Abstract Title Page

Title: Using a scientific process for curriculum development and formative evaluation: Project FUSION

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Abstract Body

Background / Context:

A central focus within the Institute of Education Sciences (IES) is on the development and validation of instructional approaches and interventions that improve student achievement. Despite increased interest by IES, there is compelling evidence from the What Works Clearinghouse (WWC) that suggests just a handful of curricular programs are evaluated under rigorous experimental conditions. For example, of the 72 early mathematics programs reviewed by the WWC, seven met the clearinghouse's evidence standards. Of the seven programs, just one demonstrated potentially positive effects for improving math outcomes.

For establishing evidence-based mathematics programs, researchers have considered curriculum development as a design science (Brown 1992; Chard et al., 2008; Clements, 2007). That is, curriculum developers engineer complex instructional interventions through an iterative process that incorporates a sequence of *design-analysis-redesign* cycles or phases (Shavelson, Phillips, Towne, & Feuer, 2003). Clements' (2007) proposed "curriculum research framework" (CRF) highlights the importance of this science and explains the impact of anchoring math programs to the converging knowledge base of effective math instruction. Clements' framework hypothesizes that curricula developed through a scientific process can produce significant effects under authentic educational conditions.

The CRF (2007) includes 10 research-based phases of the curriculum development process. It calls for developers to subject programs to each phase of the framework, ensuring that research is present across all 10 phases. In Phase 8, for example, researchers use multiple data sources to address research questions such as: To what degree is the prescribed schedule of use adhered to and positively viewed by the teacher and students?

Given the vital importance of using a scientific approach for curriculum development, we employed a design experiment methodology (Brown, 1992; Shavelson et al., 2003) to develop and evaluate, FUSION, a first grade mathematics intervention intended for students with or at-risk for mathematics disabilities. We also expanded the development of FUSION to include elements from Clements' (2007) framework. FUSION, funded through IES (Baker, Clarke, & Fien, 2008), targets students' understanding of whole number concepts and skills and is being designed as a Tier 2 intervention for schools that use a multi-tiered service delivery model, such as Response to Intervention (RtI). In developing this intervention, we have drawn extensively from the converging knowledge base of effective math instruction (Gersten et al., 2009; National Math Advisory Panel, [NMAP] 2008) and the critical content areas of first grade mathematics recognized by national bodies (Common Core State Standards for Mathematics, [CCSS-M] 2010).

Purpose / Objective / Research Question / Focus of Study:

Guiding the FUSION project are three primary objectives: (1) develop a 60-lesson intervention program that fosters students' procedural fluency and conceptual understanding of whole number concepts, (2) assess the feasibility of the FUSION intervention and (3) assess the potential efficacy of the intervention in a subsequent randomized efficacy trial.

This presentation will focus on FUSION's initial feasibility study. We examined whether FUSION lessons were feasible for the teachers and students for which they are designed. We conceptualized feasibility 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. The study also targeted growth in student math outcomes to demonstrate the potential promise of the intervention. Under Clements' (2007) CRF framework, our present research would map onto *Phase 8*: *Formative Research – Multiple Classrooms.* We will present student performance data, implementation fidelity data, and results from classroom observations that measured the quality of math instruction. In addition, we will describe FUSION's early phases of development and evaluation (i.e., Phases 1-7 of the CRF). Implications for future curriculum development and research will be discussed.

Setting:

The 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.

Population / Participants / Subjects:

Eight teachers (1 male) with varying experience levels participated in the feasibility study. They represented a range of teaching roles: 1 general education teacher, 5 special education teachers, and 2 educational assistants. Participants in this study included 39 first grade students, of which 23 were females. Student participation was based on: (a) teacher recommendations of students' overall math proficiency and (b) students' scores on two curriculum-based measures (CBM) of early mathematics.

Intervention / Program / Practice:

FUSION curriculum. 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).

Teachers 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.

Professional development. Prior to the study, participating teachers 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. Teachers also learned how to administer all 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 teachers received on-going professional development in the classroom (i.e., expert coaching).

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. Development of FUSION also included elements from Clements' (2007) framework. Formative evaluation of FUSION is taking place across three implementation studies: (a) Brief Learning Trials Study, (b) Feasibility Study, and (c) Pilot Study. The present research is the Feasibility Study of Project FUSION. The Pilot Study will be conducted during the 2011-2012 school year.

Data Collection and Analysis:

We provide information on the data collected to date and the analyses planned for the presentation.

Project staff collected observation data within each small group. Direct observations of teaching were conducted to provide preliminary evidence that teachers can feasibly implement FUSION in authentic educational settings. Instruction was also observed and evaluated through teacher-recorded videos. Data obtained from the observations helped us examine elements of feasibility (e.g., adherence to specific time parameters) and usability (e.g., amount of teacher scripting). Observations were coded using the FUSION observation instrument (see Figure 2 in Appendix B). The instrument contains two sections. The first section 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 second section of the observation instrument measures the quality of classroom instruction (11 items) across three domains: learning environment, classroom management, and the delivery of instruction. We are targeting teachers' delivery of effective math instruction to demonstrate the potential promise of the intervention. 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*) Previous work documented the instrument's capacity to predict student math outcomes (Doabler et al., in preparation). Teachers also completed instructional logs following each lesson, providing key information on lesson usability. Teachers' professional feedback was utilized to revise critical features of the FUSION program (e.g., determining the number of instructional examples in activities). At the end of the study, teachers will complete demographic, perception and feasibility surveys.

We are targeting student learning gains to demonstrate the potential promise of Fusion. Student performance was assessed using a set of measures that are considered proximal to the FUSION intervention: ProFusion and two CBMs of early mathematics. All measures were group administered. ProFusion, a researcher-developed assessment, was used to measure students' knowledge of whole number concepts and skills. The measure is comprised of 40 items that assess students' knowledge of place value, simple addition and subtraction word problems, multi-digit addition and subtraction, and basic number combinations. Modified versions of the Quantity Discrimination (QD) and Missing Number (MN) measures (Clarke & Shinn, 2004) were also used to assess the potential impact of the program. The QD measure requires participants to circle the larger of two numbers. For the MN measure, participants write in the missing number from a string of numbers between 0 and 10 (e.g., 3 _ 5). FUSION teachers administered all measures at pretest (fall) and posttest (spring). Project staff scored all student assessments.

Findings / Results:

Preliminary analyses indicate that teachers are meeting 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. Inter-rater reliability was (72%) for the implementation fidelity and (82%) for the quality of instruction.

Overall, teachers have expressed encouraging views of FUSION. Anecdotal records from classroom visits and professional development sessions indicate that teachers are satisfied with FUSION's overall structure and comfortable with lesson implementation. Teachers report that students are benefiting from the program and in particular building conceptual knowledge and procedural fluency in whole numbers.

For student performance data, we plan to investigate student gains across the academic year. We expect to find strong relationships between FUSION and changes in CBM and ProFusion scores. These preliminary findings would serve as promise of FUSION for positively influencing student math outcomes. Analyses are currently underway.

Conclusions:

Persistent problems in student mathematics achievement have become a national concern. This attention is most visible among the math performances of children from low-income backgrounds, minorities, and students with or at risk for math difficulties. 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. According to Clements' (2007) framework, researchers should use 10 research-based phases to develop and evaluate programs. FUSION was developed through sequence of *design-analysis-redesign* phases. Though preliminary, our findings indicate that teachers can feasibly implement FUSION in small-group settings.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

Figure 1

Sample lesson from FUSION program

Activity	Strand	Objective
Warm Up	NC	Flashcard game (subtraction = 0)
1	PV	Count by ones to 100
2	PV	Identify and sequence numbers 91-100; Find missing number 91-100
3	PV	Decompose and write numbers 14-95 from expanded notation
4	PV	Greater than / less than
Wrap Up	NC	Math facts minus 1 timed practice

Materials: Flashcards (subtraction facts = 0), hundreds chart, numeral cards 91-100, teacher whiteboard, place value mat and 10 ten sticks and 9 cubes per student, flashcards 1-1 to 10-1, minus 1 subtraction facts worksheet and cumulative worksheet, pencils

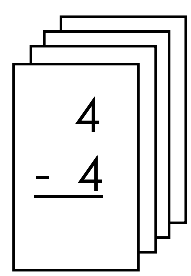
Vocabulary: Tens, ones, greater than, less than, more, less, subtraction, minus

Group Responses	Math Talk	Possible Error	Monitor for Understanding
			✔

Warm Up: Flashcard game *5 minutes*

Materials: Flashcards (subtraction = 0)

- ○ **We're going to do problems that *subtract* the same number. Tell your partner how to figure out the answer to a problem like 4 - 4.**
- Monitor math talk. Call on a student to offer the idea that the answer is always 0.
  - ○ **When we subtract a number from itself, the answer is always 0. What does 4 – 4 equal?** (0)
- Play the flashcard game:
  - ○ Allow each student 3 seconds per fact.
  - ○ If correct, give card to the student.
  - ○ If incorrect call on another student to provide the correct answer, then review the strategy (see below), and return the card to the pile for another turn.



- Strategy correction:

- 4 - 4 (*when we subtract a number from itself, the answer is always 0*)

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

1. Count by ones to 100

Materials: Hundreds chart

- Show the hundreds chart.
  - **In our last lesson, you counted all the way to 100! You're going to count by ones to 100 starting with 91.**
  - **What number do we start with?** (91) **What number do we end with?** (100)
  - **Count by ones from 91 to 100 as I touch the numbers on the hundreds chart. Ready, count.**
- After students have counted, turn the hundreds chart over so they can't see it.
  - **Now count from 91 to 100 without looking at the hundreds chart.**
- Repeat until firm.
  - **Now count from 51 to 100 without looking at the hundreds chart.**

CORRECT RESPONSE	STUDENT ERRORS
Wow! You counted all the way to 100! Tomorrow you'll count to 100 beginning with 1!	If students make an error, stop and model the counting sequence beginning with a few numbers before the error through a few numbers after the error. Practice with the students until they can count this short sequence correctly by themselves. Go back to 51 and repeat to 100 until firm.

2. Identify and sequence numbers 91-100; Find the missing number 91-100

Materials: Number cards 91-100

- Show number cards 91-100 in random order. Have group identify each number.
  - **What number?**

CORRECT RESPONSE	STUDENT ERRORS
Right, this number is [97]. Place the number card on the table.	**This number is [97]. What number?** (97) **Yes, 97.** Keep number card for another turn.

- Distribute cards so each student has several numbers.
  - **Now let's put the numbers in order. What are we going to start with?** (91) Have the student who has 91 place it on the table to the left of the group.
  - **What number goes next?**
- Continue until all the cards have been placed in order.
  - **Let's see if all the numbers are in order. Let's count them starting with 91.**
- Touch each number as students identify 91-100.
- Play the "*Missing Number Game*."
  - Have students close their eyes while you turn a card over.
  - Have students open their eyes and put their thumb up when they know the missing number.
- Repeat with 3-4 more "*missing numbers.*"
- Have the group count from 91-100 without looking at the numbers.

3. Decompose and write numbers through 99 from expanded notation

Materials: Teacher place value whiteboard; Place value mat, 10 ten sticks, 9 cubes per student
Vocabulary: Tens, ones

  - **You have been doing such a great job that we're going to make models for lots of numbers that you know.**
- Write on the board: 90
  - **Everyone, what number?** (90)
  - **Ninety has how many *<u>tens</u>*?** (9) **How many *<u>ones</u>*?** (0)
  - **Your turn. Use your ten sticks and cubes to show me 90.**
- Monitor as students place the models in the correct columns.
  - **Everyone, count the ten sticks and cubes to make sure we have 90.**
- Add "+ 3" on the board: 90 + 3
  - **Now want you to show me what 90 + 3 looks like.**
  - **How many *<u>tens</u>*?** (9) **How many *<u>ones</u>*?** (3)
  - **Your turn. Use your ten sticks and cubes to show me 90 plus 3.**
- Monitor as students place the models in the correct columns.
  - **Does anyone know what number 90 + 3 equals?**
- Call on an individual student. Confirm that 90 + 3 is 93.

- **Everyone, count the ten sticks and cubes to make sure we have 93.**
- **Now write 93 on your board. Make sure to put the numbers in the correct columns.**

- Monitor that students write 93 in the correct place value columns.

4. Greater than / less than

Materials: Teacher white board **Vocabulary:** greater than, less than, more, less

- **Today we're going to learn how to find out if a number is *greater than* or *less than* another number.**

- Write on the board: >   <
  - **We use this symbol** (write on the board: >) **for greater than and this symbol** (write on the board: <) **for less than.**
- Write on the board: 7   4
  - **You already know which of these numbers is *more* and which is *less*.**
  - **Which number is more?** (7) **Yes, 7 is more or greater than 4.**
  - **Which number is less?** (4) **Yes, 4 is less than 7.**
  - **Now I look at the first number, which is 7. Is 7 greater than or less than 4?** (Greater than)
  - **Since it is greater than, I write this symbol for greater than** (write > between the numbers). **This says 7 is greater than 4.**
  - **Say that with me.** (7 is greater than 4)
  - **You can see that the big side of the arrow faces the big number. That will help you remember which way the arrow should point.**
  - **Say this by yourself.** (7 is greater than 4)
  - **Let's do another one.**
- Write on the board: 2   8
  - **Which number is more?** (8) **Which number is less?** (2)
  - **Now I look at the first number, which is 2. Is 2 more than or less than 8?** (Less than)
  - **Since it is less than, I write the symbol for less than** (write < between the numbers). **This says 2 is less than 8.**
  - **Say that with me.** (2 is less than 8)
  - **See how the small side of the arrow faces the small number? That will help you remember which way the arrow should point.**

- **Say this by yourself.** (2 is less than 8)

Wrap Up: Math facts minus 1 timed practice

Materials: Minus 1 facts worksheet, and minus 1 cumulative worksheet, pencils
Vocabulary: Subtraction, minus

- Give worksheets with minus 1 fact problems if students did not meet criteria in the previous lesson, or minus 1 cumulative worksheet to students who did meet the criteria.
- Pass out pencils and give the following directions.
  - **Look at the problems on your worksheet. Remember to use your thinking strategies to solve each problem.**
- If time allows you may review the strategy for each type of problem and/or have students orally solve a few problems in the first row on their worksheet.
  - **Today you're going to write the answer to 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.
- 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.

Teacher Note: In the next lesson, all students will move on to a new fact timing. If students have still not met criteria, try to provide extra practice on these facts within and outside the lesson.

Figue 2

FUSION Observation Instrument

Date: ☐☐ ☐☐ ☐☐ Observer: ☐☐☐ School: ☐				
Teacher ID: ☐☐☐☐ # Students in Group: ☐☐ Lesson #: ☐☐☐				
Start Time ☐☐ : ☐☐ End Time ☐☐ : ☐☐	CBMs: Fidelity of Administration Y or N			
General Observation Features				
Features	**1** *not present*	**2** *somewhat present*	**3** *present*	**4** *highly present*
1. Community of positive learning (Rapport, Respect, Positive Attitude)	o	o	o	o
2. Organization of instructional materials and learning tasks (Preparation, teacher-initiated transitions, accessibility)	o	o	o	o
3. Support of students' emotional needs (Sensitivity & Respect)	o	o	o	o
4. Effective and efficient classroom management (Clear expectations, minimizes non-instructional time, addresses appropriate beh)	o	o	o	o
5. Productive disposition of mathematical learning (Positive outlook on math, views math as important, confidence)	o	o	o	o
6. Clear and consistent delivery of instruction (Teacher demonstrations, pacing, consistent language, minimizes student confusion)	o	o	o	o
7. Student participation and engagement (Active involvement, compliance, completion of work)	o	o	o	o
8. Checks of student understanding (Timely checks, active monitoring and feedback, individual and group response opportunities)	o	o	o	o
9. Use of instructional adjustments (Student response time, accommodates learning needs, allows independent learning)	o	o	o	o
10. Accomplishment of instructional tasks and activities (Scheduling, completion of tasks, use of instructional time, student routines)	o	o	o	o
11. Teaching for mathematical proficiency (States purpose of lesson, addresses *big ideas,* effective teaching examples, anticipates student misconceptions, frequent instructional interactions)	o	o	o	o

Fidelity of Implementation				
Activity:	***Level of Implementation***		***Feasibility***	
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N
Activity:					
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N
Activity:					
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N
Activity:					
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N
Activity:					
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N
Activity:					
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N
Activity:					
Notes:	○ *Full*	○ *Partial*	○ *Not Taught*	**Materials** Y N	**Instr. Ex.** Y N