LXXXIII, are also given the results of the Clapp Analyses of the two texts before mentioned and known as Texts A and B. By means of these charts easy comparison may be made between the findings of the Clapp Study and those of the present one.
It would serve no purpose to include here the actual 57,000 and more combinations, or any large part of them, that go to make up the numerous examples of these several Services. However we are giving the combinations in addition of the Osburn Book for the third grade as an example. See Chart VI. An attempt will be made then to carry through the work in successive steps by charts that follow that of # 6, in order to make clear to the reader the procedure followed in this study in its entirety.
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Chart VI.

Addition Combinations - from Osburn III.

(But one page of such included here.)
The combinations, a few of which were given on the preceding page are next tabulated as shown in Charts VII and VIII on the next two pages. From these tables, they are gathered together and recorded in another similar table. See Chart IX. To interpret this last and other charts of the same type throughout this work, note that the numbers above the diagonals are read from top to left as 1+9, a total of 38 times; 3+6 a total of 14 times. The numbers below the diagonals are read from left to top as , 9+1, a total of 16 times; 6+3, a total of 18 times. In every case the upper addend represents the number of primary or basic combinations, while the lower addend represents the number of decade or secondary combinations. Of course the sums are the total numbers of combinations involving the particular digits. The reader is referred to pages 1 to three inclusive for a complete summary of the primary combinations.

Only in addition has any distinction been made between primary and decade combinations. An interesting comparison might be made between the relative frequency of appearance of primary and decade combinations, but such falls outside the scope of this study.

The totals of the various combinations were next tabulated (Chart X) each in their proper quartile according to the Clapp Order B of Difficulty. Order of Difficulty B, as we have already seen, has reference to the functional difficulty of the combinations. It has to do with the difficulty of combinations as they are met in examples as is the case in text book work, Hence comparisons are made with the Order B of Difficulty and NOT with Order
A, which has to do with combinations only when presented singly, and when the automatic response is what is sought.
Chart VII.

Number of Various Primary Combinations as Found in:

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Chart VIII.

Number of Various Decade Combinations as Found in:

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Number of Various Combinations as Found in: OSBURN III ADDITION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.

Lower addends represent the number of decade combinations.
Upper addends represent the number of primary combinations.

See page 21.
Chart X.

Osburn III Addition

Comparison with Clapp Order of Difficulty - B (decreasing order)

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In Chart X, we note that the total number of combinations falling in quartile I is 615. In the second, third, and fourth quartiles, they are respectively 667, 573, and 413. Reduced to percentages the combinations falling in Quartiles I to IV are respectively 27, 29, 25, and 18. Here we have results pretty much as they should be; especially would this be so, were the totals of Quartiles I and II interchanged. Compare this showing with those of the Clapp Study in Addition - either Text A or B - where it is readily seen that many less combinations fall in Quartile I (the most difficult) than any of the other three quartiles, and many more falling in Quartile IV than any of the other three. Said in other words, in these two texts, the easiest combinations are given much more drill; the most difficult combinations, much less. In the case of Osburn III, more drill and practice is allotted to the hardest combinations and less drill to the least difficult ones.

We have used Osburn III - Addition - as an example as said before, to illustrate the procedure followed herein. Commencing on page 28 each of the several Services are taken up one by one by means of tables and charts only, as just shown in the case of the one used for illustration. At the end of each section, results are shown graphically as well as numerically. All deductions and conclusions however are reserved until the final pages.

In the case of division, a somewhat different chart was necessary for the tabulating of combinations. The form as appearing in these pages seemed to meet the requirements best. It is as will be seen, quite similar to the one already made familiar and will not need further explanation.
Number of Various Combinations as

Found in: OSBURN II ADDITION.

Below diagonals: Read left to top.

Above diagonals: Read top to left.

See page 21.

Upper addends represent the number of primary combinations.

Lower addends represent the number of decade combinations.
Chart XII.

Osburn II  Addition.

Comparison with Clapp Order of Difficulty - B (decreasing order)

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Number of Various Combinations as found in: OSBURN II SUBTRACTION.

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Above diagonals: Read top to left.

See page 21.
Comparison with Clapp Order of Difficulty – B. (decreasing order)

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Number of Various Combinations as found in: OSBURN II MULTIPLICATION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.
See page 21.
Osburn II Multiplication.

Comparison with Clapp Order of Difficulty -B.(decreasing order)

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| 20 | 26 | 39 | 48 |

| 15% | 20% | 29% | 36% |
Number of Various Combinations as Found in:

**OSBURN II DIVISION.**

Red figures in body denote dividends.
Top row of digits are divisors.

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Chart XVIII.

Osburn II Division

Comparison with Clapp Order of Difficulty - B. (decreasing order)

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<td>40%</td>
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Below diagonals: Read left to top.

Above diagonals: Read top to left.

Upper addends represent the number of primary combinations.

Lower addends represent the number of decade combinations.

See page 21.
Table of Osburn III Addition and Comparison with Clapp Order of Difficulty - B (decreasing order)

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Total: 615 667 573 413

27% 29% 25% 18%
## Chart XXI

The chart illustrates the number of various combinations as found in the OSBURN III SUBTRACTION method. The table is structured with numbers from 0 to 9 in both rows and columns. The numbers represent the count of combinations for each possible pair of numbers when subtracting in a certain direction:

- **Below diagonals**: Read left to top.
- **Above diagonals**: Read top to left.

To find specific combinations, follow the instructions below the chart:

See page 21.
<table>
<thead>
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<th>Quart 1</th>
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Number of Various Combinations as found in: OSEBURN III MULTIPLICATION.

Below diagonals: Read left to top.

Above diagonals: Read top to left.

See page 21.
### Osburn III Multiplication

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Chart XXV.

Number of Various Combinations as Found in:

**OSBURN III DIVISION.**

Red figures in body denote dividends.
Top row of digits are divisors
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Number of Various Combinations as
Found in: OSBURN IV ADDITION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.
Upper addends represent the number of primary combinations.
Lower addends represent the number of decade combinations.
See page 21.
Osburn IV  Addition

Comparison with Clapp Order of Difficulty - B (decreasing order)

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|--------------|--------------|--------------|--------------|
| Percentage   | 24%          | 26%          | 27%          | 23%          |
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Number of Various Combinations as Found in: OGBURN IV SUBTRACTION.

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Above diagonals: Read top to left.
See page 21.
Comparison with Clapp Order of Difficulty - B (decreasing order)

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24% 22% 27% 27%
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Above diagonals: Read top to left.

See page 21.

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Number of Various Combinations as found in: OSEBURN IV MULTIPLICATION.
Chart XXXII.

Osburn IV  Multiplication

Comparison with Clapp Order of Difficulty - B. (decreasing order)

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Osburn II, III and IV  Addition

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Comparison with Clapp Order of Difficulty - B. (decreasing order)

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29%  29%  22%  20%
# Chart XXXVIII.

## Osburn II, III and IV Division

Comparison with Clapp Order of Difficulty - B (decreasing order)

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Total: 307 (24%) 311 (25%) 358 (29%) 276 (22%)
Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill.

Least difficult combinations given this amount of drill.

Quartile I

Quartile II

Quartile III

Quartile IV

20

24

24

31

Osburn II, III and IV Subtraction.

Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill.

Chart XLI.

Least difficult combinations given this amount of drill.

Osburn II, III and IV. Multiplication.

Comparisons of percentages of frequency of appearances of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill,

Least difficult combinations given this amount of drill,

Osburn II, III and IV Division.

Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
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Number of Various Combinations as
Found in: CIAPP IV ADDITION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.
Upper addends represent the number of primary combinations.
Lower addends represent the number of decade combinations.

See page 21.
Comparison with Clapp Order of Difficulty - B (decreasing order)

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See page 21.
Chart XLVI.

Clapp IV  Subtraction

Comparison with Clapp Order of Difficulty - B (decreasing order)

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Number of Various Combinations as Found in: CLAPP IV MULTIPLICATION.

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See page 21.
Comparison with Clapp Order of Difficulty - B. (decreasing order)

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Red figures in body denote divisors.

Chart XIX

Number of various combinations is found in:

Chart XIX
Chart L.

Clapp IV Division

Comparison with Clapp Order of Difficulty - B. (decreasing order)

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Number of Various Combinations as

Found in: CLAPP V  ADDITION.

Below diagonals: Read left to top.

Above diagonals: Read top to left.

Upper addends represent the number of primary combinations.

Lower addends represent the number of decade combinations.

See page 21.
Comparison with Clapp Order of Difficulty - B (decreasing order)

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Number of Various Combinations as Found in: CLAPP V SUBTRACTION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.
See page 21.
Chart LIV.

Clapp V Subtraction

Comparison with Clapp Order of Difficulty - B (decreasing order)

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Number of Various Combinations as Found in: CLAPP V MULTIPLICATION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.
See page 21.
Chart LVI

Clapp V Multiplication

Comparison with Clapp Order of Difficulty - B. (decreasing order)

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Red figures in body denote divisors. Top row of digits are divisors.

Chart IV.

CIAPPY DIVISION

Number of Various Combinations as Found in:

74.
Chart LVIII.

Clapp V Division

Comparison with Clapp Order of Difficulty - E. (decreasing order)

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|            | 376          | 322          | 607          | 524 |
| 20%        | 21%          | 32%          | 27%          |     |
Chart LIX

Clapp IV and V Addition

Comparison with Clapp Order of Difficulty - B (decreasing order)

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17\% & \quad 28\% & \quad 22\% & \quad 33\%
\end{align*} \]
### Chart LX.

#### Clapp IV and V Subtraction

Comparison with Clapp Order of Difficulty - B (decreasing order)

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Clapp IV and V Division

Comparison with Clapp Order of Difficulty - B. (decreasing order)

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Most difficult combinations given this amount of drill.

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Quartile I

Least difficult combinations given this amount of drill.

28

II

22

III

33

IV

Clapp IV and V Addition.

Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - E.
Most difficult combinations given this amount of drill.

Quartile I

22

II

23

III

27

IV

28

Least difficult combinations given this amount of drill.

Clapp IV and V Subtraction

Comparisons of Percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill.

18

23

30

29

Quartile I  II  III  IV

Least difficult combinations given this amount of drill.

Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill.

Least difficult combinations given this amount of drill.

Quartile I

Clapp IV and V Division.

Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
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Number of Various Combinations as Found in: HILLEGAS ADDITION.

Below diagonals: Read left to top.
Above diagonals: Read top to left.
Upper addends represent the number of primary combinations.
Lower addends represent the number of decade combinations.

See page 21.
Chart LXVIII.

Hillegsa Addition

Comparison with Clapp Order of Difficulty - B. (decreasing order)

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Hillegas Subtraction

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See page 21.
## Hillegas Multiplication

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Chart LXXIII.

Number of Various Combinations as Found in:

HILLEGAS DIVISION.

Red figures in body denote dividends.
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Most difficult combinations given this amount of drill.

19

Quartile I

27

II

28

III

25

IV

Least difficult combinations given this amount of drill.

Comparison of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill

20

Most difficult combinations given this amount of drill.

31

Hillegas

Subtraction

Comparisons of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill.

Least difficult combinations given this amount of drill.

Quadrant I  II  III  IV

Hillegas Multiplication.

Comparison of percentages of frequency of appearance of combinations with Clapp Order of Difficulty - B.
Most difficult combinations given this amount of drill.

Quartile I

24

Least difficult combinations given this amount of drill.

Quartile II

22

Quartile III

30

Quartile IV

24

Hillegas - Division.

Comparison of frequency of appearance of combinations with Clapp Order of Difficulty -E.
Chart LXXIX.

Percentages of Frequency of Appearance of the Combinations in Drill Services by quartiles

(Quartiles arranged in decreasing order of difficulty)

For these same results graphically, see charts on the next four pages.

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<td>Percentages of Frequency of Appearance of Combinations in Drill Services by quadrants.</td>
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Subtraction

Chart LXXXII

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Most difficult comb's given this much drill.

Least difficult comb's given this much drill.

Percentages of Frequency of Appearance of combinations, by quartiles.

First quartile - the most difficult.
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Most difficult comb's given this much drill.

Least difficult comb's given this much drill.

Percentages of Frequency of Appearance of Combinations by Quartiles.

First quartile, the most difficult.
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Most difficult comb's given this much drill.

Least difficult comb's given this much drill.

Percentages of Frequency of Appearance of Combinations by Quartiles.

First quartile, the most difficult.
If my reader has followed through carefully the numerous tables, etc., as found in Charts XI to LXXXIII; even if he has hastened over them and contented himself with but a cursory review of the final graphs, there is but one conclusion at which he can arrive. One must be impressed with the fact that in every case the Services analyzed make a much better showing than did the texts studied by Clapp. This is not saying that certain of these Services do not make a better showing than others; indeed, that such is so is very evident at first glance. But that there may be unseen influencing factors entering in to disturb what would have been otherwise a gradual decrease in the length of the graphical bars of the four quartiles in certain instances is perhaps the after thought on a moment's reflection. Whether or not such is the case we shall see presently.

But if what has been said is true, that the texts we have analyzed show a considerable improvement over Texts A and B analyzed by Clapp; as a second conclusion quite equal in weight with the first, it will not be denied that there is still room for considerable improvement in more than one instance.

Turning back to the four charts of graphical results - Charts LXXX, LXXXI, LXXXII, and LXXXIII, let us see what they have to tell us in detail. The same is told numerically by Chart LXXXIX. These graphs, as has been explained represent the percentages of frequency of appearance of the combinations of the particular service. The first of each of the four bars represents the percentage of combinations falling in the first quartile which it will be remembered in our scheme is the quar-
tile of greatest difficulty. In the same way, the last of each of the four bars represents in percentages the number of combinations falling in the fourth, or quartile of easiest combinations.

Commencing with Osburn II and following through the addition, subtraction, multiplication, and division charts we are struck by the fact that in every case, according to the bars, the most difficult combinations appear less frequently and the least difficult combinations appear much more frequently; especially marked is this, for instance, in addition, where of the most difficult combinations, there is not even one appearance. But is this not as it should be for Grade II? Most certainly it is, that if any of this formal drill is to be introduced as early as the second grade; but we doubt very much the feasibility of this entire procedure so early, and the Fourth Year Book of the Department of Superintendence just published sustains us in this opinion.

Quite the reverse condition is found in the results of the two succeeding books of this series. Referring to the fourth set of bars of each of these four charts, we have before us the results of the three books of the series summarized. In multiplication, at least, conditions are quite ideal; while in the other three operations, if not quite as satisfactory are still many times better than was the case with Texts A and B with which comparisons should be made constantly.

Taking the Clapp Series next, separately and collectively, we note results not quite as satisfactory as were those of Osburn. In the case of multiplication, for instance, in the Osburn Series - combined - there is a gradual decrease
in the length of the bars from the first to the fourth as we should desire. But in the Clapp Series - combined - there is a gradual increase, rather than decrease, in the length of these four bars in multiplication. Even the casual observer will recognize perhaps yet other discrepancies. But as hinted before, perhaps there is some other factor entering in here, which we may discover later, and which does not enter into the Osburn Series.

Now turning to the Hillegas Service, it is apparent that there is not the wide divergence in the length of bars, from what would be the median bar, whether it be the upper or lower ones. This indicates a somewhat more staple number of combinations, on the whole at least, allotted to each of the four quartiles of relative difficulty of the combinations according to the scheme of Clapp which we repeat again is so fundamental to this study. Here as elsewhere, we should have expected a somewhat heavier allotment of combinations to the first two quartiles. This would have been indicated in somewhat longer bars of the first quartiles with a corresponding decrease in length of the lines of the third and fourth quartiles.

But it bears repetition that in the case of everyone of the several books analyzed, the results are much more gratifying than were the conditions found existing in the texts studied by Clapp. That one or other of our Services apparently meets our standards better than do the others, is but saying again what has been pointed out already in another way.

Here the reader is referred to a statement on page 16 which at the time probably appeared innocent enough. But it has considerable bearing on the matter at hand.
There it was said that the present study has involved a handling of a grand total of 87,730 combinations, and of which the Hillegas Book furnished 9,069, the Osburn Series 11,484, while the Clapp Series furnished 37,177 combinations.

We see that Clapp was working with more than three times as many combinations as was Osburn, and with more than four times as many as Hillegas. Osburn makes a rather good showing according to our standards with his 11,000 combinations. To do as well handling 37,000 combinations, the task of Clapp would have been tremendously greater. Using almost 2500 fewer combinations than did Osburn, Hillegas certainly makes the poorest showing by far of any of the three — again be it understood, according to the standards we have set up herein.

Moreover and very worthy of note, in both books of Clapp (Grades IV and V) analyzed herein, he has introduced no less than thirty-nine pages of concrete or statement problems which would no doubt to no small extent increase his task in allotting to the more difficult combinations the greater recognition. And even more, he has introduced six pages of beginning work in fractions in each of the four operations, which despite almost anything he could do would tend to throw the alignment off. Neither Hillegas nor Osburn offer any work at all in either concrete problems or work in fractions.

On the other hand, Osburn has given over entirely one of his books to the very beginning work in the four operations thus necessitating for the time being a much heavier use of the easier combinations. But as we have seen, taking his series as a whole, the results have not been appreciably affected even by this.
As was said at the outset, the tendency in text books in arithmetic of the past, and even quite up to the present, has been to give much more drill and practice to the easiest combinations and much less drill to the more difficult combinations. It was as stated at that time our task to determine which, if any, of the more modern Services in Drill in the Fundamentals was most nearly approaching the ideal condition. Everything considered, it is our judgment based on the evidence as presented that the Osburn Series most nearly conforms to this standard, with of course the reservations as suggested. The Hillegas Book, especially as we recall the comparatively fewer combinations used, approaches this ideal less nearly of any.