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CHAPTER 2

Effective Core Math Curriculum and Instruction

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Math curriculum and instruction has been undergoing various reform efforts over the last two decades to facilitate deeper understanding of mathematical principles. The purpose of this chapter is to capture the most recent efforts for improving math education in the United States. We begin the chapter by discussing the evidence available for guiding the selection of an effective math curriculum and then briefly describe the CCSS for Mathematics (NGA & CCSSO, 2010). Next, we discuss recommendations for providing effective core instructional content and practices. Finally, we describe supplemental programs that can be used alongside general math instruction.

CURRICULAR CONTENT

A unique problem with math instruction in the United States has been the poor performance of the general education curricula. In a review of available curricular programs at the elementary level only a weak effect (median effect size = 0.10) on student outcomes was found (Slavin & Lake, 2008). Unfortunately, there were also a limited number of quality studies that examined curricula. This lack of quality studies regarding math curricula persists according to recent evaluations from the What Works Clearinghouse (WWC; *http://ies.ed.gov/ncee/wwc*), which has found only four primary-level curricula as providing evidence of potentially positive outcomes on math achievement (see Table 2.1). The Best Evidence Encyclopedia (*www.bestevidence.org/math/elem/top.htm*), another reputable website that evaluates various math programs (created by the Johns Hopkins University School of Education's Center for Data-Driven Reform in Education [CDDRE]), did not identify *any* traditional math curriculum as having either strong or moderate evidence according to their rat-

TABLE 2.1. Elementary-Level Math Curricula Receiving a Potentially Positive Effectiveness Rating from the WWC

Curricula	Number of empirical studies meeting WWC evidence standards[a]	Number of empirical studies not meeting WWC evidence standards[c]	Effectiveness rating[b]	Explanation of rating
Everyday Mathematics®	1	33	Potentially positive	One study showed a statistically significant positive effect on math achievement.
Investigations in Number, Data, and Space®	2	6	Potentially positive	One study showed an unclear effect and one study showed a statistically significant positive effect on math achievement.
Saxon Math	2	12	Potentially positive	One study showed an unclear effect and one study showed a statistically significant positive effect on math achievement.

[a]Includes studies meeting standards with and without reservations.
[b]WWC defines the potentially positive effectiveness rating as a positive effect without contrary evidence.
[c]Studies that did not meet evidence standards (those ineligible for review are not included in this count).

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ing criteria. When considering these findings it is important to keep in mind the challenges affiliated with the effective evaluation of math curriculum:

1. It is difficult (e.g., cost, feasibility) to conduct highly controlled randomized studies to accurately evaluate curriculum.
2. The impact of a curriculum on student outcomes may take several years (Fuchs, Fuchs, & Compton, 2012; Slavin & Lake, 2008).

Nationwide, only a small number of curricula are used at the elementary level—for example, seven curricula represent 91% of all programs used by teachers in grades K–2 (Resnick, Sanislo, & Oda, 2010). A comparison of four common curricula provided to students in grades 1 and 2 showed that some curricular comparisons produced different outcomes for first and second graders, whereas for other comparisons no differences were found (Agodini et al., 2010). The curricula compared were Investigations in Number, Data, and Space (Russell et al., 2008), Math Expressions (Fuson, 2009), Saxon Math (Larson, 2008), and Scott Foremen-Addison Wesley Mathematics (SFAW; Charles et al., 2005). First graders who were instructed with *Math Expressions* outperformed students who were instructed with Investigations and SFAW. No differences in math achievement were found between first graders taught by Math Expressions as compared with those taught by Saxon Math. Second graders who were instructed with Math Expressions and Saxon Math outperformed students who were instructed with SFAW. Only small nonsignificant differences among the other curriculum comparisons were found.

These findings help support recommendations from the NMAP (2008) that a blend of student-centered and teacher-directed instructional approaches is important. Investigations is considered a student-centered approach, whereas SFAW and Saxon are both teacher-directed approaches. Math Expressions represented the only blended approach, comprising both teacher-directed and student-centered activities. Interestingly, these four curricula differed in the amount of teacher training embedded, amount of time spent on instruction, and number of lessons taught within each content area. For example, teachers using Saxon reported providing 1 more hour of instruction per week than teachers using the other three curricula (Agodini et al., 2010). These other aspects of instruction may be important for educators to consider when evaluating the success of the core curriculum.

The NMAP (2008) also reported that traditional U.S. math curricula have favored breadth over depth, and provided a weak conceptual emphasis and insufficient opportunities to build procedural fluency. Note that curricular gaps are related to *both* conceptual understanding and procedural fluency. Conceptual knowledge refers to math concepts, laws, and ideas (Doabler & Fein, 2103; NRC, 2001; Wu, 1999). Procedural knowledge refers to students' ability to use algorithms, mnemonics, mental math, and other strategies (e.g., counting on, doubles + 1) appropriately and efficiently (NRC, 2001). Furthermore, the NMAP suggests that conceptual understanding, computational fluency, factual knowledge, and problem solving are *equally important* and serve as foundational skills necessary for algebra.

The emphasis in the NMAP report on the importance of all aspects of foundational skills is noteworthy because it reflects an end to the math curricular wars that have been operating over the past two decades. The two opposing central viewpoints that have historically shaped math curriculum discussions include an emphasis on either (1) mastering basic fasts and standard algorithms, or (2) the math problem-solving process (Schmidt, Wang, & McKnight, 2005). The former tends to be teacher directed and the latter tends to be student centered. These approaches differ with respect to how much and when guidance is provided during instruction. The current consensus is that *both viewpoints are important* for math learning and represent essential aspects of math proficiency, as described in Chapter 1 (Kilpatrick et al., 2001; NMAP, 2008).

Concerted efforts to make national improvements to math achievement have been commissioned through the NRC (2001), the NCTM (2006), and the NMAP (2008). Readers are encouraged to access *Adding It Up* (*www.nap.edu/catalog/9822/adding-it-up-helping-children-learn-mathematics*), the seminal publication produced by the NRC, and visit the NCTM website (*www.nctm.org*) for more information. We briefly review the report provided by the NMAP (see the comprehensive document at *www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf*). The NMAP provided 45 findings and recommendations across the seven areas of math instruction and learning including (1) curricular con-

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tent, (2) learning process, (3) teachers and teacher education, (4) instructional practices, (5) instructional materials, (6) assessment, and (7) research policies and mechanisms. Table 2.2 lists selected NMAP recommendations in four of these areas that are most relevant to the purposes of our book. The most recent of these efforts, which builds upon these previous recommendations, is the CCSS for Mathematics (NGA & CCSSO, 2010).

As noted in Chapter 1, math performance in the United States lags behind other countries. Although the reasons for this are likely multidimensional, one area of investigation has been to identify what "very successful" countries do differently in terms of the curricular content. In every successful country there is only one national curriculum (Schmidt, Houang, & Cogan, 2002). It also turns out that successful countries have a more demanding, more focused, and more coherent curriculum (Schmidt & Houang, 2012). Focused means that the number of topics covered at each grade level is smaller than traditionally occurring in the United States, and coherent means that topics are sequenced across grades in a manner that is sequential and hierarchical.

The number of math topics covered by successful international countries begins small and gradually increases, ranging from five (grade 1) to 21 (grade 5; Schmidt & Houang, 2012). However, a sample of state standards across the United States from 2000 to 2009 revealed that on average the number of math topics covered ranged from 13 (grade 1) to 21 (grade 5), reflecting the "mile-wide and inch-deep" descriptor that has historically characterized the U.S. curriculum. Although by grade 5 the number of topics taught in the United States (on average) compares with international standards, far more content areas are included in U.S. standards across grades 1–4 (Schmidt & Houang, 2012; Schmidt et al., 2002). The CCSS for Mathematics (NGA & CCSSO, 2010) attempt to address this problem and include standards ranging from eight (grade 1) to 21 (grade 5). A potential outcome of the adoption of the CCSS is to alter curricular content to be more focused and coherent, potentially facilitating a more common national focus, which is similar to the highly effective international approaches to curriculum development.

It is an understandable finding that the U.S. curriculum has been ineffective given the challenge to ensure that textbooks adequately cover all content areas according to these traditional standards (NMAP, 2008; Schmidt et al., 2002). In fact, traditional U.S. textbooks have covered three times the content that a textbook in Japan does, which is an important factor to consider given that Japan represents one of the top-performing countries in math in the world (Schmidt et al., 2002). Some experts argue that U.S. curricula has actually *complicated* math learning by covering so many topics when in actuality, math comprises a small number of central ideas (Schmidt et al., 2002; Wu, 2011). Despite acknowledgment that prerequisite skills should be mastered before more complex material is introduced, U.S. students historically have learned composite (sequences of component skills) and component (basic foundational skills) skills simultaneously (Daly, Martens, Barnett, Witt, & Olson, 2007; Gersten, Beckmann, et al., 2009; Johnson & Layng, 1992; Mayfield & Chase, 2002). Many math topics continue to be reviewed or covered across multiple grades and analyses have demonstrated there is little consensus among states regarding what content ought to be covered (e.g., Porter, Polikoff, & Smithson, 2009; Schmidt, Cogan, Houang, & McKnight, 2011).

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TABLE 2.2. Selected Sample of Key Recommendations from the NMAP (2008) Final Report

Content area	Recommendations
Curricular content	1. Math curricula in elementary and middle school should be focused, with an emphasis on key areas, and progress coherently.
	2. A central goal for K–8 math education programming should be to cultivate proficiency with whole numbers, fractions, and essential elements of geometry and measurement. These three areas are thought to be critical foundations of algebra.
Learning processes	1. Integration of conceptual understanding, computation fluency, and problem-solving skills is necessary to prepare students for algebra.
	2. Computational proficiency requires automatic recall of whole-number operations, fluency with standard algorithms, and understanding of core math laws of operations. Sufficient opportunities for practice with whole-number operations are necessary to develop automatic recall of addition, subtraction, multiplication, and division facts.
	3. Math learning of all students can be improved by interventions that address social, affective, and motivational factors.
	4. Educational professionals should emphasize the importance of effort and persistence during math learning.
Instructional practices	1. Exclusive use of either student-centered or teacher-directed instructional approaches is not supported by research.
	2. A cooperative learning approach, Team Assisted Individualization (TAI), has been shown to improve students' computation skills but not conceptual understanding or problem solving.
	3. Formative assessment should be used on a regular basis to assess student learning during the elementary grades.
	4. Mathematical ideas instructed using "real-world" contexts only improves performance on similar real-world problems but does not improve computation, simple word problems, or equation learning.
	5. Students with mathematical difficulties (i.e., students with learning disabilities as well as nonidentified students performing in the lowest third of the general education class) should be provided with some explicit math instruction on a regular basis directed toward ensuring these students have foundational skills and conceptual knowledge.
Instructional materials	1. Educational publishers should produce shorter and more focused textbooks.
	2. States and districts should reach an agreement on common topics to be emphasized and addressed at each grade level. Textbook publishers should use these common topics on the material that is emphasized in the textbooks.
	3. Publishers of math textbooks should include math experts in the development of their materials to ensure accuracy.

Note. Based on information in National Mathematics Advisory Panel (2008).

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Some evidence exists to support the notion of common math standards. For example, states with standards more aligned with the CCSS had higher National Assessment of Educational Progress (NAEP) scores, on average, after accounting for low socioeconomic indicators (Schmidt & Houang, 2012). That being said, there is agreement among experts that the idea of CCSS for Mathematics may be helpful, but until the states that have officially adopted the CCSS observe changes in students' math achievement, evidence supporting this potential remains ambiguous (Lee, 2011; Porter, McMaken, Hwang, & Yang, 2011; Powell et al., 2013; Schmidt & Houang, 2012).

Some experts also suggest that the transition to using the CCSS will be more challenging for some states than others due to the wide variability in current state alignment with the Common Core, which averages about 25% (Porter et al., 2011). According to others, the CCSS may emphasize more cognitively demanding mathematical material with less emphasis on math procedures and foundational understanding, which is inconsistent with the NMAP (2008) recommendations and the curricular focus of some of the top-performing countries (Porter et al., 2011; Powell et al., 2013; Russell, 2012). Therefore, it is important that educators balance the more focused, coherent, demanding curriculum that may come with the adoption of the CCSS with ensuring deep understanding of foundational skills and concepts.

CORE INSTRUCTION

The lack of curricula that meets evidence-based standards along with limited consensus on what characteristics comprise effective math instruction (Gersten, Beckmann, et al., 2009) means that little guidance is available for implementing high-quality instruction. This is problematic because the IDEIA of 2004 requires the use of evidence-based approaches within general instruction as well as intervention. Core instruction refers to the primary instruction provided to all students in the general education classroom. Within an RTI framework, core instruction is also considered to have a central role in preventing future academic challenges (Batsche et al., 2006). Put another way, the hope is that by providing evidence-based curricula and effective instructional practices, the needs of 80–90% of students within a school will be met (Batsche et al., 2006). Focusing resources on improving core instruction is cost-effective because such efforts will hopefully result in helping the vast majority of school-age students. Form 2.1 provides a checklist of ways to promote effective math instruction in light of the current challenges the ideas for which are discussed throughout the remainder of this chapter.

It is clear that providing *all students,* regardless of learning disability status, access to core math instruction within the general education classroom during an established block of instructional time is essential for math learning (Bryant, Kethley, Kim, Pool, et al., 2008; Fuchs et al., 2012). Preliminary research has shown that at-risk students who receive both validated core math instruction in the general education classroom and small-group tutoring outperform students who only receive small-group tutoring (Fuchs et al., 2012; Fuchs, Fuchs, Craddock, et al., 2008). Therefore, small-group tutoring for at-risk students should

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not replace access to core instruction. Ensuring that a block of time is designated daily to math instruction is also critical, with some experts recommending 45–60 minutes of core instruction be provided (Riccomini & Witzel, 2010). This does not include time for additional tutoring or individual supports provided to advanced students, at-risk students, or students with disabilities. Additional time (e.g., 20–40 minutes extra) should also be allocated for those activities (Fuchs et al., 2012).

Instructional Content

Instructional content for primary grades should be sure to cover the key aspects necessary for building math proficiency with whole numbers. According to the NMAP (2008), math proficiency means that students should (1) understand key mathematical concepts; (2) know basic facts automatically; (3) use standard algorithms accurately, fluently, and flexibly; and (4) apply the previous three elements when solving math problems. Both the NMAP (2008) and the CCSS (NGA & CCSSO, 2010) consider proficiency with whole numbers as the central student outcome achieved by the end of fifth grade. In order to display proficiency with whole numbers, the following should be achieved by students at the end of elementary school (NMAP, 2008; Wu, 2011):

- Understand place value.
- Be able to compose and decompose numbers.
- Know the meaning of the four basic operations (i.e., addition, subtraction, multiplication, and division).
    - Know and fluently use the standard algorithms for the four operations.
    - Know the basic laws of operations (i.e., associative, commutative, and distributive properties).
- Apply the basic operations to problem solving.
- Automatically recall basic facts for the four operations.
- Use and understand estimation.

Educators should consider several different approaches to identifying research-supported curricula. First, websites such as the WWC (*http://ies.ed.gov/ncee/wwc*) and the Best Evidence Encyclopedia (*www.bestevidence.org*), which evaluate and identify evidence-based curricula, can be reviewed. Second, educators can independently evaluate curricula using the Common Core grade-level standards (*www.corestandards.org/Math*) and the NMAP (2008) recommendations. The focal points generated by the NCTM (2006) can also be used to guide instructional content (Lembke, Hampton, & Beyers, 2012); however, some of the topics differ from those recommended via the CCSS and the NMAP. Third, textbooks could be evaluated for research-supported instructional design principles. Form 2.2 provides a checklist for evaluating curricula using 11 instructional design principles based on previous math textbook reviews conducted by researchers (Bryant, Bryant, Kethley, et al., 2008; Doabler, Cary, et al., 2012). These instructional design principles were empirically derived and appear to be important for both typically performing students

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as well as those students struggling in math (e.g., Baker, Gersten, & Lee, 2002; Gersten, Chard, et al., 2009; NMAP, 2008); however, most of this evidence has focused on students at risk for or with math learning disabilities.

Regardless of the curriculum selected, it is also important to determine that the curriculum is delivered as intended by measuring procedural fidelity (Lembke et al., 2012). Procedural fidelity can be assessed by school psychologists, principals, teacher leaders, RTI coordinators, math coaches, or other designated school professionals using checklists. Checklists may come with some curriculum or could be constructed using teacher manuals (Doabler et al., 2014; Lembke et al., 2012). Using this format, core math instructional time is observed to ensure that all central content areas are delivered the way the instructional manual suggests. If the curriculum is not being implemented with fidelity, this may signal that one or more of the following could be considered: (1) provide additional professional development opportunities, (2) hold booster training sessions, (3) implement a supplemental program, (4) revisit the curriculum choice, (5) use a math coach to support teachers, or (6) reorganize math instruction to utilize a central math instructor at each grade level (NMAP, 2008; Riccomini & Witzel, 2010).

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Instructional Practices

As we have discussed, both teacher-directed and student-centered approaches to instruction are important to include in the classroom (NMAP, 2008). Other essential instructional practices to consider are the provision of differentiated instruction, explicit instruction, classroom management, and formative assessment.

Differentiated instruction serves to meet the needs of all students as well as provide any necessary accommodations to ensure that all students can access the curriculum (Fuchs et al., 2012; Gersten, Beckmann, et al., 2009; Lembke et al., 2012). Because the expectation is that students who struggle with grade-level math will be included in general instruction it is important to ensure all students' participation. Differentiation of instruction can be imbedded into independent work times as well as small-group or peer-pair-based activities.

Explicit instruction provided to the whole class daily, for at least a portion of the time allocated to core instructional activities, facilitates struggling students' ability to access the curriculum and even reduces the achievement gap with their typical classroom peers (Clarke, Smolkowski, Baker, Fien, Doabler, et al., 2011; Doabler & Fein, 2013; Doabler et al., 2014; Fuchs et al., 2012; Gersten, Beckmann, et al., 2009; NMAP, 2008; Riccomini & Wetzel, 2010). Explicit instruction is characterized as a systematic and structured instructional approach that has extensive support for use with students struggling to learn math (e.g., Baker et al., 2002; Gersten, Chard, et al., 2009; Swanson, 2009). The emphasis on explicit instruction is on mastery learning and establishing concrete roles for teachers and students (Doabler & Fein, 2013; Fuchs, Fuchs, Powell, et al., 2008; Swanson & Sachse-Lee, 2000). Box 2.1 provides a list of explicit instruction characteristics.

Incorporating appropriate classroom management strategies can also improve math outcomes (Slavin & Lake, 2008). Research has demonstrated that in-class attentive behavior, often as rated by teachers, contributes to math achievement (e.g., Claessens et al., 2009;

BOX 2.1. Aspects of Explicit Instruction

1. Break tasks into small, sequential steps.
2. Provide a wide range of examples and non-examples of the math topic being described.
3. Provide repeated practice and cumulative review of math concepts.
4. Provide frequent and immediate corrective feedback.
5. Present an advance organizer to the class prior to beginning the lesson.
6. Demonstrate and model the skill or strategy that students will learn about.
7. Provide guided practice opportunities with a gradual shift to more independent practice activities.
8. Provide independent practice opportunities.
9. Monitor student progress toward mastery using frequent assessment.
10. Provide periodic checks to ensure that students are maintaining mastered skills.

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Duncan et al., 2007; Fuchs et al., 2012; Fuchs, Geary, Fuchs, Compton, & Hamlett, 2014; Geary, Hoard, & Nugent, 2012). Attentive behavior refers to task engagement, persistence, eagerness to learn, organization, and independence; however, it is unclear which aspects of attention are important for math learning (Claessens et al., 2009; Geary, Hoard, & Nugent, 2012). Establishing a positive, consistent, and cooperative learning environment through the use of (1) classroom and instructional organization and planning (e.g., seating arrangements, routines, transitions; see Kern & Clemens, 2007, for more information on classroom management), (2) teacher and student cooperatively developed discipline components (e.g., co-constructed classroom constitution), and (3) parent/community involvement appears to influence math outcomes (Friedberg, n.d.; Slavin & Lake, 2008).

Finally, universal screening can be used to identify all students' performance levels on grade-appropriate math measures (see Chapter 3). These data are typically collected two or three times during the course of the academic year during the fall, winter, and spring and can be used to guide instruction and instructional groupings (Gersten, Beckmann, et al., 2009). Screening can also be used to designate whether performance below expected levels is specific to a child or a classroom of children (Ardoin, Witt, Connell, & Koenig, 2005; Burns, Deno, & Jimerson, 2007; VanDerHeyden, Witt, & Naquin, 2003). If it appears that specific classrooms of children are experiencing difficulties, then interventions directed toward classroom needs can be developed. Furthermore, the current IES practice guideline for applying RTI to math (Gersten, Beckmann, et al., 2009) suggests that monthly progress monitoring be conducted with students close to, but still above, the locally or national determined performance cutoff point (often perceived of as the 25th percentile) on the screening measure.

SUPPLEMENTAL INSTRUCTIONAL PRACTICES

Given the transition in curricular focus brought on by adoption of the Common Core as well as the limited availability of evidence-based curriculum (Gersten, Beckmann, et al., 2009), it might be useful to supplement core instruction with effective instructional practices (Slavin & Lake, 2008). When we have consulted with districts that just purchased a curriculum *not identified* as one of the evidence-based options, we often recommend to curriculum directors and principals that core instruction be supplemented. Therefore, supplemental programs can be considered as a way to ensure that core math instruction is well-rounded, uses recommended instructional practices, and addresses all key grade-level content areas. Another way the term *supplemental instruction* has been used is to assist students struggling with math, including those with math learning disabilities, to participate in core instructional activities (e.g., Gersten & Newman-Gonchar, 2011). For our purposes we refer to supplemental instruction as programs or strategies used within the general education instructional time to address *all students*' needs rather than providing a separate program to specifically support at-risk learners (i.e., we refer to this type of support as targeted or Tier 2 intervention supports), although the programs below may also be useful for this alternative purpose as well.

Computer-Assisted Instruction

One of the most widely used supplements to general instruction is computer-assisted instruction (CAI; Slavin & Lake, 2008). We cover the uses of CAI in Chapter 5 and therefore only briefly describe this option now. Currently, CAI programs represent integrated learning systems that incorporate math instruction with placement tests to identify appropriate instructional matches for individual students. The NMAP (2008) suggests that high-quality CAI implemented with fidelity is a useful tool for building students' automaticity with math skills, particularly computation skills. However, it is important that educators carefully evaluate the quality of software packages and ensure that the purpose for using CAI matches the needs of the student users. Slavin and Lake's (2008) review found a medium effect size (0.19) for CAI, with better outcomes for computation than problem solving or conceptual learning. However, Xin and Jitendra (1999) found that CAI that contained representation and strategy training was highly effective for word problem solving, and outcomes were more positive for simple as compared with complex word problems. An added benefit of CAI is the brevity of the sessions required to see student improvement (e.g., maximum of 30-minute sessions, three times weekly; Slavin & Lake, 2008). Unfortunately, most of these reviewed programs are no longer available, which prompted us to include a separate chapter (Chapter 5) on recent programs.

Instructional Process

Another avenue for supplementing the curriculum is not to add another type of instruction but to change the instructional format for using curricular content, also referred to as instructional process strategies. Examples of effective instructional process strategies include cooperative learning (learning in teams or groups), pair learning strategies (otherwise known as peer tutoring), mastery learning, and professional development programs emphasizing math content, classroom management, or student motivation (Slavin & Lake, 2008). According to Slavin and Lake's (2008) review of the research on instructional process

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strategies, a medium effect size (0.33) on student achievement was found *and* the research was of high quality. Use of these instructional process strategies may assist with differentiating math instruction (Lembke et al., 2012) and also addresses the NMAP recommendation to include social, affective, and motivational strategies within math instruction.

Most of these instructional process strategies provide some form of cooperative learning whether in pairs (i.e., peer tutoring) or teams of four. Cooperative learning may be particularly effective when included within general math instruction because working with other students may encourage persistence on tasks, which is required when solving math problems (Baker et al., 2002; NMAP, 2008). Benefits of cooperative learning includes modest increases in (1) social skills such as conflict resolution, helping behaviors, and attitudes toward others; (2) self-concept about one's self, academics, and competence with targeted skill areas; and (3) learning behaviors such as on task, effort, participation, rule compliance, and frustration tolerance (Ginsburg-Block, Rohrbeck, & Fantuzzo, 2006; Robinson, Schofield, & Steers-Wentzell, 2005).

Programs that are rated as having strong evidence of effectiveness and require students to work in teams of four include (1) PowerTeaching: Mathematics (*www.sfapowerteaching.org*), formerly known as Student Teams-Achievement Divisions, and (2) Team Assisted Individualization: Mathematics (TAI). Both of these programs are designed for intermediate elementary and middle school students, and TAI may be more appropriate for improving computation than applied skills (Slavin & Lake, 2008). Peer tutoring programs have been used with all primary grade levels. Common programs include ClassWide Peer Tutoring (CWPT; Greenwood, Delquadri, & Carta, 1997) and Peer Assisted Learning Strategies (PALS; *http://kc.vanderbilt.edu/pals/index.html*; Fuchs, Fuchs, Hamlett, Phillips, Karns, et al., 1997).

Peer-Assisted Learning

Several meta-analyses have been conducted evaluating the impact of peer tutoring (students work in pairs) or the broader conceptualization of peer-assisted learning (students work in small groups, also described as cooperative or team-based learning). Table 2.3 provides a sample of some of these meta-analyses and the outcomes for math (Baker et al., 2002; Bowman-Perrott et al., 2013; Gersten, Chard, et al., 2009; Kroesbergen & Van Luit, 2003; Kunsch, Jitendra, & Sood, 2007; Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller, 2003). Average effect sizes for peer tutoring or peer-assisted/mediated learning range from small (0.14) to large (0.89) with smaller gains often found when isolating outcomes for students with learning disabilities (Gersten, Chard, et al., 2009; Kunsch et al., 2007) and larger gains often found when used with students struggling in math but without identified disabilities (Baker et al., 2002; Kroesbergen & Van Luit, 2003; Kunsch et al., 2007).

Most of the research examining peer tutoring has focused on computation. A meta-analysis conducted by Kunsch and colleagues (2007) compared the effects of computation versus the conceptual and problem-solving aspects of math, confirming that greater benefits for peer tutoring are found with computation skills. Another important finding, given U.S. achievement gaps identified for students from low-income families, minority students, and

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TABLE 2.3. Summary of Selected Meta-Analyses That Included Evaluation of Peer Tutoring and Peer-Assisted Instruction on Math Outcomes for Elementary School Grades

Authors	Total number of studies reviewed	Number of math studies reviewed	Type of peer learning	Grades included	Type of math content	Setting	Treatment duration	Overall mean effect size for math
Baker, Gersten, & Lee (2002)	15	6	Peer tutoring	2–5	Computation	Not reported	10–32 weeks	0.62[a]
Bowman-Perrott et al. (2013)	26	6	Peer tutoring	1–12	Multiplying decimals, changing decimals to fractions, computing %, adding/subtracting time	General education; special education	280–1,137.5 minutes[b]	0.89[a]
Gersten, Beckmann, et al. (2009)	44	6[d]	Peer tutoring	Not reported	Not reported	Not reported	Not reported	0.14[f]
Kroesbergen & Van Luit (2003)	58	10	Peer tutoring	K–6	Computation; problem solving	Not reported	1–52 weeks	0.87[e]
Kunsch, Jitendra, & Sood (2007)	17	17	Peer tutoring	K–5; 7–12	Computation; computation with concepts and application	General education; special education	4–25 weeks	0.53[c,e]
Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller (2003)	90	33	Peer assisted	1–6	Not reported	Not reported	1–144 weeks	0.22[a]

[a]Includes students at risk for math failure.
[b]Duration in terms of weeks was not available; rather dose here refers to a calculation of total weeks of peer tutoring × number of minutes per week × number of sessions per week.
[c]K–5 (elementary) effect size only.
[d]Cross-age peer tutoring data not included.
[e]Includes students at risk for and with disabilities.
[f]Includes students with disabilities only.

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students attending urban schools, is that these are the very students who appear to benefit *most* from peer-assisted/mediated learning (Ginsburg-Block et al., 2006; NMAP, 2008; Robinson et al., 2005; Rohrbeck et al., 2003). Some evidence suggests that students in younger elementary grades (e.g., first, second, and third) may benefit from peer-assisted learning more than students in later elementary grades (e.g., fourth and fifth; Ginsberg-Block et al., 2006; Rohrbeck et al., 2003). An implication of these findings for classroom practices is that peer tutoring has the potential to be effective as a general education activity to enhance the computation skills of all students, including struggling students and those students experiencing other environmental risk factors.

Within the classroom setting, same-age peer tutoring can be incorporated with students who have similar or different math skills—that is, both low and typically achieving students benefit from peer tutoring (Bowman-Perrott et al., 2013; Kunsch et al., 2007; Robinson et al., 2005). Peer tutoring offered in general education settings is more effective than when provided in special education settings (Kunsch et al., 2007). Most of the time peer tutoring is reciprocal (Robinson et al., 2005; Rohrbeck et al., 2003), meaning that all students serve as both the tutor (e.g., guiding the instructional activity) and tutee (e.g., practicing the instructional activity in response to the tutor's instructions). However, nonreciprocal tutoring (cross-ability groupings) during which one student is designated as the tutor and a different lower-performing student is identified as the tutee, produces similarly effective outcomes for both tutors and tutees (Menesses & Gresham, 2009). This finding means that peer pairings do not need to include a higher-performing student with a lower-performing student for successful outcomes.

Other factors that are important to consider when developing a peer tutoring intervention are (1) use of rewards, (2) self-management, and (3) use of individualized evaluation procedures. Two meta-analyses demonstrated that general achievement outcomes (i.e., not specific to any subject area) were substantially higher when rewards were incorporated into peer-assisted learning (Bowman-Perrott et al., 2013; Rohrbeck et al., 2003). These studies found that social (e.g., applause, praise) and tangible (e.g., stickers, pencils, certificate of achievement) rewards, along with privileges (e.g., line leader, teacher helper, messenger), were the most commonly used reward types. Interdependent group contingencies were the most commonly used reward format. Interdependent group contingencies are when the whole class is given the same reward after meeting a classwide goal (see Greenwood, Terry, Utley, Montagna, & Walker, 1993; Hawkins, Musti-Rao, Hughes, Berry, & McGuire, 2009). Box 2.2 provides instructions for how to construct a group contingency—for example, students could have extra computer time if the class earned more points during peer tutoring than the previous week.

Rohrbeck and colleagues (2003) also demonstrated that when students participated *in more than half* of the following tasks: (1) set their own performance goals, (2) monitored and (3) evaluated their own performance, (4) selected potential rewards, and (5) administered their own rewards—peer-assisted learning had greater outcomes on student achievement. Finally, even though students are working in pairs or small groups it is essential that evaluation of the skills targeted for use with peer-assisted learning is conducted individually (Rohrbeck et al., 2003). Meeting individual students' needs is a natural part of peer-assisted

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BOX 2.2. How to Design a Group Contingency

Interdependent Group Contingency: The entire class is rewarded depending on the class's performance as a group. The target behavior, criteria, and reward are the *same* for all students.

	Components
Target behaviors	• Appropriate responding (e.g., saying the correct answer and correcting your own mistakes). • Listening. • Being respectful (e.g., waiting your turn, using kind words). • Staying on task. • Number of completed problems.
Criteria	• Assign point values to the target behaviors (e.g., 2 points for correct response; 1 point for staying on task). • Set reasonable criteria that can be achieved by the whole class (criteria can be increased over time). • Class beats the previous session point total, tickets earned, or number of problems completed.
Rewards	• Tangibles: certificates, pencils, erasers, stickers, silly bands, stamps, mechanical pencils, highlighters, crayons, markers. • Activities: extra recess time, computer time, games. • Edibles: popcorn party, candy.
Format	• Divide class into two teams, sum points for each team, and compare with criteria selected or reward team with highest points. • Sum total points earned across the whole class and compare with criteria. • Teacher distributes lottery tickets or cards to individual students and class aspires to earn an established number of lottery tickets.

Steps

1. Identify and define target behaviors. Usually task engagement and math performance behaviors are chosen.
2. Select and define criteria. Make sure the criteria can be attained by the class. Criteria can be randomly selected each week or changed to improve student performance over time.
3. Identify rewards that are acceptable and available for your classroom and school. Survey students to gauge their interest in the rewards. Create a menu of options. Rewards can be provided in order according to the menu or can be randomly selected from the list. Mystery prizes can also be used, meaning that the reward is not revealed to students until the class earns the criteria.
4. Determine how points will be awarded. Will lottery tickets be distributed by the teacher? Will each student have a point card that is stamped by the teacher? Will students allocate points on a card for their peer partner? Will points be determined by scoring their own papers and counting the number of completed problems?
5. Select the format that is preferred.

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learning when students are encouraged to monitor their own progress, set their own performance goals, and are involved with their own reward selection and administration. This is true as long as an evaluation tool is being administered during or immediately following one or more peer tutoring sessions each week. Peer-assisted learning activities can be implemented for as little as 1 week or as long as 144 weeks (Bowman-Perrott et al., 2013; Kunsch et al., 2007; Robinson et al., 2005; Rohrbeck et al., 2003). Of course, neither of the extreme options (1 week or 144 weeks) is generally recommended.

It is important that peer tutoring be implemented accurately so that achievement gains can be observed. Accurate implementation of peer tutoring steps can be facilitated by procedures already built into the peer tutoring script (see Appendix 2.1 for the Peer Tutoring Intervention Brief): teachers circulate around the classroom and monitor each peer pair at least once per session following training, and teachers review and reinforce peer tutoring steps and rules for partner work. When students experience difficulties grasping the peer tutoring procedures, teachers can provide (1) booster training sessions to the whole class or to specific peer pairs, (2) specific performance feedback on the steps that were missed and those executed correctly immediately prior to or after peer tutoring sessions, or (3) prompt the whole class or specific peer pairs on the peer tutoring steps that are frequently missed (Dufrene, Noell, Gilbertson, & Duhon, 2005).

CONCLUSION

This chapter described four ways to provide core math instruction that is accessible to all students: (1) select empirically supported curriculum, (2) evaluate curriculum according to evidence-based content recommendations, (3) use research-based instructional design principles, and (4) incorporate supplemental instructional strategies such as peer-assisted learning. Table 2.4 provides a summarized list of action steps associated with each of these four ways to make core math instruction accessible to all students. In addition, Form 2.1 provides a checklist for promoting effective classwide math instruction and Form 2.2 provides a checklist for reviewing textbook content for recommended instructional design principles.

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TABLE 2.4. Making Core Instruction Accessible to All Students

Options	Examples of action steps
Select, use, and integrate empirically supported curriculum during daily instructional blocks	1. Periodically visit clearinghouse websites, the purpose of which is to evaluate math curriculum such as the WWC website, *http://ies.ed.gov/ncee/wwc*. These websites provide occasional updates on the curricula that are reviewed and the evidence supporting these curricula. Note: Publisher claims that a curriculum is evidence based needs to be verified by other sources. 2. Be sure that 45–60 minutes of core instruction is provided to all students (regardless of disability status) daily. 3. Encourage administrators to plan for a 30-minute intervention block *in addition to* the core instruction block that can be used to provide enrichment, target interventions for at-risk students, and more intensive interventions for students with disabilities. 4. Identify a math coach, instructional or RTI coordinator, or math teacher leader to collaborate with teachers on curriculum implementation. Period reviews of teachers' implementation of the curriculum can be used to facilitate discussion, training, and support of curriculum components.
Evaluate curriculum according to evidence-based content recommendations	1. Educators can review the curriculum in use according to whether it aligns with the Common Core grade-level standards (*www.corestandards.org/Math*). 2. Educators can review the curriculum in use according to whether it aligns with the curriculum focal points generated by the NCTM (2006). 3. Conduct a textbook analysis to ensure that effective instructional design principles are used (see Form 2.2 for a checklist).
Use research-based instructional design principles	1. Embed a blend of teacher-directed and student-centered activities daily. 2. Use differentiated instruction during at least one portion of each math lesson (e.g., independent seatwork, peer-pair activities, and/or small-group work). 3. Provide explicit instruction to explain primary concepts and skills introduced in each lesson. 4. Incorporate classroom management and motivation strategies to encourage students' effort, engagement, and persistence. 5. Use formative assessment (e.g., universal screening three times each year) to guide instruction and instructional grouping.
Incorporate supplemental instructional strategies to enhance core instruction	1. Use CAI to support students' fluency of computation and word-problem-solving skills. 2. Embed the use of cooperative learning groups. 3. Use peer-assisted learning/tutoring within the classroom including same-age groupings during which each student has a turn as the tutor and tutee or facilitate cross-age tutoring with classes from higher grade levels.

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