CENTER ON INSTRUCTION

A Summary of Nine Key Studies

Multi-Tier Intervention and Response to Interventions For Students Struggling in Mathematics

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CENTER ON INSTRUCTION

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INTRODUCTION

What is Response to Intervention? What is a multi-tiered intervention system?

Fuchs, Fuchs, & Vaughn (2008) provide a working definition of Response to Intervention (RTI) and the multi-tiered system of instruction in critical areas such as reading and mathematics:

> "The context for preventing academic difficulty in the schools has changed over the past 5 years with the introduction of multi-tiered prevention systems. Adapted from the health care system, school-based multi-tier prevention systems typically involve three tiers. The first tier is research-principled or validated classroom instruction. Students who are deemed at-risk for difficulty with the classroom program, usually on the basis of screening near the beginning of the school year, also receive a second tier of prevention, using a standard, validated small-group tutoring protocol (that can be expected to benefit most students). Only students who prove unresponsive to classroom instruction and to tutoring are referred for a comprehensive evaluation to consider the possibility of a disability that requires a third, more individualized tier of prevention, usually special education. Because such a multi-tier prevention system involves assessing students' responsiveness to intervention (RTI), it is conventionally referred to as an RTI prevention system…"

At its core, Response to Intervention (RTI) is invariably coupled with multi-tiered interventions in academic and social domains. A strong multi-tier RTI model requires:

- use of **evidence-based practices** in classroom instruction so that a minimal number of students will struggle to learn the content;
- **regular screening** of all students using valid and reliable measures to see which students require additional support in their regular classroom in core academic areas such as reading/language arts and mathematics;
- use of **preventative methods** (typically small group instruction/tutoring) for the students requiring additional assistance. This type of in-class support or tutoring is called Tier 2 intervention;

- regular use of formative assessments to ensure that these students are progressing (**progress monitoring**); and
- use of valid **diagnostic tests** as part of a comprehensive evaluation of a student's strengths and weakness to guide instructional planning.

An overarching goal of the tiered RTI prevention system is the use of evidence-based practices across all tiers of intervention. This goal has not yet been fully reached in any field, which is particularly true in the area of mathematics. However, a good deal of progress has been made recently, especially in terms of measures to use for universal screening, and effective Tier 2 preventative interventions for students in the primary grades.

Evolution of RTI in education

A major tenet of RTI is the premise that intervening early with struggling students will increase their chances of being successful in general education and avoid special education placement later. RTI is integrally linked to the concept of providing intensive early intervention to prevent academic failure. As sensible as this idea seems in 2008, in the past 20 years most students with disabilities in reading or mathematics were not identified until they reached second, third or fourth grade.

An impetus for early intervention was research in the field of reading (e.g., Juel, 1988) documenting that students who were weak readers by the end of the first grade tended to be weak readers for the rest of their academic careers. The need for intensive intervention in kindergarten and first grade in reading became well established. Although no such long-term research exists in mathematics, studies conducted over two or three years (e.g., Hanich, & Jordan, 2001) suggest some similarities between reading and mathematics. The research of Griffin, Case, and Siegler (1994), and subsequent research by individuals such as Sarama and Clements (2004), Starkey, Klein, and Wakeley (2004), and others demonstrates the power and effectiveness of early intervention in mathematics.

Current federal and state policy

In order to provide a free, appropriate education for all students, educators must identify those students who might need further assistance. This is "the child find provision" of Public Law (P.L.) 94-142, The Education of All Handicapped Children Act, enacted in 1975. It requires that educators determine their students' eligibility for services and find ways to aid them in their learning. In the years following the enactment of PL 94-142, many

controversies ensued about the label "learning disability" (LD) and the traditional procedures used to determine a student's eligibility for services. Many argued that determining eligibility by considering only a discrepancy between a child's achievement and his/her intellectual ability neglected the fact that classroom instruction can also impact the achievement of some students. RTI arose in part from the limited success of the pre-referral intervention approach advocated in the 1980s and 1990s and problems in accurately measuring the discrepancy between aptitude and achievement in young children. Reflecting these concerns, the reauthorization of the Individuals with Disabilities Education Act (IDEA) in 2004 allowed RTI to be utilized as a component of an evaluation for special education eligibility.

Educators were encouraged to use scientific, research-based interventions as part of the process to determine eligibility for special education. Students who responded to the additional intervention were not identified as having a learning disability, while those who continued to struggle and did not respond to the intervention with higher achievement were referred for a complete evaluation.

Coherence and coordination between special education and general education to assist students struggling with mathematics

As noted in a recent publication by the Council for Exceptional Children's Division for Learning Disabilities (2007),

> "by the late 1990s, researchers began experimenting with models of intervention that incorporated general education teachers into the first (i.e., preventative) layer of intervention. In these studies, improvements in classroom teaching were achieved by providing ongoing professional development for teachers and having teachers employ frequent measurement of students' …progress." (p. 4)

One major goal of RTI is to increase coherence and coordination between special education, Title I services, and classroom instruction for struggling students. The hope is that because all three types of service providers will share common measures, and share the same database for understanding student progress, or lack of progress, the long awaited objective of substantive communication and shared responsibility between special education and general education practice can be reached (Will, 1986). As the Learning Disabilities Roundtable (2002) noted: "Close collaboration between general and special education will promote a more seamless system of

service provision that will strengthen both the delivery of high-quality interventions for all students and the integrity of the disability identification process" (Johnson, Mellard, Fuchs, & McKnight, 2006, p. 3).

The purpose of this summary

This summary of nine studies provides information about evidence-based practices for Tier 2 interventions and how to use RTI in mathematics. It gives a critical technical analysis and review of research on RTI and multi-tiered instructional systems. In an earlier Center on Instruction publication, we described valid and reliable measures for early screening and identification of students with mathematics disabilities and systems for progress monitoring in mathematics (Gersten, Clarke, & Jordan, 2007).

Research articles are often hard to read and filled with irrelevant information. With the reauthorization of IDEA, state and local school officials have been given permission to use Response to Intervention as one way to help students in need of instructional intervention and to identify those students who need further services. Interest in Response to Intervention has increased tremendously as a result, especially in Title I schools. This summary will help inform those who are interested in this field about the most current research available.

How were the studies chosen?

Our goal was to find all articles that reported on experimental studies using Response to Intervention to help students struggling to learn math. We conducted a literature search in EBSCO Information Services, First Search, and PSYCHINFO databases. We located 541 studies when we limited the search to studies published in the United States between 1990 and 2007. The key words used in several combinations to search these databases included: mathematics, math, math education, Response to Intervention, RTI, Tier 2, Tier 3, learning disabilities, and students with learning disabilities. In addition to our database searches, we also contacted leading researchers in the field of Response to Intervention and asked them to suggest articles that dealt with experimental studies of Response to Intervention in mathematics education.

Of the 541 studies listed, 72 studies were selected for further review based on the title and key words. Of these 72 studies, 33 were selected for possible inclusion based on two research associates' reviews of the studies' abstracts. To be included in the final bibliography a study had to meet three

criteria. The criteria were derived from a list of RTI features presented in the introduction to this paper. A study needed to include:

- a defined screening process to identify students in need of intervention,
- the delivery of a tier 2 intervention, and
- a procedure to monitor student response to the intervention.

A number of well-designed research studies that examined intervention programs for at-risk students were not included because students were not screened into the study and/or their progress was not monitored. Summaries of interventions for at-risk students that do not include critical RTI elements are available (Baker, Gersten & Lee, 2002; Gersten, Chard, Jayanthi, Baker, Morphy, & Flojo, 2008; and Kroesbergen & Van Luit, 2003).

Organization of this annotated bibliography

We subdivided this report into several groups of studies based on their themes. Those studies that examined the effectiveness or efficacy of Tier 2 interventions for first, second, and third graders are reported first. The studies that examined the overall impact of RTI on achievement are reported next, followed by those that assessed the use of Response to Intervention as a method for preventing and identifying mathematics difficulties. Several studies reported results on more than one theme; their results were separated and reported under the appropriate theme. Under results, we did not merely transcribe the author's reports; we also confirmed that the interpretation of the results was aligned with the data analysis. Researchers reviewed the adequacy of the data analysis and the quality of the research design.

FIRST AND SECOND GRADE TIER 2 INSTRUCTION

The prevention, identification, and cognitive determinants of math difficulty
L. S. Fuchs, D. L. Compton, D. Fuchs, K. Paulson, J. D. Bryant, and C. L. Hamlett. (2005). *Journal of Educational Psychology, 97*(3), 493-513.

Design: RCT

The authors conducted a randomized control study (RCT) to examine the effects of first grade mathematics Tier 2 tutoring on student math achievement. The intervention group received 40 minutes of tutoring (Tier 2) in addition to their regular mathematics instruction, while the control group received only regular mathematics instruction. The authors reported on the extent to which tutoring reduced the achievement gap between tutored students and their non-tutored peers. They explored the extent to which intensive tutoring removed students from the mathematics disabilities (MD) category. They also explored which pretest measures predicted students' response to intervention. In this sense, they hoped to refine the methods we currently use to screen for potential mathematics disabilities.

Nature of the instructional intervention. The 40-minute Tier 2 intervention consisted of 30 minutes of intensive small group instruction and 10 minutes of computer-based instruction. The intensive small group instruction used, when relevant, a concrete-representational-abstract (CRA) teaching sequence (Butler, Miller, Crehan, Babbit, & Pierce, 2003). Concrete objects were used to introduce concepts about number and measurement. The teacher then expeditiously moved students to the use of visual representation and finally to the use of the procedures or concepts involving abstract numbers and symbols only.

For the remaining 10 minutes, students worked individually with a software program called Math Facts (Fuchs, Hamlett, & Powell, 2003). Math Facts was designed "to improve automatic retrieval of math facts." One hallmark of students with LD is slow and sometimes inaccurate retrieval of these basic facts, which precludes understanding of complex concepts.

Tutoring sessions focused on building number sense with topics on number and number operations such as: identifying and writing numbers to 99; identifying more, less, and equal with objects; place value (0-99); addition and subtraction facts; and two digit addition and subtraction without regrouping. Each topical lesson included manipulative objects and a worksheet. To maintain consistency, the tutors used scripts, but were

permitted to paraphrase or to use other strategies with advance approval of the three authors. Mastery of the topic(s) covered during a lesson was assessed each day. If students in the small group did not master the material, the topics were reviewed and, if necessary, retaught the next day.

Participants were 564 first graders and all 41 first grade teachers in 10 metropolitan schools (six Title I and four non-Title I). Approximately 52% of the students were female, 55% Caucasian, 34% African American, 7% Hispanic, and 4% identified as other. Forty-three percent received free and reduced lunch.

Based on a score computed across three brief pencil and paper measures involving basic addition and subtraction facts, beginning concepts and applications, and beginning computation, the researchers identified 308 lowest-scoring students for further testing. Teachers added 11 more students who they felt were struggling, although the pretest scores on the brief screening measures did not place them in at-risk status. After taking a much more extensive individualized battery, 139 of the 319 students were identified as the lowest performing students. The lowest performing students were randomly assigned to tutoring (N = 70) and control conditions (N = 69).

Results. Tutoring had a significant impact on at-risk students' scores on three major performance measures: two norm referenced achievement tests (WJ III Computation, First-Grade Concepts/Applications), and a test on basic Story Problems developed by Nancy Jordan. The only area of weakness was fact fluency performance, which was the major emphasis of the individualized computer components. The main lesson learned was that overall, tutoring as a supplement for classroom math instruction does significantly improve at-risk students' growth in mathematics, but it does not close the performance gap entirely between the at-risk and not-at-risk students.

Mathematics intervention for first and second grade students with mathematics difficulties: The effects of tier 2 intervention delivered as booster lessons.
D. P. Bryant, B. R. Bryant, R. Gersten, N. Scammacca, & M. Chavez. (2008).
***Remedial and Special Education, 29*(1), 20-32.**

Design: Regression discontinuity

The authors used a regression discontinuity design to study the effectiveness of a Tier 2 "booster" intervention on the mathematics achievement of first and second grade students who the research team identified as having mathematics difficulties. Regression discontinuity designs are considered the most rigorous type of quasi-experimental designs (Shadish, Cook & Campbell, 2001).

Participants were 266 students from one suburban elementary school in central Texas (126 first grade students, 140 second grade students). Only 51 students (26 first grade students, 25 second grade students) identified as having mathematics difficulties (scoring at or below the 25th percentile on the Texas Early Mathematics Inventories-Progress Monitoring in the fall) received the intervention.

Nature of the instructional intervention. Four tutors conducted the Tier 2 "booster" intervention. The booster sessions were supplemental to the core mathematics instruction and based on the concrete-semi-concrete-abstract (CSA) approach (Butler, Miller, Crehan, Babbit, & Pierce, 2003; Mercer, Jordan, & Miller, 1996). Emphasis was placed on those concepts students at-risk for math difficulties struggle with the most. The booster sessions were conducted with homogeneous groupings (two to five students per group) three to four times per week for 15 minutes for 18 weeks to provide additional explicit instruction in the areas of number, operation, quantitative reasoning, and fundamentals of algebra.

The tutoring sessions were meant to boost students' understanding and achievement in number, number operations, and quantitative reasoning. These skills and concepts were drawn from the Texas Essential Knowledge and Skills (TEKS) standards. The tutoring provided an explicit, systematic, and strategic instructional intervention on a chosen number range (e.g., 20-30) across a series of lessons on content such as number concepts and relationships, base ten, and place value before moving on to a new series of lessons with a new number range (e.g., 30-40). The scripted lessons led the teachers through modeling, think alouds, guided practice, pacing, and error correction. Tutors modeled the processes needed to solve problems, (e.g., taught specific strategies for learning addition and subtraction combinations) and provided opportunities for students to practice skills and concepts.

Results. Project staff members administered the Texas Early Mathematics Inventories-Progress Monitoring (TEMI-PM) and the math subtests from the Stanford Achievement Test-Tenth Edition (SAT-10) to examine the impact of the Tier 2 intervention on student achievement. The first grade at-risk students who received the intervention demonstrated gains. Second grade students who received the intervention showed statistically significant improvement while first grade peers showed improved scores but not to the level of statistical significance. Both first and second graders' overall achievement remained below that of their typically achieving peers. One possible explanation for the differential effects is that first grade students need more time to learn number sense tasks. Students may also need more time with numerical concepts, place value, and arithmetic combinations.

THIRD GRADE TIER 1 AND TIER 2 INSTRUCTION

A recent survey asked algebra teachers to describe the major deficiencies that they see in students who enter algebra classes ill-prepared (Zimmer, Christina, Hamilton, & Weber Prine, 2006). The two major issues that surfaced were (a) a lack of understanding of fractions, ratio, and proportion, and (b) an ability to transfer word problems into mathematical expressions or equations.

The interventions described in these four articles attempt to teach at-risk third graders to translate word problems into mathematical equations. The first study describes, and evaluates the effectiveness of, a Tier 1 intervention, a curriculum program taught to all students to address a common problem, that is, the relatively poor level of proficiency in translating word problems into mathematical expressions.

The next three studies examined Tier 2 interventions that addressed the same topic, but did so with much more intensive, small group instruction. These interventions were only used for students who demonstrated weak mathematics performance at the beginning of the year. Taken together, these studies presented a picture of a multi-tiered intervention system attacking a major problem area in mathematics.

Tier 1 intervention: demystifying complex word problems

Responsiveness to mathematical problem-solving instruction: Comparing students at-risk of mathematics disability with and without risk of reading disability.
L. S. Fuchs, D. Fuchs, & K. Prentice. (2004). *Journal of Learning Disabilities, 37*(4), 293-306.

Design: RCT

In their earlier research, the researchers developed and evaluated a method for teaching third graders to solve complex, multi-step word problems (Fuchs, Fuchs, Prentice, Bruch, Hamlett, Owen et al., 2003a; Fuchs, Fuchs, Prentice, Bruch, Hamlett, Owen et al., 2003b). Whereas the earlier research focused on overall class performance, this study examined the impact of the Tier 1 intervention on three types of third grade students: (a) those with disabilities in both reading and mathematics, (b) those with disabilities in mathematics but acceptable reading performance, and (c) those with no apparent academic disability.

Two key features characterize the supplemental curriculum Hot Math. They include:

- emphasis on systematically teaching students to transfer problem-solving strategies they learn to a wide array of different contexts; and
- emphasis on methods to increase students' task persistence and enhance their awareness of how they could transfer what they learned in mathematics class to situations that occur during the rest of the day.

Nature of the tier 1 intervention. The goal of Hot Math is help students "understand the underlying mathematical structure of the problem type, to recognize the basic schema for the problem type," (Fuchs, L. S. et al., 2008, p.159) to practice using the mathematics they already know to solve the problems, and to understand how previously untaught problem situations fit into the schema they have learned. Typically, teachers do little explicit instruction in this domain. Rather, they assign problems to students and discuss alternative solutions, or provide corrective feedback. The intervention is predicated on the premise that transfer can be learned, and that a teacher can not assume that students will transfer what they learned to novel situations without a good deal of guidance and instruction.

The intervention consisted of 32 lessons lasting 25 to 40 minutes. The curriculum included five three-week units. The first unit addressed general problem-solving strategies—how to make sure the answer made sense, practice in setting up the appropriate arithmetic operation from a word problem, and practice in use of mathematical signs to label a problem type.

The curriculum covered one problem type every three weeks. There were four problem types covered in this way:

- two and three step addition problems,
- problems involving one half,
- "step up functions" (e.g., if gum comes in packages of eight, how many packs would you need so that all 20 children get one stick of gum?), and
- addition problems involving simple pictorial representations.

These four problem types were identified by Riley, Greeno & Heller (1983). They are considered difficult problems for third graders, but experts in mathematics increasingly advocate their use and an inability to solve this type of story problem has been cited as a major reason for students' inability to succeed in algebra (National Mathematics Advisory Panel, 2008).

Teaching involved explicit instruction by the teacher as she or he worked through several examples and practice in heterogeneous pairs, followed by independent seatwork and homework. Students were taught the rules for

each problem solution during instruction and the rules remained on a poster on the wall. The teachers presented a worked example and then explained the strategy rules for solving the problem while referring to the poster. The problem structures for the worked problems remained the same, but the cover stories and quantities changed, in order to teach for transfer.

Next the teacher presented a partially worked example and allowed students to work in pairs to solve the problem. Finally, students were given several problems to work on entirely in pairs and at the end of each lesson the students worked on one problem alone. The teacher then provided a cumulative review. Self-regulation instruction in the form of goal setting was also incorporated into the lessons for each unit. Students scored their work, graphed their score, and then set goals for the session before beginning the lesson.

Participants were 201 third grade students from six urban schools in the Southeast. Approximately 44% were female, 58% were African American (no other ethnicities were identified), and 50% received free and reduced lunch. Students were identified as either not at-risk for reading or mathematics difficulties (60 control, 69 experimental), at-risk for math disabilities only (five control, eight experimental), at-risk for math and reading disabilities (20 control, 12 experimental), or at-risk for reading disabilities only (12 control, 15 experimental).

Sixteen teachers were randomly assigned to treatment and control conditions (eight control and eight transfer plus self-regulation). Control teachers followed the district's curriculum, while intervention teachers used the Hot Math supplemental curriculum during part of their mathematics lessons. By design, both groups spent similar amounts of time each week focused on mathematics instruction (control groups spent 275.00 minutes on math each week, treatment groups spent 276.88 minutes on math each week).

Two alternate forms of the outcome measures served as pre- and posttest, with the same numbers, operations, and length of words presented. Each form was scored in three ways: understanding, computation, and labeling. Labeling credit was given if the student figured out the proper problem type. Credit for understanding was given when the student's work reflected understanding of the problem, while credit for computation was given if the student used correct computation.

Results. Significant effects were found for the use of the supplemental curriculum as a whole class intervention. As anticipated, students deemed at-risk for math disabilities at pretest improved less than those with better scores on screening tests on computation and labeling. This suggests these

students may need more extensive, more intense, or even a different type of instruction to successfully solve mathematical story problems. Students with problems in both mathematics and reading improved the least. They also showed the least improvement in their understanding scores. Students with only MD improved as much in understanding as their non-disabled peers. Students' pretest scores in arithmetic computation seemed to be the best predictors of which students were likely to struggle with acquiring this material.

Tier 2: impacts of intensive two-tier interventions

***Effects of preventative tutoring on the mathematical problem solving of third-grade students at-risk for math and reading disabilities.* L. S. Fuchs, P. M. Seethaler, S. R. Powell, D. Fuchs, C. L. Hamlett, & J. M. Fletcher. (2008). *Exceptional Children, 74*(2), 155-173.**

Design: RCT

The study evaluated the impact of a preventative tutoring intervention to teach students who fail to benefit from whole classroom instruction in solving word problems. The previous set of studies indicated that students who demonstrate problems in either math or reading are unlikely to achieve a high level of proficiency in word problems if they only participate in whole class instruction. Thus, third graders with low scores in both reading and mathematics computation were considered eligible for preventative tutoring, and were randomly assigned to either the tutoring or the control condition. All students participated in typical classroom mathematics instruction using a commonly used core mathematics series. Students in the experimental condition received tutoring three times a week for 13 weeks on solving mathematics word problems. The intervention appears to be useful for either Tier 2 or Tier 3 intervention since all students below the 26th percentile were eligible to participate.

The researchers screened 511 third grade students in 29 classrooms in eight schools in an urban district. Participants were 42 students who scored below the 26th percentile on Wide Range Achievement Test (WRAT) Reading and who achieved a T score above 36 on a subtest of Weschler Abbreviated Scale of Intelligence (WASI). Approximately 57% of the third grade students were female, 57% African American, 23% Caucasian, 14% Hispanic, and 6% bi-racial. Eighty-nine percent received free and reduced lunch, 23% received special education services, and 23% had disabilities (9% LD and 14% speech/language).

Nature of the instructional intervention. The preventative tutoring was done on a one-on-one basis for 20-30 minutes per session. Students received tutoring three times a week for 12 weeks. Tutors were given scripted lessons but told to study them and feel free to use whatever phrasing they were comfortable with.

The tutoring focused on the more difficult material covered in whole class instruction: the three types of word problems described by Riley et al. (1983). The approach was similar to Hot Math but adjusted for one-on-one instruction. The pace was more deliberate.

Students were taught to "run" through a problem. The RUN process involved three steps: Read the problem, Underline the question, and Name the problem type (i.e., change, difference, or total). Instruction focused on understanding the underlying mathematical structure of the three problem types. At first, tutors used concrete objects and role-playing. They then moved into algebraic representations of the problem and reviewing procedures for solving the equations. Students were provided with practice in, and guidance on, how to transfer their skill to understanding the mathematical structure of problems with extraneous information and other distracting features.

Each session began with practice in retrieval of basic mathematics facts, followed by a brief review of previously taught material. Part of the tutoring session involved practice in linking word problems to their underlying structure. Students could earn tokens for correct responses, and turn them in for weekly prizes.

Results. The researchers administered four word problem measures. Effects were significant on two of the measures (Jordan's story problems and a researcher-developed measure) but not significant on the two commercial measures (Key Mathematics and ITBS problem subtests.) Differences on measures of procedural skills were not significant (except for WRAT-3), although all effect sizes were positive.

The researchers note that the small sample size led to a design with weak statistical power. They discuss the advantages of teaching third graders rudiments of algebra as a tool for understanding the mathematical structure of word problems.

Extending responsiveness to intervention to mathematics at first and third grades. **L. S. Fuchs, D. Fuchs, & K. H. Hollenbeck. (2007). *Learning Disabilities Research & Practice, 22*(1), 13–24.**

Design: N/A—Summary of two ongoing studies

Two studies are described and discussed in this article: the Fuchs, Compton, Fuchs, Paulsen, Bryant, and Hamlett (2005) study with first grade students discussed earlier and a study with third grade students, which we focus on here. The third grade study examined the effects of Tier 1 and Tier 2 interventions on students' word problem solving skills. This article discusses aspects of the interim findings from the third grade study. The unique aspect of this study was the examination not only of the effects of Tier 1 and Tier 2 (small group preventative) interventions in mathematics, but also an analysis of the value added by students who experience both Tier 1 and Tier 2 based on a similar curriculum design. The focal area was word problems and the intervention curriculum was Hot Math. Classrooms were randomly assigned to receive either the intervention curriculum or the regular classroom instruction. The purpose of this study was to replicate the effectiveness of Hot Math as a Tier 1 intervention. In this study, unlike the previous one, the Tier 2 intervention was administered in small groups of two to four students.

Nature of the instructional intervention. The authors indicate similarities and differences between Tier 1 and Tier 2 instruction. Among the distinguishing features of the tutoring were the use of visual representations (called a picture template) and the use of token reinforcement. Of course, in a small group instruction, students receive much more feedback and guidance tailored to their current performance level.

Classrooms were randomly assigned to receive either the regular mathematics instruction from the teacher or instruction using the intervention curriculum from a research assistant. Then at-risk students in each classroom were randomly assigned to receive tutoring using the intervention curriculum in addition to the classroom instruction or to receive the classroom instruction only. Four groups of at-risk students were compared: (1) those who received both the Hot Math classroom instruction and the Hot Math tutoring, (2) those who received the Hot Math classroom instruction and no tutoring, (3) those who received the regular classroom instruction and Hot Math tutoring, and (4) those who received the regular classroom instruction and no tutoring.

Results. At-risk students' problem-solving performance improved when they received the intervention classroom instruction. Those students who received both intervention classroom instruction and the intervention tutoring improved even more than those who received only intervention as their core classroom instruction.

Authors report data on "lack of responsiveness," which they define as performance below the 16th percentile based on a norm sample they created. For at-risk students receiving only traditional instruction, 86% and 100% fit into the "unresponsive" category, based on two measures of word problems. For students who received traditional instruction but also explicit systematic Tier 2 instruction with Hot Math, the proportions dropped to 55% and 62%. For students who received Hot Math as Tier 1, proportions were more impressive: only 29% and 54% were unresponsive. For students who received the experimental curriculum and the tightly aligned intensive tutoring, non-responsive results were even more impressive, 12% and 26%, suggesting the synergy the authors had hoped to achieve.

This program appears to reduce the prevalence of mathematics disabilities. Fewer students were at-risk for mathematics difficulties after they received classroom instruction using this program. Even fewer students were at-risk after they received both classroom instruction and tutoring using this program.

Effects of small-group tutoring with and without validated classroom instruction on at-risk students' math problem solving: Are two tiers of prevention better than one? **L. S. Fuchs, D. Fuchs, C. Craddock, K. M. Hollenbeck, C. L. Hamlett, & C. Schatschneider. (In press).** ***Journal of Educational Psychology.***

Design: RCT

This four-year study consisted of four groups similar to the Fuchs, Fuchs & Hollenbeck (2007) study discussed in the previous section. For this study, the approach to teaching word problems was also similar but included four problem types: (1) problems involving a shopping list (i.e., involving complex double digit addition), (2) problems involving the concept one half, (3) buying bags, and (4) pictograph problems. The approach, though similar to Hot Math is called schema broadening instruction. Teachers explicitly teach students strategies for transferring the knowledge of mathematical structures they know to more complex word problems involving information presented in pictorial form and problems with extraneous information.

Participants were 1,141 third grade students from 119 classrooms in the Southeast. Approximately 60% were female, 42.1% were African American,

40.7% European American, 10.5% Hispanic, 1.5% Kurdish, and 5.3% other. Thirty-seven students (3.2%) were English language learners and 54.9% received free and reduced lunch.

Nature of the instructional intervention. The schema-broadening instruction (SBI) tutoring covered the same content as the whole class instruction but in a small group format. Tutoring also included a motivational self-regulation component. The research assistants providing the intervention classroom instruction explained the problem types, worked several examples, and provided students with opportunities to practice in dyads. The SBI tutoring covered the same content and included self-regulation learning strategies.

In this publication we focus on the results for the at-risk students only. Those who received a double dose of schema-broadening instruction, i.e., students whose Tier 2 intervention was tightly aligned with their core mathematics instruction, performed the best.

Results. The most interesting finding is that the schema-broadening instruction was particularly effective as means of providing Tier 2 instruction. Students who received this tutoring were able to narrow the achievement gap between the at-risk and the not-at-risk students. Students responded positively to the self-regulation learning strategies. This was deemed important in that many of these students display problems attending to academic activities.

The number of students at-risk for mathematics disabilities decreased significantly for the SBI tutoring only group. Nearly half as many at-risk tutoring students were designated as having difficulties with math as the at-risk control students. There was no difference between the SBI classroom instruction group and the typical instruction group.

USING RTI TO BUILD COMPUTATIONAL FLUENCY AND QUICK RETRIEVAL OF ARITHMETIC FACTS

A multi-year evaluation of the effects of an RTI model on identification of children for special education. **A. M. Van der Hayden, J. C. Witt, & D. Gilbertson. (2007). *Journal of School Psychology, 45*(20), 225-256.**

Design: Interrupted time series (with multiple baseline components)

This study examined the impact of a specific RTI model, Screening to Enhance Equitable Educational Placement (STEEP), on teacher requests for pre-referral evaluations of students for possible special education placement. Unlike the preceding studies in this publication, this one evaluated the impact of a relatively easy-to-implement decision-making model. The goal was to refer fewer students for extensive evaluation for possible special education referral, and to guide teachers towards selecting students with more precision.

The study took place in a suburban district in the Southwest. Five schools participated. The sample included 2708 elementary school students; approximately 75% were white, 17% Hispanic, 5% African American, and 3% other. Approximately 20% received free and reduced lunch, 1% were English-language learners, and 14% received some type of special education service.

The authors phased the intervention into each school in a staggered fashion, reflecting one aspect of a multiple baseline design. During the baseline (pre-intervention) year(s), researchers collected data on referral rates and ultimate placement, but did not in any way intervene. The same measures were collected once intervention was phased into each school.[1]

In each school, data were collected for one to three years. Baseline data were collected for two school years in schools one and two, followed by intervention data for one-year in school one and three years in school two. Baseline data were then collected again in school one for one year, followed by intervention data for one year. For schools four and five, baseline data were collected for three years and intervention data were collected during the following two years. The criterion measures were:

[1] Although typically, one waits until post-intervention performance is stable in the first school implementing the intervention before intervening in the second school, in this case, the researchers intervened in one new school per year. Thus this is not an actual multiple baseline design.

- number of students that teachers referred for evaluations by the multidisciplinary team for possible special education placement, and
- the percentage of those students who qualified for special education placement.

The baseline and treatment data were compared to estimate the impact of STEEP on these measures.[2]

Nature of the interventions. In Tier 1 all students in the school were given a screening test on mathematics computational fluency. If the class mean was below the benchmark determined 30 years ago by Deno and Mirkin (1977), the entire class received a Tier 1 intervention geared towards building computational speed and accuracy. This intervention lasted 10 minutes a day for 10 days.

Target areas for the class were determined by the screening measure. The teacher modeled appropriate implementation of the computation algorithm several times, gave the class several problems to solve, and provided immediate feedback to the group (guided practice). Next, all students received no more than five minutes of timed practice on the computational skill. Students who were unsuccessful were provided with 10 minutes of individual tutoring by the classroom teacher during regular mathematics instructional time. These Tier 2 interventions were scripted. Students in Tier 2 received a reward if their performance level improved from the day before. Students who received the daily individual intervention also had the opportunity to earn a reward for earning a score higher than their last highest score. This part of the intervention was meant to maximize the students' motivation to respond and to build fluency in the math area with which they struggled.

If the class median was above the Deno and Mirkin (1977) benchmark, students performing at the bottom one-sixth of their class received an additional 10-minute Tier 2 intervention. The individual instruction was designed so that the difficulty level of the intervention matched the student's abilities. The authors of this study did not report if any classes were above the Deno and Mirkin (1977) median.

Determining which students required evaluation for possible special education placement. Only those students who did not respond to the Tier 2 intervention were recommended for evaluation for possible special education placement. Successful response to intervention was determined by the Deno and Mirkin (1977) benchmarks. This method was used in lieu of teacher judgment.

[2] The study also included a small reversal design. For further detail on this mini-study, see the article.

Results. When the STEEP intervention was used, teachers requested fewer children be evaluated for possible special education referral. Those children who were evaluated for special education services were more likely to be found eligible, suggesting that the intervention procedure led teachers to make fewer, yet more appropriate requests for placing a child in special education.

The percent of students of minority ethnicity evaluated and identified as needing services did not appear to change. Results of this study must be considered exploratory, given the focus on computation only, the brief duration of the intervention, and the fact that the study did not investigate whether Tier 2 students improved in mathematics proficiency.

Application of a three-tier response to intervention model for instructional planning, decision making and the identification of children in need of services. **S. P. Ardoin, J. C. Witt, J. E. Connell, & J. L. Koenig. (2001).** ***Journal of Psychoeducational Assessment, 23*****(4), 362-380.**

Design: One shot case study (with staggered implementation)

This study was a much smaller but more in-depth exploration of the STEEP decision making process in mathematics. It involved the students in two fourth grade classrooms considered low performing in mathematics by their teachers. Prior to intervention, all students in the two classes were screened on brief timed tests involving computation for all four basic arithmetic operations. The purpose of the screening tests was to gauge the appropriate topic and level at which to conduct a classwide (Tier 1) intervention. The target topic was two-digit subtraction involving regrouping.

Fourteen students were considered at-risk. A "Can't Do Won't Do" assessment process was administered to low performing students to discern whether their problem was caused by a skill deficit or a lack of motivation. Students were shown a variety of prizes they could select if they scored better than their baseline score on a math probe. If the students did not beat their baseline score, the researchers felt the problem was not primarily motivational.

Nature of Tier 1 and Tier 2 intervention. The class-wide intervention was conducted by one of the researchers. It was a very minimal intervention; the main goal seemed to be to improve fluency. First, the researcher modeled a set of problems for the students. The students then completed a worksheet (untimed) and two sets of timed probes on subtraction with regrouping. Each student's previous high score was written in the corner of the probe and the student attempted to beat that score.

The next phase lasted 14 minutes. It involved peer tutoring using heterogeneous dyads. Here, the goal was building fluency and mental mathematics skills with foundational subtraction facts, for example, problems involving one digit subtraction, such as 9–7 or 24–6.

Students alternated in the role of tutor and tutee. The tutor flipped through flashcards. If the tutee provided the wrong answer or failed to respond in five seconds, the tutor provided the answer. At the end of each session, all students completed a two-minute timed probe of these easier problems. The scores on these daily probes were the dependent measures in analysis, that is, the determinants of which students to refer for possible special education placement.

Results. Five students were provided with a more intensive 20–minute intervention using all types of subtraction problems (i.e., with both single and double digit numbers). The research team recommended that only one student—the one who failed to respond to either of the Tier 2 interventions—be considered for evaluation for possible special education services in mathematics.

This study is a descriptive one-shot case study. Because the authors did not use an experimental design, no inferences can be drawn. The class-wide intervention improved students' mean achievement scores on a subtraction probe and the post-intervention mean scores for four of the five students receiving the individualized intervention were greater than their mean score at baseline. However, we do not know if the same benefits would have occurred without any intervention since there was no control condition. We include the study because it is one of the earliest published studies of RTI in mathematics.

Using curriculum-based assessment and curriculum-based measurement to guide elementary mathematics instruction: Effect on individual and group accountability scores. **A. M. VanDerHeyden, & M. K. Burns. (2005).** ***Assessment for Effective Intervention, 30*****(3), 15-31.**

Design: One shot case study

The authors examined the effectiveness of using screening and progress monitoring data to plan and deliver instruction in mathematics computation. One school, participating in a school-wide RTI model called Screening to Enhance Equitable Educational Placement (STEEP) developed by Witt, Daly, and Noell (2000), participated in this study. There was no true control group.

Participants were in grades 3, 4, or 5 in one rural elementary school. Gender was equally distributed. The students were approximately 79%

Caucasian, 16% Hispanic/Latino, 4% African American, and less than 1% Asian and Native American. Approximately 11% received special education services, 3% were eligible for Title 1 services, and 1.7% were English-language learners. The teachers ranged in experience from 1 to 25 years.

As with the other studies in this chapter, all of the classes demonstrated a median score below the Deno and Mirkin (1977) benchmark on computational fluency. In this study, however, the Tier 1 intervention lasted for 30 minutes per day. Students with high error rates also received an additional five-minute scripted lesson each day. This was the Tier 2 intervention.

Nature of the instructional intervention. All the classes in grades 3, 4, and 5 practiced computation and rote recall of basic facts. Classwide peer tutoring (Tier 1), similar to the classwide peer tutoring used by Greenwood, Carta, and Hall (1988), was the core of instruction. The teachers then paired all their students by skill level and monitored the tutoring pairs to ensure high engagement and accurate implementation. The tutoring intervention was administered at the student's current proficiency level and was focused on a series of skills required by the state standards for each grade level, from basic skills and progressing through computational skills. The pace of instruction was intense and each student received immediate corrective feedback from his/her peer.

The teachers recorded the number of digits correct during a two-minute probe of the skill level on which they were working and then the teachers provided delayed corrective feedback. Students who reached the criterion for mastery were moved to the next skill level. The teacher used a script to provide students with high error rates an additional five minutes of instruction (Tier 2) outside of the 30-minute class-wide intervention.

Teachers administered a single skill probe (e.g., double digit addition, division with double digit divisors) at the student's instructional level daily to assess mastery of the lesson content. They also received a grade level probe of computational fluency (Shinn, 1989) monthly to track the students' growth on a metric of consistent difficulty. These probes only assessed computational proficiency and fluency.

Results. This was largely a descriptive study, so no large-scale generalizations can be made from the results of this study. VerDerHeyden and Burns suggest that using the data from curriculum based assessments (CBA) and curriculum based measures (CBM) to guide remediation efforts increased student growth substantially, and led to improved standardized test scores across the school. Descriptive data indicates that students' computational skills did improve. The number of low performing and middle performing students decreased between January and April, while the number of high performing students increased. This suggests that some low performing and middle performing students moved to the next highest performance level in computation as a result of the daily practice. However, there was no control group to allow for inferences to be drawn.

Results from the SAT-9 suggest very little change for students scoring below average before the intervention, but the students scoring above average did increase, which suggests that these interventions (classwide peer tutoring and five minutes of additional instruction for struggling students) improved standardized scores for proficient students, but had little or no effect on the standardized scores of struggling students.

CLOSING

The studies included in this summary are all quite new. The quality of many is high. We have clearly indicated those that used weaker research designs so that one does not draw inappropriate conclusions from the information provided.

Many of the studies present specific ideas for implementing effective instruction for Tier 2 interventions. Schools may also want to use this knowledge to conceptualize interventions in grades other than first, second, and third.

More studies are not available at this time mainly because Response to Intervention research in the field of mathematics education is just beginning. More researchers are beginning to study mathematics disabilities and the impact of Response to Intervention. We expect the number of published works in this area to increase in the coming years.

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