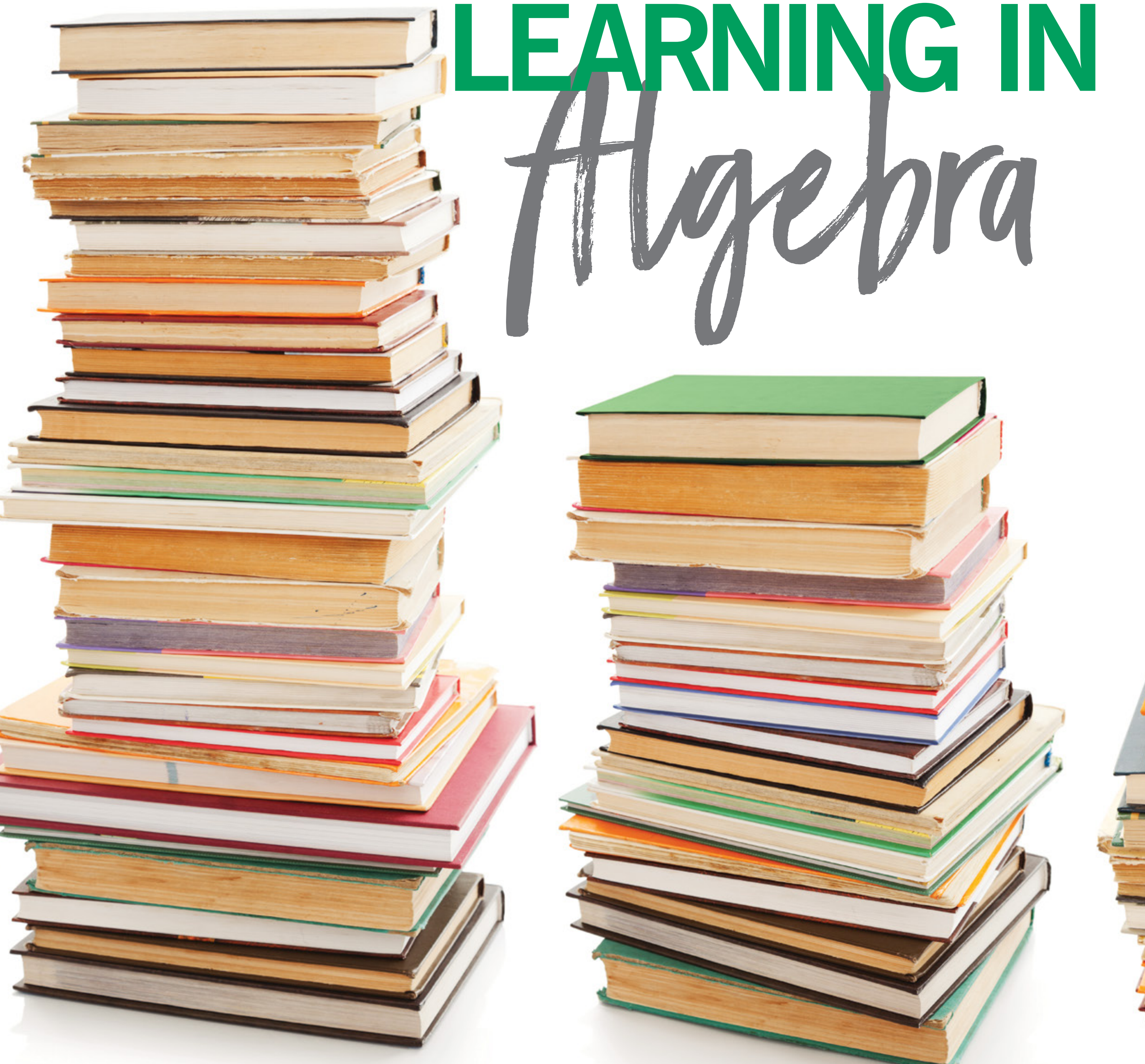
MONITORING STUDENT LEARNING IN *Algebra*



ART-SIBERIA/THINKSTOCK

Multistep algebra problems and formative assessment are the focus of two middle level classrooms.

Amy L. Accardo and S. Jay Kuder

Mr. Perez and Mrs. Peterson co-teach a ninth-grade algebra class. They are seated at a table, reviewing student data on solving multistep algebra word problems. Perez observes, "I see that several students did not use parentheses when combining their expressions."

Peterson adds, "Let's chart responses by students so we can identify patterns within these data."

Perez and Peterson's class includes four students with individualized education programs (IEPs). In response to legislation, such as the No Child Left Behind (NCLB) Act (2001) and the Individuals with Disabilities Education Improvement Act (2006), an increasing number of students with disabilities are taking mathematics classes, including algebra, in inclusive settings. This situation brings up key questions: Which instructional methods can teachers such as Perez and Peterson use to determine if instruction is working for all students in their mixed-ability classroom? Which daily instructional methods can teachers implement to ensure that all students are making progress?

One method for monitoring student learning is formative assessment. Research has found that formative assessment can be an effective method for improving student performance (Black and Wiliam 1998; Kingston and Nash 2011), including the performance of students with disabilities and English language learners (Madison-Harris and Muoneke 2012). In a review of effective methods for teaching mathematics to students with learning disabilities, Gersten and his colleagues (2009) found that formative assessment and its associated feedback contributed to student success. Specific to algebra, a recent review of algebra interventions concluded that a critical element in the instructional cycle is the monitoring of instructional effectiveness (Hughes et al. 2014). Formative assessment provides a way to measure instructional effectiveness.

OUR FORMATIVE ASSESSMENT PROJECT

As part of a project funded by a state department of education grant, mathematics teachers received professional development (PD) in the principles of formative assessment to enhance the learning of all students in their classroom, including those with exceptional learning needs. This article shares the formative assessment methods spotlighted in this project, along with how formative assessment was implemented in two algebra classrooms.

The State Collaborative on Assessment and Student Standards (SCASS) defined formative assessment as "a process used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes" (CCSSO 2008, p. 3). Through the formative assessment project, teachers received PD on formative assessment provided by university faculty with expertise in mathematics education and instructional methods for students with exceptional learning needs. The teachers were supported in implementing formative assessment methods by coaches who observed instruction and provided feedback and suggestions. Specifically, the teachers formed professional learning communities and agreed on the use of specific questions to guide implementation of formative assessment repeatedly in their mathematic classrooms (see the **sidebar**, "Guiding Formative Assessment Questions in Mathematics," on p. 355).

Throughout the project, teachers received PD on formative assessment methods, including breaking problems into steps for error analysis; using data collection charts to identify student response patterns; providing multiple probes to assess student understanding; and embedding one key question into a formative assessment for analysis. Classroom examples using these methods follow, along with how each teacher adjusted instruction based on the resulting student formative assessment data.

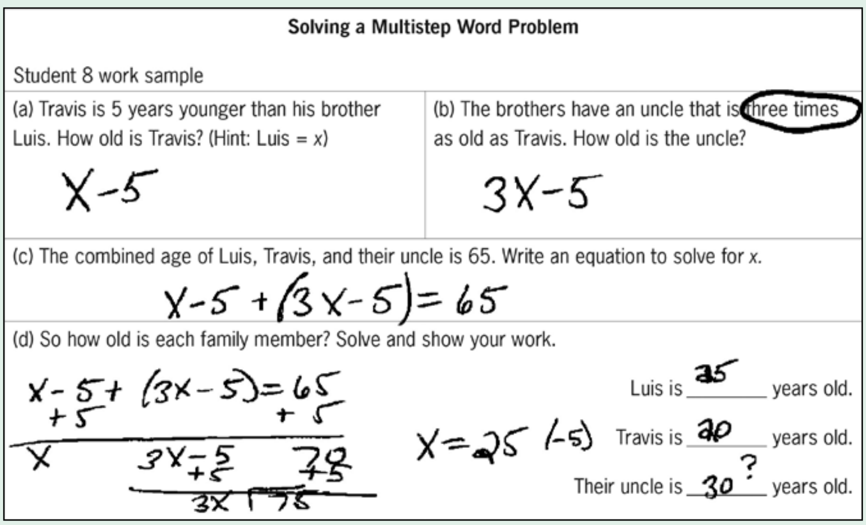
Classroom 1: Perez and Peterson's Ninth-Grade Algebra Class

In Perez and Peterson's classroom, students are working on writing equations to solve word problems. To pinpoint student errors and misconceptions in the process, Perez and Peterson considered the guiding question What's the math? and developed a formative assessment probe using the method of breaking a problem into steps for error analysis. They developed an exit ticket breaking one word problem into four steps (see **fig. 1**):

1. Write a basic expression.
2. Write an expression with parentheses.
3. Combine the expressions into one equation.
4. Solve the equation.

The teachers knew that breaking the problem into steps would help their students solve the word problem. Then, Perez and Peterson could identify where student difficulties lay. Furthermore, they preplanned

Fig. 1 With the formative assessment method, a problem can be broken into steps for error analysis.



the use of a data collection chart to support a visual analysis of student errors. The teachers have adopted the formative assessment method of using data collection charts to identify student response patterns (in lieu of grading) to provide a foundation for next steps in instruction and to provide students with explicit feedback toward learning goals.

Analysis of results: After implementing the formative assessment task as an exit ticket, Perez and Peterson entered the results into a data collection chart (see **table 1**). They considered their reflection questions:

1. What does the student work tell us about what each student knows, understands, and is able to do? and
2. What patterns of thinking emerge among the group?

By charting the student results, they were able to answer the questions

Guiding Formative Assessment Questions in Mathematics

Analyzing these questions can helped elicit strategic assessment information.

1. Planning the formative assessment task
   - What is the math (focus on understanding)? What are the standards?
   - What background information is needed? What skills will students need to solve the problem?
   - What mistakes and misconceptions do we anticipate students making?
2. Analyzing student data
   - What does student work tell us about what each student knows, understands, and is able to do?
   - What patterns of thinking emerge among the group?
   - What are our next steps?
   - Instructional implications?
   - Feedback for students (beyond grades)?

Table 1 Using a chart to analyze student data is one formative assessment method.

Formative Assessment ________ Luis is X years old… ___________

Date ______________ Class ____

Objective	(a) Write a basic expression.	(b) Write the expression with parentheses.	(c) Combine into one equation.	(d) Solve the equation.
Student 1	+	+	+	+
Student 2	+	+	+	+
Student 3	+	+	+	+
Student 4	+	+	+	Left blank
Student 5	+	+	+	Missed a step
Student 6	+	+	+	Needs help
Student 7	+	+	Incorrect	Wrong result
Student 8	+	No parentheses	Forgot to add Luis	Wrong result
Student 9	+	+	Had a problem combining	Wrong result
Student 10	+	No parentheses	Left blank	Left blank
Student 11	+	No parentheses	Had a problem combining	Left blank
Student 12	+	No parentheses	Left blank	Used 2 variables

Strategies for Increasing the Use of Formative Assessment

These strategies can help one ease into more and better assessment.

- Break mathematical problems into steps for quick error analysis.
- Embed one key question into each formative assessment.
- Provide multiple probes to assess understanding of major mathematical concepts.
- Organize data visually to identify patterns, both individual and group.
- Develop a simple data collection chart and use it to guide student feedback.
- Start a formative assessment professional learning community (PLC) in your school.

quickly, identify which students were struggling with solving the problems, and focus on the source of students' difficulty. In this case, they found that all twelve of their students were able to complete step 1 successfully, writing a basic expression. Four students made errors in the use of parentheses, including student 8, as evidenced in the work sample, part b response of $3x - 5$ instead of $3(x - 5)$. Six students made errors in combining expressions into one equation, and nine students made errors in solving the equation. The last result was surprising to the teachers because the class had been successful in a prior unit in solving equations outside of a word problem format.

Instructional response: Next, Perez and Peterson considered the essential reflection question, What are our next steps? Using the data collection chart, they developed a revised plan for instruction for the next class meeting. Specifically, they determined that the instructional strategy most appropriate in response to the student results would be error analysis. They explained to the class that they had noted a common error in student work. They displayed a work sample (with the student's name removed) with the common error, the lack of parentheses, at the start of instruction. They challenged each student to identify the error and how to correct it. They then used the learning opportunity to elicit student understanding of using parentheses to group parts of an expression and using order of operations to obtain a solution. They went through the same process to help the class fix order-of-operations errors. Perez and Peterson strive to use evidence-based practices, and they know that using incorrectly solved problems is an effective instructional strategy to elicit critical thinking in their algebra students (Star et al. 2015). By using examples from actual student work and involving their students in analyzing the source of errors, Perez and Peterson improved the ability of their students to identify their own errors as they solved algebra word problems. Furthermore, Peterson, guided by her data chart, provided specific feedback to several individual students at their desks, modeling the use of parentheses and solutions step by step.

Classroom 2: Mrs. Jennings's Basic Skills Algebra Classroom

Mrs. Jennings's class consists of ninth-grade students with learning needs that span from several years below grade level to on grade level in mathematics. Jennings is working with her students on describing (in context) the meaning of the point of intersection of two linear equations. She considered the guiding question What skills will students need to solve the problem? She was confident that each student could label points and graph data; however, she was using this specific formative assessment task as her gauge for whether each student had a clear understanding of what the intersection of graphed equations represented.

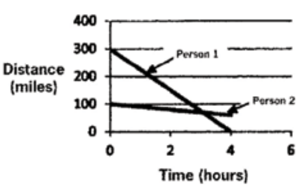
Fig. 2 This example shows one student's response to the formative assessment method of embedding one key question into a task.

Understanding of Point of Intersection (key question b)

Student 1 work sample

Graph

1. Distance from home



(a) Point of intersection: (3.5, 60)

(b) What is the meaning (in context) of the point of intersection? At 3.5 hours both people are the same distance from home.

(c) How far away from home is each person starting?

Person 1 300m Person 2 100m

(d) Who is traveling faster? Person 1

Table 2 Charting multiple probes to assess understanding is a popular formative assessment method.

Understanding Point of Intersection (Stations Activity with 3 Graphs)
Date ____________

Students	Graph 1 Question b	Graph 2 Question b	Graph 3 Question b	
Student 1	+	+	+	Clear statement all graphs
Student 2	-	+	-	Left 1b blank; misconception of axis on 3b?
Student 3	+/–	+/–	+/–	"Where points intersect"—too general/support too specific
(*Continues for all students*)				

Jennings knows that her basic skills students benefit from repetition and takes this into consideration when designing tasks. She uses the formative assessment method of asking multiple questions to assess understanding by presenting three similar graphs with related assessment questions. This situation supports her students and allows her to identify both common and individual patterns within responses. She integrated the use of stations into the formative assessment task, with small groups of students rotating throughout the room. At each station, students were presented with a graph and related tasks to (a) identify the point of intersection, (b) describe in context the meaning of the point of intersection, and (c and d) answer related application questions based on understanding of the graph.

Analysis of results: Jennings has also learned through the PD project that she does not need to analyze data in relation to every question on her formative assessments. As a result, in addition to asking multiple questions to assess understanding, she also used the formative assessment method of embedding one key question into a task. This method allows Jennings to review student data quickly for patterns related to mathematical understanding. For example, on the point of intersection assessment, Jennings will look at student responses to questions a–d, but the key focus of this assessment is question b, the task asking students to explain the meaning of the point of intersection (see **fig. 2**).

In her preplanning, Jennings also prepared a data collection chart to record student responses. She developed a system in which she uses a key (+, +/–, and –) to identify student level of mastery and a column to make anecdotal notes about student work (see **table 2**). Jennings used the chart to consider the guiding questions (1) What does the work tell me about what each student knows, understands, and is able to do? and (2) What patterns of thinking emerge among group members? An analysis of the charted student responses to graph 1, question b revealed that only four of ten students successfully explained the meaning of the point of intersection.

Perez and Peterson strive to use evidence-based practices, and they know that using incorrectly solved problems is an effective instructional strategy to elicit critical thinking.

Instructional response: On the basis of the data, Jennings was able to consider the question What are the instructional implications? and to purposefully make student-centered instructional decisions. The data collection chart indicated a clear need to differentiate instruction. Jennings defined two tiered groups for the following lesson:

- Group 1: Four students displayed mastery and were grouped with one student who needed to simply polish her point-of-intersection statements. The students were given graph application tasks.

- Group 2: The remaining five students who did not do well on the formative assessment were placed together. Jennings prepared sentence starters to help students develop their statements. She began by modeling the use of the sentence starters, for example,

  "The point where ____________ and ____________ are both ____________ tells us ____________."

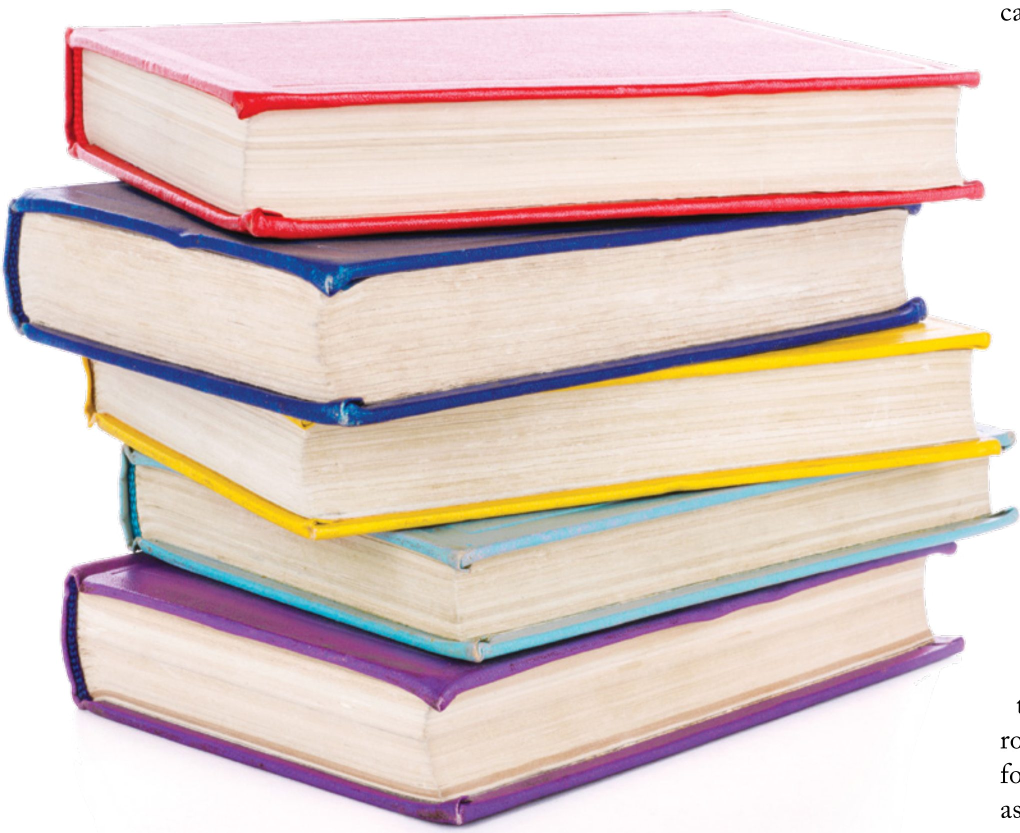
Next, through the use of flexible grouping, students were reassigned to mixed-ability groups and instructed to coach one another in reviewing and editing their responses to the formative assessment tasks. Class-wide peer tutoring (CPT) has been identified as an evidence-based practice for improving the academic skills of both general and special education students (Foegen 2008). Jennings has found that pairing the strategies of CPT and teacher modeling to be highly effective. She used guiding formative assessment questions, developed a formative assessment to probe student understanding, and used a data collection chart to align instructional decisions with the specific needs of each student.

Teachers had developed their own future goals of continuing their PLCs and working together to develop common formative assessments.

THE OVERARCHING TAKE-AWAY

Learning algebra skills can be challenging for all students, including those with exceptional learning needs, and providing purposeful instruction can be challenging for their teachers. Teachers in our PD project began with a goal of increasing their use of formative assessment through development of supportive PLCs in their schools. Next, teacher PLCs spent time developing and discussing common guiding formative assessment questions in mathematics. Finally, as a result of ongoing PD, teachers began to implement formative assessment methods consistently, including breaking problems into steps for error analysis, using data collection charts to identify student response patterns, providing multiple probes to assess student understanding, and embedding key questions into a formative assessment for analysis. At the conclusion of the PD project, teachers had developed their own future goals of continuing their PLCs and working together to develop common formative assessments to be shared among teams of algebra teachers.

Through the ongoing use of formative assessment and evidence-based instructional practices, teachers can evaluate student understanding of concepts and procedures and monitor student progress over time. Teachers can identify where students need help and focus additional instruction on those students who need it most. The teachers in this article used a variety of formative assessment methods to gather data on their students' performance and then used targeted instructional strategies and provided explicit feedback to move students closer to learning targets. As with any kind of formative assessment, it is important for each teacher to select and design formative assessments and data collection procedures that are easy to use and meet their specific classroom needs. Practical suggestions for increasing the use of formative assessment in your own classroom



ROSE_CARSON/THINKSTOCK

are presented in the **sidebar** titled "Strategies for Increasing the Use of Formative Assessment," on p. 356.

REFERENCES

Black, Paul, and Dylan Wiliam. 1998. "Assessment and Classroom Learning." *Assessment in Education: Principles, Policy & Practice* 5 (1): 7–74.

CCSSO Formative Assessment Advisory Group. 2008. "Attributes of Effective Formative Assessment." Paper prepared for the Formative Assessment for Teachers and Students (FAST) State Collaborative on Assessment and Student Standards (SCASS) of the Council of Chief State School Officers (CCSSO). Washington, DC: CCSSO.

Foegen, Anne. 2008. "Algebra Progress Monitoring and Interventions for Students with Learning Disabilities." *Learning Disability Quarterly* 31 (Spring): 65–78.

Gersten, Russell, David J. Chard, Madhavi Jayanthi, Scott K. Baker, Paul Morphy, and Jonathan R. Flojo. 2009. "Mathematics Instruction for Students with Learning Disabilities: A Meta-analysis of Instructional Components." *Review of Educational Research* 79 (September): 1202–42.

Hughes, Elizabeth, M., Bradley S. Witzel, Paul J. Riccomini, Karen M. Fries, and Gibbs Y. Kanyongo. 2014. "A Meta-Analysis of Algebra Interventions for Learners with Disabilities and Struggling Learners." *Journal of the International Association of Special Education* 15 (Spring): 36–47.

Individuals With Disabilities Education Improvement Act of 2004, 20 U.S.C. § 1400 et seq. 2006.

Kingston, Neal, and Brooke Nash. 2011. "Formative Assessment: A Meta-Analysis and a Call for Research." *Educational Measurement: Issues and Practice* 30 (Winter): 28–37.

Madison-Harris, Robyn, and Ada Muoneke. 2012. "Using Formative Assessment to Improve Student Achievement in the Core Content Areas." Briefing Paper, Southeast Comprehensive Center at SEDL. http://secc.sedl.org/resources/briefs/formative_assessment_core_content/

No Child Left Behind Act of 2001, Pub. L. No. 107-110, 20 U.S.C. § 6319.2002.

Star, Jon R., Anne Foegen, Matthew R. Larson, William G. McCallum, Jane Porath, Rose Mary Zbiek, Pia Caronongan, Joshua Furgeson, Betsy Keating, and Julia Lyskawa. 2015. "Teaching Strategies for Improving Algebra Knowledge in Middle and High School Students." Practice Guide. Washington, DC: National Center for Education Evaluation and Regional Assistance (NCEE), Institute of Education Sciences, U.S. Department of Education. http://ies.ed.gov/ncee/wwc/PracticeGuide/20

Amy L. Accardo, accardo@rowan.edu, is an instructor with the Department of Interdisciplinary and Inclusive Education at Rowan University in New Jersey and a former middle school special education teacher. Her interests include working with preservice and in-service educators to promote thinking skills in learners of all ability levels. **S. Jay Kuder**, kuder@rowan.edu, is a professor in the Department of Interdisciplinary and Inclusive Education at Rowan University. He is a former middle school special education teacher and was director of a grant-funded program to train secondary mathematics teachers in the use of formative assessment. He currently teaches a course in adapting instruction in science and mathematics for prospective mathematics and science teachers.

Let's Chat about Student Learning and Algebra

On Wednesday, February 15, 2017, at 9:00 p.m. EDT,

we will expand on "Monitoring Student Learning in Algebra" (pp. 352–59), by Amy L. Accardo and S. Jay Kuder. Join us at #MTMSchat.

We will also Storify the conversation for those who cannot join us live. Our monthly chats will always fall on the third Wednesday of the month.