Year 3 Findings Report - 2009

Background

From 2003-2005, in our previous NSF Grant #0310171, we worked with 26 students from 3rd to 5th grade. In 3rd and 4th grades we implemented two weekly 60-minute early algebra lessons, each followed by a homework assignment and 30-minute homework review sessions (50 lessons in 3rd grade and 36 lessons in 4th grade). In 5th grade, we implemented weekly lessons, each 90 minutes long; a total of 18 5th grade lessons were implemented, each followed by a homework assignment and a 45-minute homework review session (see Brizuela, Martinez, & Cayton, 2008 and 2009, submitted; Carraher & Schliemann, 2007; Carraher, Schliemann, & Brizuela, 2008; Martinez & Brizuela, 2006; Carraher, Martinez, & Schliemann, 2008). During 2004 and 2005, the school’s regular teachers taught the 3rd and 4th grade lessons to a new cohort of 24 students.

With the current NSF REESE grant #0633915 we aim to evaluate the impact of their early algebra experiences in the elementary grades on their understanding of algebra over the middle school years. We are following students who participated in the 2003-2006 early algebra interventions, documenting their learning of algebra in middle school (students are currently in 8th and 9th grade) and comparing their algebraic understanding to that of control peers. As reported last year and in the current activities report, to allow for better recruitment and evaluation of the experimental and control groups, in 2008 we implemented a free algebra summer camp for students from our 2003-2006 study as well as control students from schools throughout the Boston area. The summer camp was again offered in the summer of 2009, allowing for more extensive data collection. Details on the summer camp preparation and activities are provided in the activities report.

Results

Sixth Grade Assessment

Figure 1 shows the percent of correct answers by the experimental and control groups in the first cohort, in each of the sub-areas included in the written assessment given at the end of 6th grade, one year after the early algebra intervention study had ended. The data reveals that the total of correct answers by the experimental group was significantly higher and that the difference was more pronounced and significant for items on algebraic notation and equations (see year 2 report and Brizuela, Martinez, & Cayton, 2008 and 2009, submitted, for detailed analyses of the results).
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Figure 1: Percent of correct answers in the 6th grade written assessment.

Seventh and Eighth Grade Assessment

The 28 problems in the assessment given to 7th and 8th graders were graded according to a total of 89 sub-items. Of these, 61 sub items (old items) had been included in the assessments given to students when they had been in 3rd to 5th grades and 28 (new items) were specially designed to evaluate more advanced understanding of algebra addressed through the Summer Camp lessons. These new items dealt with algebraic content usually found in the middle or high school curriculum.

The number of sub-items related to (a) Functions, (b) Graphs, (c) Production of Algebra Notation, and (d) Solution and Interpretation of Equations, for both the old and new items, are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Functions</th>
<th>Graphs</th>
<th>Notation</th>
<th>Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old or related to 3rd to 5th grade lessons (N=61)</td>
<td>12</td>
<td>28</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>New or related to Summer Camp lessons (N=28)</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Total (N=89)</td>
<td>19</td>
<td>35</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

Figures 2 to 4 show the performance of 7th and 8th grade control and experimental students in the written assessment, two (for 7th grade) or three (for 8th grade) years after the end of the 3rd to 5th grade intervention. This set of data includes a total of 19 control and 17 experimental group students. Control group students and data for six experimental group students were collected at the onset of the Algebra Summer Camp offered in 2009. The other 11 experimental group students did not attend Summer Camp and were individually given the assessment in their homes, right before or soon after the summer break.
The experimental group continues to outperform the control group in all sets of problems, but none of the differences were significant. Non-significant statistical differences reflect the wider range of results among control group students.

![Graph 1](image1.png)

**Figure 2:** Results on items related to summer camp lessons (new items).

![Graph 2](image2.png)

**Figure 3:** Results on items related to 3rd to 5th grade intervention lessons (old items).
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Figure 4: Results on all assessment items.

A second set of analyses, depicted in Figures 5 to 13, focused on the differences between the experimental and control group students who participated in Summer Camp 2009 and had taken the assessment before and after camp.

Figure 5: Results by the control and experimental groups on items related to summer camp lessons (new items), before and after participation in Summer Camp 2009.
Figure 6: Results by the control and experimental groups on items related to 3rd to 5th grade intervention lessons (old items), before and after participation in Summer Camp 2009.

Figure 7: Results by the control and experimental groups on all assessment items before and after participation in Summer Camp 2009.
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Figure 8: Results by the control and experimental groups on items related to 3rd to 5th grade intervention lessons, on items related to Summer Camp 2009 lessons, and on all assessment items, before and after participation in Summer Camp 2009.

Again, the experimental group performed better than the control group for every set of assessment items. Mann-Whitney Us showed that most of these differences were significant. The experimental group showed greater improvement from the pre-test to the post-test on most areas, thus suggesting that their participation in early algebra lessons from 3rd to 5th grade better prepared them to learn new algebra materials in 7th and 8th grades.

Figures 9 to 14 show some of the new items in the assessment where the experimental group showed a better understanding of algebra concepts and representations in the post-assessment test.
Question 12

Marisa drank one cup of milk and ate \( x \) small vanilla cookies for a snack. The linear equation below represents \( y \), the total number of calories in Marisa’s snack.

\[ y = 12x + 120 \]

a. What is the \( y \)-intercept of the line represented by this equation?

120

b. Explain what the \( y \)-intercept tells us about Marisa’s snack.

\[ \text{how many calories} \]
\[ \text{the milk had} \]

c. What is the slope of the line represented by this equation?

12

d. Explain what the slope tells us about Marisa’s snack.

\[ \# \text{ of calories per cookie} \]

e. If Marisa eats 9 small vanilla cookies, what is the total number of calories in her snack? Show or explain how you got your answer.

\[ y = 12(9) + 120 \]
\[ 108 + 120 = 228 \text{ calories} \]

Figure 10: Written work from one experimental group student on an assessment item from notations and equations groups given during Summer Camp 2009.
Figure 11: Written work from one experimental group student on an assessment item from graphs group given during Summer Camp 2009.
The table below shows a relationship between values of $x$ and $y$.

<table>
<thead>
<tr>
<th>$x$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y$</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>18</td>
<td>27</td>
</tr>
</tbody>
</table>

Which of the following equations describes the relationship between $x$ and $y$ for the values in the table?

A. $y = 3x$
B. $y = 5x - 2$
C. $y = x^2 + 2$
D. $y = x^3$

Figure 12: Written work from one experimental group student on an assessment item from notations and equations group given during Summer Camp 2009.
Question 25

Which graph matches the table for x and y from Question 24? Circle the letter A or the letter B for your answer.

Figure 13: Written work from one experimental group student on an assessment item from graphs group given during Summer Camp 2009. This item is a follow up question to the one presented in Figure 12.
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The problem in Figure 14 was taken from a 10th grade item from the state-mandated Massachusetts Comprehensive Assessment System (MCAS) test. It exemplifies the complexity of an item on which the experimental group performed better than the
control group, using algebraic notation to represent verbal statements, setting up an equation to describe the verbal problem situations, solving the equation, and correctly interpreting the result. The average score on this item among 10th grade students in the Boston schools was 2.80 (out of 4 possible points). The average score of our experimental group, at the end of 7th and 8th grades, before participating in the 2009 Summer Camp, was 3.00 and that of the control group was 1.63. After participation in the Summer Camp, the experimental group continued to outperform the control group on this item, with average scores of 3.83 as opposed to 1.81 for control group students (see Table 2).

Table 2: Average scores for question 26 on notations and equations (see Figure 14) before and after Summer Camp 2009.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Assessment</th>
<th>Post Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.63</td>
<td>1.81</td>
</tr>
<tr>
<td>Experimental</td>
<td>3.00</td>
<td>3.83</td>
</tr>
</tbody>
</table>

**Discussion**

We had previously found that the systematic introduction of early algebra lessons from 3rd to 5th grade has a positive impact on participants’ understanding of algebraic concepts and notation while they were in elementary school. We are now finding that students’ experiences and interactions with algebraic concepts and representations, through systematic and regular early algebra lessons, also have a positive long-term effect. To date, not only do the experimental group students outperform their peers who have not had similar experiences, but also and most importantly, their experiences with algebraic concepts in elementary school better prepared them to engage in, understand, and excel on new and more complex algebraic content.