Title:
Using Single-case Design to Explore the Potential Promise of a Tier 2 Math Intervention on Student Mathematics Achievement

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Abstract Body

Background:
There is convincing evidence that many students experience an early and lasting onset of learning difficulties in mathematics (Aud et al., 2011; Morgan, Farkas, & Wu, 2009). The National Center of Educational Statistics (2009) reports that just 39% and 34% of students in Grades 4 and 8, respectively scored at or above the Proficient level on the 2009 National Assessment of Educational Progress (NAEP). For many of these students their difficulties resonate with specific aspects of whole numbers, particularly in developing number sense, acquiring efficient counting strategies, and retrieving number combinations (Geary, 1993; Gersten, Jordan, & Flojo, 2005).

One plausible way to increase student proficiency in whole numbers and consequently pave a pathway for successful mathematics learning is the implementation of strategic interventions within the context of multi-tiered service delivery models, such as Response to Intervention (RtI) frameworks. Though much of the thinking of RtI focuses on special education eligibility (Fuchs, Fuchs, & Stecker, 2010; NASDE, 2006), there is also increased interest in using RtI to prevent learning difficulties through effective, research-based instruction and intervention (Baker, Fien, & Baker, 2010). In recent years, RtI models in early mathematics have begun to accumulate promising results in Tier 1 (Chard et al., 2008; Clarke et al., 2011), Tier 2 (Bryant et al., 2008, 2011; Dyson et al., 2011), and Tier 3 (Fuchs Powell et al., 2010) settings.

Researchers at the University of Oregon are engaged in a three-year Development project to develop FUSION, a Tier 2 mathematics intervention program. FUSION, funded by the Institute of Education Sciences (Baker, Clarke, Fien, & Chard, 2008), is (a) intended for Grade 1 students at risk for mathematics difficulties and (b) designed for schools that take a multtiered approach to math instruction. Goals of the FUSION project include designing an intervention program that is feasible to implement by teachers and one that fosters students’ procedural fluency and conceptual understanding of whole number concepts and skills. Investigation of program feasibility is taking place through a design experiment (Brown, 1992; Shavelson et al., 2003) across several implementation studies. A team of special and general education teachers, teacher-educators, and educational researchers authored FUSION. The development team utilized an iterative design process to develop and revise FUSION’s instructional design features and mathematical content.

Purpose:
This presentation reports on student performance and implementation fidelity data from a single-case design (SCD). These data were collected within the larger FUSION feasibility study. The SCD, conducted during the 2010-2011 school year, served as part of the recursive process of developing and refining the FUSION intervention. The primary purpose of the SCD was to document the potential promise of FUSION on student math achievement. Researchers have begun to establish SCD as a rigorous methodology for exploring causal relations between outcome variables and experimentally-manipulated independent variables (Kratochwill et al., 2010). As suggested in the NCSER RFA (2011), we intend to use data from the SCD in support of the FUSION program for a future efficacy trial proposal in the IES goal structure. To reach our primary objective, we explored preliminary data regarding gains in student math outcomes. A secondary purpose of the single-case design was to explore variables of implementation fidelity that are hypothesized to improve student math learning. Although implementation
fidelity has been defined in multiple ways, we conceptualized it as the ability for teachers to (a) implement the program as intended, (b) adhere to specific time parameters (i.e., 30 minute lessons), (c) use small-group implementation guidelines, (d) manage a variety of math models during instructional activities, and (e) deliver effective math instruction.

Setting:

The larger feasibility study took place in seven schools in two suburban school districts located in the northwest. Several schools within both districts receive Title-1 funding. One district enrolls approximately 10,850 students: 17.4% receive special education services, 5.9% are English learners, 59.8% are eligible for free/reduced lunch, and 25.5% are minorities. The other district enrolls approximately 5,800 students: 19.6% receive special education services, 3.1% are English learners, 57% are eligible for free/reduced lunch, and 24.1% are minorities.

Participants:

The larger feasibility study consisted of eight instructional groups, utilizing 5:1 student-teacher ratios. Of the eight instructional groups, four were selected to participate in the single-case design. Thus, four interventionists and twenty students participated in the single-case design. Participating interventionists were two special education teachers and two educational assistants. Of the 20 participating first grade students, nine were females. Students were nominated by their general education first grade teacher to participate in the larger feasibility study because of difficulties in reaching proficient levels in early mathematics.

Intervention (Independent Variable):

The FUSION program is a Grade 1 (Tier 2) mathematics intervention that focuses specifically on building students’ early knowledge of whole number concepts. Four math strands comprise the program: (a) base-10/place value, (b) basic number combinations, (c) multi-digit addition and subtraction without renaming, and (d) word problems. Each strand reflects the critical content of first grade mathematics (CCSS-M, 2010; NCTM, 2006) and aligns with the recommendations of the NMAP (2008) and other experts in the field (Kilpatrick, Swafford, & Findell 2001; Wu, 2009). FUSION’s 60 scripted lessons utilize an explicit instructional format. Lessons contain teacher modeling, scaffolded instructional examples, and opportunities for academic feedback. Lessons incorporate a variety of math models and offer frequent opportunities for student practice and judicious review. A sample lesson is presented in Appendix B (Figure 1).

Interventionists were encouraged to complete one lesson per day, three times per week. Lessons lasted approximately 30 minutes and were delivered in small-group instructional formats, with approximately 4-5 students per group. FUSION instruction occurred outside of students’ core math and reading time. Thus, the FUSION program provided participating students with an additional 90 minutes of math instruction per week.

Prior to the study, interventionists received four hours of professional development in early mathematics instruction. This session focused on three key elements: (a) the research-based principles of math instruction, (b) the instructional design and delivery features of the FUSION curriculum, and (c) an overview of lessons 1-30. In the session, participating teachers were provided opportunities to deliver sample lessons and receive feedback on their teaching from the project staff. Interventionists also learned how to administer and score the two student assessments. Midway through the study, all teachers participated in a four-hour follow-up
workshop. A central focus of this session was previewing lessons 31-60 of the curriculum. During the study, all interventionists received on-going professional development in the classroom (i.e., expert coaching).

**Baseline:**
During the baseline phase, all participating students remained in the general education classroom and continued to receive their core mathematics instruction as approved by the participating school district. Interventionists administered baseline assessments outside of the general education classroom and at a time that was scheduled for the FUSION intervention. Data collection during baseline varied between 2-3 times per week.

**Research Design:**
In this development project, we use a design experiment methodology (Brown, 1992; Shavelson et al., 2003) to develop a complex, feasible math intervention that is positioned for a Goal 3 efficacy trial in the IES goal structure. Design experiments offer a methodological structure for refining and developing instructional interventions through iterative cycles of development, observations, analysis, and refinement. Formative evaluation of FUSION is taking place across three implementation studies: (a) Brief Learning Trials Study, (b) Feasibility Study, and (c) Pilot Study.

The research discussed in this presentation draws from a single-case design that was conducted within the Feasibility Study of project FUSION. The single-case design used a multiple-baseline-across-groups design to measure the impact of the Fusion intervention on the math achievement of students at-risk for math difficulties. The unit of analysis for the single-case design was instructional groups.

**Data Collection and Analysis (Dependent Variable):**
We provide information on the data collected to date and the analyses planned for the presentation.

The primary outcome measures were two curriculum-based measures (CBM) of early mathematics: Quantity Discrimination (QD) and Missing Number (MN). The QD and MN measures are modifications of the Early Numeracy-Curriculum-Based Measurement measures (EN-CBM; Clarke & Shinn, 2004). For our purposes, we modified the QD and MN measures to be group-administered CBMs. Each is a 1-minute fluency-based measure that assesses an important aspect of early numeracy development. The QD measure requires students to circle the number in a pair (numbers 0 to 10) that has a higher value. The MN measure requires students to write in the missing number among a string of numbers (0-10). Students are given strings of three numbers with the first, middle, or last number of the string missing. During the intervention phase, the CBMs were administered once per week by the FUSION interventionists. Trained project staff rescored 100% of the student measures.

Project staff collected observation data within each of the four small groups. Observations were coded using the FUSION observation instrument and the Ratings of Classroom Management and Instructional Support (RCMIS; Doabler & Nelson-Walker, 2009). The FUSION observation instrument measures implementation fidelity of the FUSION program. After each activity (range 4-5 per lesson), observers rated the fidelity of teacher’s implementation. Observers rated implementation fidelity for each activity using a 0-2 scale (0 = not taught, 1 = partial implementation, and 2 = full implementation). An overall fidelity score for
each observation was calculated by averaging ratings across the activities.

The RCMIS is a measure based primarily on the CLASS observation instrument developed by Pianta and Hamre (2009) and the Framework for Teaching developed by Charlotte Danielson (1996). It measures the quality of classroom instruction (11 items) across three domains: learning environment, classroom management, and the delivery of instruction. At the conclusion of each observation, observers recorded their overall impressions of 11 features of instructional quality using a 4-point holistic rating scale (1 = not present, 2 = somewhat present, 3 = present, and 4 = highly present). Inter-rater reliability was estimated as intraclass correlation coefficients ranging from .46 to .60. Current studies are beginning to empirically link the three RCMIS domains with increased student math achievement (Doabler, Baker, Smolkowski, Fien, Kosty, Miller, & Clarke, manuscript in preparation).

Findings and Results:

For student performance data, we plan to investigate student gains across the 20-week intervention. We expect to find a functional relationship between FUSION and changes in CBM scores. These preliminary findings would serve as promise of FUSION for positively influencing student math outcomes. Analyses are currently underway and results of student outcomes will be interpreted through systematic visual analysis (Kratochwill et al., 2010).

Preliminary analyses also indicate that teachers met acceptable levels of implementation fidelity. The average fidelity score from the first set of observations was 1.44 (SD = .22). Scores for the quality of instruction were: learning environment (M = 3.29, SD = .08) classroom management (M = 3.06, SD = .27), and delivery of instruction (M = 2.95, SD = .10). While preliminary, these findings indicate that teachers can feasibly implement FUSION as intended.

Conclusion:

This presentation focuses on results from a recently conducted single-case design (SCD). In this session, we will discuss how the SCD enabled us to demonstrate the potential promise of the FUSION program on student math achievement. We will also share how the SCD has allowed us to prepare for a subsequent efficacy proposal in the IES goal structure.

In conclusion, persistent problems in student mathematics achievement have become a national concern. This attention is most visible among the math performances of children from educationally and economically disadvantaged backgrounds. To improve the math achievement of these struggling learners, leading mathematicians, educators, and expert panels call for the development of curricula that are coherent, rigorous, and reflect the converging knowledge base of math intervention research. FUSION has the potential to serve as such an intervention program for Grade 1 students struggling to reach proficient levels of mathematics.
Appendices

Appendix A. References


### Activity | Strand | Objective – LESSON 14
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Warm Up | NC | Flashcard game: Plus and minus 0 facts
1 | PV | Write numbers 1-15: “Lining Up” place value columns
2 | PV | Model and decompose numbers 15-19
3 | PV | Identify number before/after 1-10
4 | PV | Count by 1s and 10s
Wrap Up | NC | Math facts timed practice: Plus 1 facts

**Teacher Materials:**
- Whiteboard, marker
- + and – 0 flashcards
- 19 connecting cubes
- Place value number card 10
- Number cards 1-10
- Hundreds chart

**Student Materials:**
- Place value (PV) chart, markers
- Fact Worksheet #1 (Plus 1), pencils

**Vocabulary:** Addition, subtraction, identity law, tens, ones, more, before, after

**Warm Up**

**Flashcard game**

**5 minutes**

**Materials:** + and – 0 flashcards

**Vocabulary:** Addition, subtraction, identity law

- Play the flashcard game.

  **Today we’re going to play the flashcard game with problems that add and subtract 0.**

  - Think about the strategy we learned for *addition* and *subtraction* problems with zero. Tell your partner the rule about how to solve these problems.

- Monitor as students share with their partner that when you add or subtract zero, the number stays the same. Have a student share her answer with the group.
o Yes, the identity law tells us that when you add or subtract zero, the number stays the same.

o I’ll show each of you a card, and you have 3 seconds to answer. If you don’t say the correct answer in time, I’ll call on another student who has a hand raised.

• Show a flashcard to the first student. If the student answers within 3 seconds, give him the flashcard to hold.

• If student doesn’t answer in 3 seconds or gives an incorrect answer, ask the others in the group to raise their hand if they have the answer. Confirm and provide correction to the student who missed the problem and return that card to the pile for another turn.

• Continue giving turns to students until all the flashcards have been correctly identified or 5 minutes have passed.

• If time permits, have students count and report the number of facts correctly answered.

Activity 1

Write numbers 1-15: “Lining Up” place value columns

Materials: Place value (PV) chart and markers for students
Vocabulary: Tens, ones

• Give each student a PV chart and marker. Review names and values
  o What is this called? (place value chart) What column is this? (ones) What column is this? (tens)
  o Today I’m going to tell you some numbers to write on your place value chart. You’ll have to listen carefully and figure out how many tens and ones there are and write the numbers in the correct place value columns. Write the first number at the top, then write the next numbers below.
  o The first number is 8. What number? (8)
  o Does 8 have any tens? (no) If there are zero tens it means you leave the tens column blank. How many ones are in 8? (8) Yes, 8. So you should write 8 in the ones column.
  o Write 8 in the ones column of your PV chart.

• Monitor and assist as needed. You may have to show students how to write the number at the top of the chart so there is room to write more numbers. If needed, have students erase and rewrite their number at the top.

  What number did you write? (8) How many tens are in 8? (0) How many ones are in 8? (8) Right! 8 is 0 tens and 8 ones.
  o Don’t erase your number. Are you ready for the next one?
<table>
<thead>
<tr>
<th>CORRECT RESPONSE</th>
<th>STUDENT ERROR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great! You wrote 13. Thirteen is 1 ten and 3 ones.</td>
<td>Thirteen is 1 ten and 3 ones. How many tens should you write in the tens column? (1) Do that. How many ones should you write in the ones column? (3) Do that. What number did you write? (13)</td>
</tr>
</tbody>
</table>

- Repeat with 12, 9, and 10 using the wording below.
  - The next number is #. What number (#) Write it.
  - What number did you write? (#) How many tens are in #? (#) How many ones are in #? (#) Right! # is # tens and # ones.
  - Don’t erase your number. Are you ready for the next one?

### Activity 2

Model and decompose numbers 15-19

**Materials:** 19 connecting cubes, place value number card 10; number cards 5-9, whiteboard, marker

- Place 15 cubes in a pile in the center of the table.
  - Today we’re going to make a group of 10 and then add on to make larger numbers like 16, 17, 18, and 19. Help me make a group of 10.

- As you connect the cubes have the students count along.
  - This is 10. How many? (10)
Let’s count on to see how many altogether. How many in this group? (10)

Start with 10 and count. (10, 11, 12, 13, 14, 15)

How many? (15) Yes, 15.

Place the PV 10 card on the table and place the number 5 card on top to make 15 as you say the following.

Yes, fifteen is 10 and 5 more.

What number? (15) Yes, 15.

Repeat for 16, 17, 18, and 19 using the following wording.

Add another cube.

Let’s count on starting with 10 to see how many there are altogether.

How many in this group? (10)

Start with 10 and count. (10, 11, 12, 13, 14, 15, 16)

How many? (16)

Place the PV 10 card on the table and call on a student to place the number 6 card on top to make 16.

Yes, sixteen is 10 and 6 more.

What number? (16) Yes, 16.

Repeat, adding a cube for 17, 18, and 19.

Give each student an individual turn to count on for models of 15-19, tell what number, and use the PV tens and ones cards to make the correct number.

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### Activity 3

Identify the number before and after 1-10

**Materials:** Number cards 1-10

**Vocabulary:** Before, after

I’m going to show you a number and you’re going to figure out the number that comes before and after.

Place the number card for 5 on the table.

What number? (5)

What number comes before 5? Provide think time. What number? (4) Yes, 4 comes before 5. If you were counting, you would say 4, 5.

Place the card for 4 in front of 5.
Activity 4  Count by 1s and 10s

Materials: Hundreds chart (corrective feedback)

Today, you’re going to count by 10s to 100. Get ready. (Ten, 20, 30...100)

• Give each student an individual turn. Listen carefully that students are saying tens numbers and not teen numbers (e.g., sixty, not sixteen).
  - Great job counting by 10s. Now count by 1s to 30, starting with 1. Get ready. Signal so students stay together.

• Give each student an individual turn to count to 30 starting with a number between 15 and 20.
### Correct Response

**Great job counting by 10s!**

**or**

**Super! You counted to 30!**

### Student Errors

**Stop.** Place the hundreds chart in front of the students. Touch a short sequence of numbers including the number missed. **My turn. 40, 50, 60** (or 16, 17, 18, 19).

**Say it with me.** Touch and say the numbers with the students.

**By yourselves.** Touch the numbers as students say them.

Remove the hundreds chart. **Count by (1s or 10s), starting with (1 or 10).**

### Wrap Up

**Math facts +1 timed practice**

**Materials:** Fact Worksheet #1 (Plus 1), pencils

- Pass out Fact Worksheet #1 with plus 1 problems.
  - **Today you’re going to write the answer to problems that add 1. Who can tell me how to add 1 to a number?**

    Call on a student to tell how to first trust the big number and then say the next number.

- Pass out pencils and give the following directions.
  - **Today you’re going to write the answers to +1 math facts using your thinking strategy. Remember to trust the big number to solve these problems. You will have one minute to answer as many problems as you can. Try your best.**

- Tell students to begin and set a timer for 1 minute. Monitor that students aren’t using their fingers. After 1 minute, stop the students and collect their papers.

- **Note:** if students only complete 1 or 2 rows, you may mark the last problem completed and use the same worksheet for the next timing. Students will gain speed over the coming lessons as they engage in fact timings for the lesson wrap up.

- After the lesson, correct the fact timings. Record how many problems each student completed correctly in 1 minute on the facts data sheet. Note if students are making errors using one of the strategies and precorrect in future lessons as needed.