ASSESSMENT AND INSTRUCTION:
THE MAKING OF AN ELEMENTARY MATH TEACHER

by

Kelly
ABSTRACT

This paper follows a pre-service elementary teacher during a six-month odyssey of learning to use assessment to guide mathematics instruction in a first-grade classroom. A careful review of mathematics assessment literature and a reform curriculum package provided the foundation of this study. From that base, I learned about planning, implementing and interpreting a variety of assessment strategies with the goal of providing thoughtfully differentiated instruction for all learners. Careful observation and collection of student artifacts provided data. Frequent analysis and intensive reflection led to a series of discoveries and insights about teaching mathematics to young learners.
BEGINNING THE JOURNEY

The responsibilities and opportunities awaiting me as an elementary teacher are as broad and varied as the students in America’s schools. One challenge that has continued to capture my attention is the importance of teaching mathematics well to all students. As a woman and the mother of an academically-gifted daughter, I’ve become especially aware of the unstated expectation that only boys “should” succeed in math. Furthermore, I recognize that when the declaration “I’m bad at math” is seemingly worn like a badge of honor in our society, our schools bear a double burden of not only providing thorough content-area instruction, but also of changing a cultural mind-set.

The challenge of helping a new generation—and especially the young women of a new generation—demystify and enjoy math excites me. The mathematical reforms of the last fifteen years, with their emphasis on students developing deep and thorough conceptual understanding, seem like such an effective way to teach, to invite young people into the science of pattern and order.

The question hovering like a dark cloud above all the exciting possibilities is that of “how?” How does a teacher effectively help students of all abilities, learning styles and attitudes build mathematical understanding? How do I teach young people to enjoy the exploration and discovery process when I learned math solely as a set of methods to be memorized to “get the right answer”? One important concept that emerges from reading textbooks, reviewing curriculum and browsing through math education journals is that of using assessment to guide instruction.

That idea—of adapting and differentiating lesson content and presentation methods to meet the needs of all students—resonates with my view of the very reason for public education:
to provide every child with the opportunity to learn and achieve. My desire, then, is to use what students know or need to know to determine what or how to teach. Once again, questions of methods and strategies arise and are distilled into this essential question: “How does the elementary school mathematics teacher use assessment to guide instruction?”

I set out to answer this question in a first-grade classroom in the company of nineteen 6- and 7-year-olds and a teacher of my own generation. Like me, the regular classroom teacher had been educated in the era of transition to New Math. However, for the last two or three years she had been using *Bridges in Mathematics*® curriculum from The Math Learning Center, a hands-on, discovery-based early elementary program carefully aligned with the standards adopted by the National Council of Teachers of Mathematics. While the specific answers belong to all twenty-one of us as we learned alongside one another for five or six months, I believe the insights gained from this student-teaching experience will serve me well in future classrooms and on other grade levels.

Those insights, in a nutshell, are that even a beginning teacher can learn and hone the skills of purposeful, ongoing, reflective assessment; the difficulty lies in judging how best to act on the information revealed through assessment and then implementing the differentiation called for by the data.
MATHEMATICAL ASSESSMENT: A Recent Historical Perspective

Throughout the 1980s, the dismal scores of U.S. students in math and science compared with students in Japan and other nations often dominated news reports about education. During the same time period, the twin forces of the information technology explosion and rapid globalization further underscored the importance of equipping students with problem-solving skills rather than teaching them a set of facts that might become outdated or irrelevant at an increasingly faster pace.

By the end of the decade, the publication of *Curriculum and Evaluation Standards for School Mathematics* (1989) by the National Council of Teachers of Mathematics (NCTM) and *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (1989) by the Mathematical Sciences Education Board had spurred a mathematics reform movement among educators nationwide. Thoughtful educators became convinced that students must develop an understanding of mathematics as the science of pattern and order and use that understanding to explore and solve problems relevant to the context of their lives. From such broad changes in how elementary teachers and students approach mathematics a shift in how student learning and progress are assessed and evaluated must logically follow.

In the last decade and a half, mathematics educators have wrestled with the questions of effective assessment. NCTM has published a series of casebooks and practical handbooks that address those questions. The reform movement also spawned at least two new professional journals, *Teaching Children Mathematics* and *Mathematics Teaching in the Middle School*, which regularly publish articles on assessment. This brief review focuses on only a representative fraction of the resources available in an attempt to answer the key questions of why, what, when and how to use mathematical assessment to guide instruction.
Why Assess?

Why use assessment to decide what or how to teach? Why not just select a good curriculum, one that is aligned with national and state standards, teach it well and reserve assessment for determining students’ grades?

Early in the current reform movement, the National Academy of Sciences convened a conference of math educators, public policy makers, business and industry leaders, and parent and community constituents. *For Good Measure*, the report of principles and goals established during that April 1991 conference, states, “The primary purpose of assessment is to improve learning and teaching. The primary use of results of assessment is to promote the development of the talents of all people” (1991, p. 17). Writing in the same year for the Office of Educational Research and Improvement, Dossey asserts that the “primary purpose of assessment is the improvement of teaching” (1991, p. 2).

*Principles and Standards for School Mathematics* defines assessment as

…more than a test at the end of instruction to gauge learning. It should be an integral part of instruction that guides teachers and enhances students’ learning. Teachers should be continually gathering information about their students…They can then make appropriate decisions about such matters as reviewing material, reteaching a difficult concept, or providing something more or different for students who are struggling or need enrichment (National Council of Teachers of Mathematics, 2000).

Kulm (1994) also describes the role of mathematics assessment as improving instruction and learning, but he lists these additional purposes: evaluating student achievement and progress; providing feedback to students by helping them see inappropriate strategies, thinking and habits; communicating standards and expectations; and improving attitudes toward mathematics.

Writing earlier about assessment in general, Stiggins (1984) points out that in addition to helping teachers determine what needs to be re-taught, assessment of students’ growth and development (rather than inadequacies and weaknesses) can impact the pace at which students learn and influence their attitudes and beliefs about their academic abilities. Bush (2001) also points out
that the shifts in assessment provide teachers a clearer picture of students’ mathematical
knowledge, their ability to use math and how they think mathematically, all of which provide
vital information to use in planning instruction.

While a host of additional experts could be cited to underscore the importance of using
assessment to guide mathematics instruction, this research project seeks more to answer the
questions of how, when and what to assess, rather than why. Although addressed separately here,
in practice such questions are considered congruently in a reflective educator’s ongoing and
organic process of evaluating student learning to guide instruction.

What to Assess?
Just like the savvy interstate motorist who slows to a law-abiding speed in certain jurisdictions,
students are quick to assign the greatest value to that which is scrutinized the most, no matter
what teachers may say about what is most important.

Throughout the evolution of the NCTM’s guiding principles, the emphasis has remained
fixed on the vital role of understanding. Teachers must understand what students know and need
to learn, students must learn with understanding. In Kulm’s (1994) view, the goal of any discrete
assessment is to find out what we know, what we don’t know and what we want to know about
students’ understanding of a particular concept. Multiple-choice tests and timed drills, the
assessment methods of choice in the last half century or more, measure student accuracy and
speed in computation. However, they provide virtually no window into students’ mathematical
thinking and understanding; hence, the emphasis in the reform movement on alternative
assessment.

If math educators value higher-order thinking they must assess higher-order thinking.
Stiggins, Rubel and Quellmalz (1988) provide an assessment planning template for use across
the curriculum that is based upon the deliberate use of questions from a hierarchy of thinking
skills, such as those outlined by Bloom. Use of that or similar systems can help educators train themselves to ask thought-provoking questions that require students to use the thinking skills of inference, synthesis and evaluation, as opposed to merely activating recall.

Effective assessment also requires clarity of purpose, particularly when assessing a process or performance. Stiggins (1984) encourages teachers to determine the reason(s) for the assessment, to identify the decision maker(s), to specify the skills or knowledge that students will be asked to demonstrate, and to decide who will be assessed. With that information, teachers can develop rubrics and checklists of what to observe and assess, helping to avoid both a glut of information and a dearth of meaningful data.

According to Clarke (1996), action must follow assessment. If the answer to the question, “What action will result from this assessment?” is “none” his counsel is to skip the assessment. By action, he means a teacher’s decisions regarding:

- instructional practice (how to teach);
- program design and review (whether to use, not use or adapt a curriculum);
- individual student tutoring and instruction (who needs what and how will they get it);
- modified student-learning behaviors (adaptations for specific students); and
- enhanced parental-support practices (suggestions for at-home activities).

Based on his advice, then, the mathematics teacher needs to gather enough and appropriate information through assessment to be able to answer those questions.

Without a context and a particular mathematical concept, the forgoing discussion of what to assess is necessarily somewhat vague and abstract. In an attempt to bring this to a more concrete level, see the comments by Driscoll (1996) below. Within the context of teaching decimals to high school students, he contrasts the answers he would have given as a math teacher
in the 1970s with those he would give now to the question of what kinds of tasks he would use to
guide instruction and help monitor student progress.

THEN
In form, they look like the decimal tasks I did when I
was a student.
Their content is narrowly defined to give clear
indicators for any needed instruction.

NOW
They invite students to enter them in a variety of ways
and at different levels of experience with decimals.
Complexity and challenge are valued, so students can
learn while doing the tasks, but so important
dimensions of each task, such as the accessibility of
the language can be identified.
They have the potential to show what the students
can do as well as what they cannot do.
To give a complete picture of decimal understanding,
single-answer tasks are balanced with tasks for which
multiple solutions exist.
At least some tasks offer opportunities for the student
to attach meaning to the use of decimals in social,
political and economic contexts in which they live (p.
16).

When to Assess?

*From advertising to zoo exhibits, the best design occurs when form follows function; the design
of effective mathematics instruction ought also to heed that maxim.*

In his model for performance assessment planning, Stiggins (1984) describes the
assessment cycle as beginning with a decision point about why an assessment is necessary and
what a teacher needs to know about student understanding of a particular skill or concept.
Throughout his systematic template, the focus is clearly on knowing the reason for an
assessment—on letting purpose dictate both method and timing.

The timing for assessment that is used only to assign a grade at the end of a textbook
section is almost unthinkingly obvious. However, in the reform mathematics classroom,
assessment is undertaken to monitor student progress so that the teacher can work to increase
student understanding. Therefore, ongoing assessment is emphasized. “Teachers should be
*continually* gathering information about their students,” [emphasis added] states the introductory
(1991), Van de Walle (2004) and virtually all who write on reform mathematics focus on the need for deliberate, ongoing gathering of information. Teachers still must know what data or kinds of insights they are seeking, though, as evidenced by the everyday practitioners cited in Bush’s (2001) casebook, who raise the almost plaintive question of what to do with the large quantities of data they’ve collected.

How to Assess?

Accepting the rationale for alternative assessment and realizing the need to assess student conceptual understanding in breadth and depth occur at the theoretical level. While effective teaching has its genesis in theory, incarnation comes about in actual practice.

Some teachers have continued to rely exclusively on traditional tests for assessment, even when embracing the aims of mathematical reforms. Perhaps that is due to the unquestioned objectivity such methods give, even if they measure only a thin slice of students’ mathematical knowledge. Alternative assessment may be seen as far too subjective, especially by those outside or on the perimeter of mathematics reform—and they also may well be the stakeholders who determine employment or make policy. Both Stiggins (1984) and Clarke (1996) address this concern by discussing the need for structured, systematic methods of recording the behaviors, comments and outcomes that inform the professional educator’s judgments about student understanding.

Clarke, a leader in Australian mathematical reform, goes on to say that often formal testing does little more than legitimize and quantify the informal (and usually accurate) opinions of student competence that teachers form through extended classroom contact (1996, p. 9). With clear goals, careful data collection and a systematized approach, educators can enhance the credibility of alternative assessment methods—methods that better serve students by giving instructors a clearer picture of what students know and need to learn.
Assessment methods can encompass a wide range of mathematical tasks. The *Principles and Standards* (NCTM, 2000) specify assessment through “questions, interviews, writing tasks, and other means.” Generally, the more open-ended the task, the more insight a teacher gets into a student’s thinking.

The following strategies and techniques reflect the suggestions and experiences of several current practitioners as presented in casebooks like Bush’s (2001), in teacher preparation textbooks like Van de Walle’s (2004), in the NCTM journals, and in the writing of education theorists.

**Performance assessments**—a student is asked to perform a certain task and/or produce a certain result. The teacher observes and compares the performance of the task with a rubric or checklist. Students are aware of the criteria by which they will be judged. (See guidebook developed by Stiggins and others for a step-by-step method of developing performance assessments.) Problem-solving performance assessments also reveal the math students choose to use as opposed to the math they can perform on demand, but might not necessarily use in an authentic context (Clarke, 1996).

**Annotated class lists**—as students complete an assignment (paper-and-pencil activities, hands-on investigations, group learning games or any other learning opportunity) the teacher observes for specific strategies, demonstration of certain skills and areas of strength or weakness. Using a class list set up in a table format (or a set of preprinted cards or labels that can later be affixed to individual records), teachers make quick notes on skills demonstrated, student comments and other relevant information about how students completed the assignment. Another method involves using a rubric or checklist for specific skills or topics to be assessed that includes a column for student names and shorthand notes (Van de Walle, 2004).

(Also, see *Teaching Children Mathematics*, March 1996, for one teacher’s inspiring narrative description of her use of annotated class lists.)
Analyses of annotated lists (either whole-class or individual) often are revealing in what they don’t contain, helping teachers to identify “invisible” students and thus become more aware of individuals who may need closer observation. To further strengthen the tie between assessment and instruction, Clarke (1996) suggests adding columns for recording needed remedial or enrichment action and a space to note when such action is taken.

**Investigations and experiments**—by its very nature, investigative learning links the development of conceptual understanding with assessment. When a student is given a crate of Unifix® Cubes and asked to show as many different combinations of 10 as possible, he or she is discovering addition facts and demonstrating mathematical thinking. The teacher can both observe (assess) and ask questions to extend student understanding (instruct). A task like the one just described also allows students to approach the learning activity from their own perspectives, giving teachers even more insight into student mathematical thinking and understanding. Asking a student to talk aloud as he or she works on a problem gives the observing teacher even more insight into student thinking (Bush, 2001).

**Open-ended questions**—whether used to pose a learning (or assessment) task or to elicit more information from a student, the questions math teachers use are critical. Questions can stimulate student thinking and learning; they can also communicate values. Clarke (1996) contrasts asking students the average of a set of numbers (a single-answer kind of question) with asking them “what five numbers have an average of 17.2?” (an open-ended question). His example clearly fits the criteria for open-ended questions set forth by Dyer and Moynihan (2000) in their work especially for elementary school math teachers. They list the following characteristics of open-ended questions:

- multiple entry points (lets students engage at their current comfort level)
- multiple solutions/paths to a solution
- require student decision-making
- require student communication about their results, methods or thinking
foster higher-order thinking
engender more curiosity

Interviews—ranging from formal, structured diagnostic sessions to quick check-in questions, interviews can provide the most direct view of student thinking as revealed by the student’s own words. They also are very time-consuming. Teachers have creatively “found” the time by trading duties with colleagues, interviewing students in small groups, training older students and parent volunteers, as well as other means.

Long and Ben-Hur (1996) adapted the formal, clinical interview into a four-step format for classroom teachers’ use. Their stages are a putting-at-ease initiation step, a questioning stage, a second questioning stage in which the teacher-interviewer formulates and tests hypotheses based on questions, and a final intervention step, should the teacher choose to use the interview as a time to modify student understanding. Kulm (1994) writes that if a student is foundering in an interview, the instructor ought to move from information-gathering to tutoring.

Moon and Schulman (1995) and Stenmark (1991), however, caution against doing instructional intervention during an interview. One great benefit of interviews is the opportunity to show students that their mathematical thinking is valued. If teachers “correct” a student’s thinking, that benefit is squelched. According to Stenmark (1991), if future interviews are planned, the teacher needs to preserve the credibility of the interview process as an opportunity for students to express unedited thinking.

In all cases, both Stenmark (1991) and Van de Walle (2004) caution against cuing and leading the child, either with evaluative comments or a series of questions that point to a certain response.

Occasionally an interview might be conversation alone. More typically, written or spoken prompts, drawings and models are used as a child explains his or her thinking about how to solve a problem, explain a concept or perform a procedure.

Journals—a specific place and procedure for writing and drawing about
math provides not only a record of student growth and development, but practice in communicating about math. Norwood and Carter’s short article in *Teaching Children Mathematics* (1996) provides a wealth of practical suggestions and proposes writing prompts easily adapted to a variety of settings.

Midgett (1996), an award-winning North Carolina elementary educator, uses math journals for students to record their discoveries and explorations in response to open-ended tasks. In working with older students who had developed a fear of mathematical risk-taking, Kulm (1994) successfully used journals in conjunction with cooperative learning to allow students to “try out” their math strategies and explanations and overcome their fears.

Journals can provide a voice for the student who is not confident about speaking. They also may engage students whose primary intelligence (after Gardner) might be visual/spatial, naturalistic or kinesthetic (Bush, 1996, pp. 84–89).

**Student self-assessment**—related to both interviews and journals, student self-assessment instruments provide a window into student attitudes, confidence and beliefs about math. Questionnaires, open-ended prompts, drawings and choosing responses from a range (e.g., always, most of the time, sometimes, never) all are methods for effective self-assessment. Clarke (1996) and many others use some form of a response sheet or directed prompts.

“In order to appropriate mathematics as their own, students must assume an active role in their own learning by becoming aware of what they know about mathematics and by being able to evaluate their attainment of mathematical power,” write Kenney and Silver (in Webb and Coxford, 1993, p. 229). When teachers foster student reflection on mathematical learning and development, they not only lead students to “own” mathematics but also gain important information to make choices about future instruction.

As their teachers respond to concerns or questions raised in self-assessments, students learn that they have a measure of control and influence in their mathematical development. Further, as Kulm points out, “it is reasonable to conclude that the more students are aware of the factors that drive their behavior,
the more potential there is for changing that behavior for the better” (1994, p. 74).

Student-selected tasks—asking students to pose questions that fairly test their peers' knowledge of a concept not only provides teachers with a pool of potential assessment questions, but also reveals student thinking and understanding. Clarke (1996) suggests extending the value of student question writing by requiring students to also submit solutions and/or strategies for their problems. As Swan points out (in Webb and Coxford, 1993), the activity engages students in the review of material learned and in practicing higher-order thinking skills as they evaluate the material for key concepts.

Group projects—assigning learning tasks to a group of students can enhance student mathematical thinking and communication and increase exposure to different approaches and strategies. When students interact in pairs or small mixed-ability groups, multiple times as many mathematical interactions occur as can in a whole-class setting—interactions that the teacher can observe and later act upon (Van de Walle, 2004). (The multiple benefits of cooperative learning groups and the challenges of their management are outside the scope of this paper.)

Managing group assessment effectively requires the teacher to provide clear expectations for group member responsibilities; teachers often assign specific roles (Leutzinger, Bertheau and Nanke, in Webb and Coxford, 1993), (de Lange in Romberg, 1993), (Moon and Schulman, 1995) and (Kulm, 1994). Assessment becomes twofold—evaluating students against a group role/participation rubric and considering the mathematical thinking done within the group and by individuals. Moon and Schulman provide several suggestions (1995, pp. 85–86) to assure a balance between group and individual accountability for learning, as does Klum (1994, pp. 67–69). Also, Pearce’s assessment strategies for science inquiry groups are easily adapted to mathematical inquiry and investigation groups (1999, pp. 125–131).

Portfolios—the deliberate acquisition of student work from several mathematical strands and over an extended period of time provides perhaps the clearest demonstration of student growth and development. Because of the nature
of information collected, Kulm (1994) points out that portfolio assessments can simultaneously be diagnostic, formative and summative.

For portfolios to be part of an effective assessment strategy, the teacher must identify clear goals for the portfolio, ideally tied to NCTM standards (Moon and Schulman, 1995). Stenmark provides an outstanding table with examples of specific materials to collect as evidence for such goals as growth in mathematical understanding, communicating mathematically, mathematical reasoning, mathematical connections and more (1991, pp. 38–39).

Involving students in the selection of portfolio items (with clear teacher- or teacher/student-defined criteria) assists in the metacognition development discussed earlier (see self-assessment section above). Moon and Schulman (1995) suggest guiding student reflection about portfolio items with questions such as:

- What did you learn in doing this mathematics task that you did not know before?
- What does this piece show about you as a mathematician?
- What part of this task did you like best? Why?

For teachers working with populations that are highly diverse or academically at-risk, portfolio assessment offers these important advantages, as noted by Stenmark in a work that focuses specifically on equity issues of mathematics assessment:

“…opportunities for improved student self-image as a result of showing accomplishments rather than deficiencies…recognition of different learning styles, making assessment less culture dependent and less biased” (1989, p. 9).

Two common themes that emerge from the techniques and strategies outlined above stand out as guidelines in answering the question of how to use assessment to guide instruction.

First, assessment needs to seek and measure student thinking and processes so that teachers can effectively address misconceptions, provide the opportunities necessary for students
and design challenges that extend mathematical thinking and power.

And second, communication about mathematics is vital to understanding. As Bush (2001) writes, “Procedural knowledge and language facility are integral to concept development.” In addition to clarifying his or her thinking, a student’s written or spoken explanation of a concept may strike chords in a peer that a teacher’s words have not. Dan Coburn, a long-time primary teacher, relates his observation of a first-grader explaining coordinate pairs to a peer who had not grasped Coburn’s initial explanation (personal communication, September 27, 2003).

Each of the techniques cited above can be employed with varying degrees of formality. The question of whether to use formal vs. informal assessment ought to be answered, in part, by the purpose of the assessment. (In this context, formal assessment is defined as “any set of questions or tasks given to all students in a consistent and replicable manner”[Rowan & Bourne, 1994, p. 102] rather than being the term used to distinguish commercially-prepared instruments from teacher-prepared ones, as is common in educational psychology.)

Stiggins (1984) points out that summative assessment done for placement or grading purposes ought to be more formally structured than that done to identify instructional or learner strengths and weaknesses. Clarke (1996) argues against typical formal assessment, which he describes as cessation of instruction while the entire class participates in an assessment event, and for ongoing informal assessment in which the collection of information of student learning happens concurrently with instruction and without disrupting the learning process. However, like Stiggins (1984), Clarke urges teachers to use structure and careful, thorough documentation in collecting assessment information. Kulm (1994, pp. 105–164) includes a series of case studies illustrating how the degree of formality is in part a function of the grade level being assessed.

Beyond techniques and strategies used to gather meaningful data, this research project
examines the difficult question of how the reflective educator uses assessment in instruction. “Educators should seek to have the best information possible available to them (from the best possible assessment techniques) when making instructional decisions that can have far-reaching consequences,” advise Lester, Lambdin and Preston (in Phye, 1997, p. 301).

As the model presented in *Principles and Standards for School Mathematics* (NCTM, 2000) illustrates, assessment involves four stages that are typically cyclical: planning assessment, gathering evidence, interpreting evidence, using the results. Driscoll (1996, p. 17) encourages teachers to complete the loop and ask: “On the basis of what I have seen in completing the cycle, what step should be next in the planning? What do I want to change in my goals for mathematics instruction? What do I see as important for the students to know and know how to do?”

Kulm challenges the past practice of “teaching, testing and grading every detailed piece of information in the curriculum” (1994, p. 39). In traditional math instruction, a teacher shows students how to perform a skill, assigns (and grades) practice problems and gives (and grades) frequent quizzes or tests over material covered. He contrasts that with the preferred practice of the teacher posing an open-ended problem and identifying the criteria on which work will be evaluated. Then the students explore solutions, recording their thinking and discovery processes, making connections to other mathematics and presenting their findings. He asserts that the amount of time teachers spend grading is equal in either case, but that how that time is spent is much different. The time spent on assessment in the reform classroom “…yields benefits in learning more about how students learn and solve problems. Rather than being forced to look only at answers, the teacher can see processes and the use of strategies and tools for problem solving” (1994, p. 40).

One final and important component in effectively using alternative assessment to guide
mathematics instruction can be as close as the classroom next door or as far as the other side of the globe—one’s colleagues. Moon (1997) writes that developing the judgment necessary to evaluate student work shown through alternative mathematics assessments comes through practice and repeated discussions with other teachers.

The mathematics teacher can prepare with a broad exposure to assessment techniques and give careful thought to the purposes of any single assessment in the context of the overall purposes for instruction. However, extensive reading makes clear that the best way to integrate assessment and instruction in mathematics is to do it! In describing her use of alternative assessment in the first-grade classroom, Midgett writes of her conviction that the “continuous monitoring of students’ progress is the heart of the teaching-learning cycle” (1996, p. 405). With each repetition of the instruction-assessment cycle, the reflective educator develops the confidence, skills and judgment to repeat the cycle more fruitfully.
CLARIFYING MY ACTION RESEARCH PROJECT

This project examines the process of a pre-service teacher in a first-grade classroom acquiring the skills and attitudes required to effectively practice “The Assessment Principle” and the “Analysis of Teaching and Learning Teaching Standard” set forth by the National Council of Teachers of Mathematics (NCTM 2000, 1991). The setting was a first-grade classroom in a rural elementary school in a district in Western Oregon’s Willamette Valley from September through February. Participants included a 44-year-old female student teacher and nineteen first-graders under the supervision of a contracted classroom teacher and university faculty. Permission to participate in the study was granted by students’ parents via a signed permission form (Appendix A). Students were assigned a pair of initials used during data collection; these appear in the sample data set (Appendix B) and the narrative.

The mathematics curriculum in use was *Bridges in Mathematics®* curriculum from The Math Learning Center in Salem, Oregon. Assessment strategies were built around the curriculum and consisted primarily of observations and anecdotal notes, artifacts and limited interviews, using some of the materials provided with the curriculum.

The belief underlying the project was that mathematics learning can be increased if teachers used information about student understanding to differentiate instruction and address learning needs unique to the current class members.
ROADMAP FOR THE PROJECT

The Plan
My research design called for daily observations and data collection, followed by weekly evaluation of information gathered and decisions about how to use that to guide instruction. As part of each math lesson, I planned to assess student understanding via performance assessments, observations and records of student comments or one-on-one interviews. From that data, my plan was to carefully evaluate students’ understanding of mathematics concepts and then provide targeted instruction, activities and home enrichment experiences.

I also anticipated that I would use the data gathered to inform a variety of instructional decisions, particularly about which students might need substantial re-teaching or more exposure to concepts, who would benefit from enrichment activities and whose understanding seemed on pace with instruction. Simple management decisions, such as how to group students for the next day’s lesson, also would be made in light of daily assessment information.

In addition, I scheduled three key reflection points where I would step back from the data and its interpretation, as well as lesson planning and scheduling to ask such questions as:

- What have I learned about 1) these students, 2) this curriculum and 3) myself as a teacher that I can use to maximize learning gains?
- How have I used (or can I use) what I have learned?
- What information do I need to gather next?

These critical analysis points were intended to shift my focus from student learning gains to my own development in using assessment effectively to plan instruction.

In my initial project design, I did not have a clear focus for how I would build data sets, in part because my research question was such an overarching, process-oriented question. As the study progressed, the need for an organizing paradigm became apparent. At my second critical
analysis point in January, as I examined the observation notes, the records of students’
explinations about their thinking and the many different kinds of paper artifacts I’d collected, I
concluded that the most useful way to assemble, analyze and act upon assessment data would be
to categorize it by mathematical strand, as presented by NCTM and the Oregon Department of
Education.

The Data Sets

Although I’d accumulated bits and pieces from math lessons over a period of four
months, the data fairly quickly fell into categories of computation and operations, problem-
solving, measurement, and money. These categories parallel the following strands set forth in the
Oregon Department of Education educational standards: Calculations and Estimations,
Mathematical Problem-Solving, and Measurement. Although understanding money falls within
the Calculations and Estimations strand, I chose to segregate data about money into its own
category because of the curriculum’s emphasis on money-based activities and especially because
of the students’ degree of engagement with such an authentic mathematical application.

The largest focus in first-grade math instruction is on foundational concepts of number
sense, calculations, estimation and operations; therefore, the computation and operations data set
is largest. The problem-solving data set also is large, in part because of the dominant focus of the
curriculum.

The measurement category is drawn primarily from a five-week integrated study of
penguins and Antarctica that I taught in January and February. Evidence of student learning
included a booklet of data sheets on each penguin species studied. In those data booklets, the
students had measured and cut string equal to penguin heights, used non-standard units to
approximate the weight of penguins and then compared penguin heights and weights to their own
height and weight.
In the problem-solving data set, I gathered information about both student problem-solving strategies and problems that students posed. Three different sets of student-created picture problems from November through February are included to give a fuller picture of student thinking and provide a means to examine growth. My observations on student solving strategies became more detailed as the months passed, reflecting my increasing respect for each student’s unique perspective and way of explaining his or her understanding.

The money category includes data from observations through the months, with particular emphasis on a Valentine’s store activity. Also included are the results of a computer-based money assignment that I created based on concepts covered in the curriculum; that activity yielded valuable information that I later used in focused teaching with students who were still struggling to build conceptual understanding of coin values.

The computation/operation category includes addition and subtraction worksheets, supplemented with observations of students using those operations in mathematical games and activities. I also included data from assignments and observations that gave students opportunities to discover and show understanding of patterns and relationships between numbers. Perhaps one of the most thrilling comments I recorded came in mid-December when one of the least mature students who struggled with math interrupted a mini-lesson that involved the hundreds chart to announce, “I see a pattern!”

**Data Collection**

In keeping with the principles suggested in the literature on assessment reviewed above, I used two primary methods of data collection: recording my observations of students engaged in mathematical tasks either during the task itself or upon completion of the lesson or teaching day and gathering examples of student work. Generally even worksheets and other artifacts collected were evaluated in light of my observations—e.g., after one round of a game involving addition, I...
invited students to change seats if doing so would help them make better learning choices. One student chose to move. After the move, not only did the student show more on-task behavior, but also when I evaluated that student’s game recording sheet I saw greater evidence of understanding.

Metacognition is not a skill that comes easily to 6- and 7-year-olds. Consequently, the amount of reflective, self-assessment data collected is limited; however, as our time together in the classroom progressed I tried to capture as much verbatim as I could when students explained how they solved problems, how they knew that their collection of coins equaled 18 cents or what the term “neighbor number” meant. By asking such questions and recording what students said, I hoped to communicate to them both the value of their unique reasoning and the importance of thinking about their thinking.

Periodically, I evaluated the data I had in order to determine if I needed to gather more information about specific students. When I saw gaps, I made it a point in the next few days to observe “missing” students or at least engage them in informal conversation about their mathematical work. Had I not gathered and examined assessment data regularly, my hunch is that I might have completely overlooked students who are quieter or those who have “average” mathematical aptitudes and attitudes; instead I learned to pay attention to students who do not call attention to themselves.

**Data Interpretation**

Two different, perhaps even opposing, viewpoints surfaced as I reviewed the extensive literature on mathematics assessment, and my work to interpret the data I gathered only underscored those differences. One view is that teachers should know exactly what they want to measure, gauge or discover and then design and implement an assessment instrument to gather that information. (See especially Stiggins & Quellmalz, 1988.) The other view, perhaps best
summarized by Midgett (1996) is that careful observation of all that students do, learn and struggle with, followed by thoughtful reflection on those observations, provides the key to successful teaching.

I found both approaches important. An example of specific, targeted assessment is the computer-based coin values exercise I designed to determine if students knew the values of coins and could determine the total value of a collection of coins. I used that assessment data to provide follow-up individual instruction and guided practice sessions. The process lent itself to effective assessment of a discrete skill and a straightforward instructional response.

However, I found the broad observation and reflection approach much more helpful for assessing and planning instruction for broader concepts such as building number sense and developing effective problem-solving strategies.

This latter approach suits the holistic, big-picture part of my nature; the former fits well with my detail-oriented, analytical self. Attempting to meld an organic, slow simmer kind of process with a quantifiable, hard data approach to data interpretation proved difficult. I’m convinced, however, that relentlessly pursuing that difficulty will not only make me a more effective teacher, it will also—and more importantly—provide young learners with more avenues to approach mathematical problems, more methods to build conceptual understanding and a fuller appreciation for the beauties and mysteries of mathematics.

A dichotomy – studying students, studying myself

The self-study aspects of this action research project provided the biggest challenge. One reason has to do with the perspective shift required. I frequently found myself so engrossed in the process of teaching—presenting mathematical concepts, observing student responses, listening for student understanding, reflecting on all the data gathered, analyzing student work, puzzling over what the data revealed, planning how to best review or teach the next concept—
that I failed to apply the skills of observation, reflection and analysis to myself as an emerging teacher. In other words, I got so caught up in the kids and their strengths and weaknesses, needs and achievements that I neglected the important task of stepping back to evaluate myself.

Another reason for my difficulty with the self-study portion of this project has to do with realistic expectations (or lack thereof). I began this endeavor more like an artist seeking to bring an internal vision to life and not like a contractor armed with a complete set of detailed blueprints setting out to build a house. Starting from a firm commitment to the goal of using assessment to guide instruction, I sometimes felt like I had stepped out into empty air with only the vaguest idea about how to achieve that goal.

Early on in the study I would sit down on a Friday evening and look over my week’s notes only to conclude that nothing I had done that week reflected anything I’d learned from the assessment data collected. (Hyperbolic emphasis mine!) However, just by keeping the goal in front of me, talking regularly with my cooperating teacher and continuing to review the information garnered through assessment, I began incorporating what I’d learned about students and their understandings into my lesson planning.

One evening toward the end of my five weeks of primary teaching duties, I had just evaluated the students’ picture problems, used that information (as well as my accumulated knowledge of the students and their abilities) to plan for the next day’s problem-solving groups, determined which students needed individual guidance to complete their problems and designed a recording sheet for problem-solving, based on prior chaotic experience without such a mechanism. I snapped my researcher’s notebook closed and exclaimed to the empty classroom, “Now, THAT’S teaching!”
THE STORY OF MY ACTION RESEARCH PROJECT:

WHAT **REALLY** HAPPENED

Having built four different sets of data (Appendix B), having practiced a variety of assessment strategies and having spent four months in the planning-instruction-assessment-planning cycle, I returned to my research question: “How can I use assessment to guide mathematics instruction?” Out of that grew three questions for evaluating the experience: “How did I effectively use assessment to plan/guide/fine-tune instruction?” “How could I have used the data I gathered more effectively in the planning and instruction process?” “What different kinds of assessment data would have allowed me to be more effective?”

Analyzing my data in light of these questions caused me to examine my findings and my experience both in breadth (focusing on multiple lessons, teaching moments, observation opportunities, etc. over the course of my student teaching) and in depth, as thoughtful reflection on a single example of effective use of assessment data sparked additional thoughts about how better to have used that data and what other kinds of information would have been helpful.

Needless to say, each data set yielded multiple answers to each question; rather than include a laundry list, I’ve chosen to illustrate my findings with salient examples.

**“Meets or exceeds standards” – effective use of assessment**

I examined my data expecting to find instances where I either gathered specific assessment information in response to experiences with past lessons or used past data to plan future instruction. I found several. However, toward the end of my student teaching, I noted with pleasure the following instance recorded in my researcher’s journal (Appendix C) when I used assessment data *immediately* to guide my teaching. While leading a learning game that used coins, I sensed that some students did not grasp coin values. To immediately assess
understanding, I asked students to hold up their fingers to show the value of the coins shown on the overhead projector. Seeing several inaccuracies, I modified my instruction to include an on-the-spot review of coin values, showing each coin on the overhead and having students recite with me each coin’s name and value.

Sometimes assessment data from a single lesson drove the next day’s instruction; on other occasions I made instructional decisions after reviewing information gathered over a period of several days. An example of the former occurred during a unit integrating math and science in the study of penguins. After an observer pointed out that one student (AB) did not seem to understand that “height” meant how tall, I recognized the need to provide a measurement overview that the curriculum did not include. The next day, I did a quick and dramatic review of the measurement concepts of height, weight and time, what attribute each measured and the corresponding units of measurement.

In contrast to that response to one day’s teaching, I puzzled at length over results from several different teaching sessions before deciding that using a chant with hand motions during line-up times would be a good way to reinforce addition “doubles” facts (1+1=2, 2+2=4, 3+3=6, etc.) for students who were ready for review and introduce the concept to students who were still constructing meaning.

One of the most authentic examples of the instruction-assessment-instruction process occurred in early December. Following my work sample unit on the friendly numbers 5 and 10, I gave students a problem-solving worksheet similar to those they will encounter on standardized state tests. Based on my past observations, I purposefully had grouped together the most capable students who I expected to finish relatively quickly. I then gave those students the challenge of creating a story problem “as hard as you want to” for me to solve. Seven students wrote and
drew problems. After scoring the students’ work, I then wrote out my solutions to their problems, showing my problem-solving strategies and verification methods (Appendix D). Whenever I could snatch a moment during the next week, I met individually with students who had written problems to have them check my answers. Those one-on-one conferences allowed me to model clear mathematical communication, verification methods and problem-solving strategies in a context they found quite meaningful.

“Needs work” – areas where assessment data could have been used more effectively

“More” is the common refrain in my responses to the question of how I could have more effectively used the assessment data I gathered. During the penguin unit, I wish I had provided more small-group guided practice to measure length and weight instead of giving students a session or two about hands-on discovery. My observations and review of the penguin booklets clearly indicated which students consistently had difficulty with measurement concepts; however, during this period of assuming all primary teaching duties, my practice lacked follow-through to address those difficulties. As I gain experience with full-time planning and teaching, I am hopeful that I will become more responsive.

My analysis of the computation and operations data set also points to missed opportunities for providing more individual and small group follow-up when conceptual understanding seemed limited. Three students in particular (EB, RW, LW), had difficulty in understanding skip counting by 2s on the 100s chart. My observation notes from that day show that I recognized their difficulty immediately. Further, my review of student worksheets that weekend confirmed that observation and also indicated that perhaps three others (MC, AG, AB) lacked clear understanding as well (Appendix E). An effective use of that assessment information might have been to work with those six students, use a tub of Unifix® Cubes and copies of the 100s chart to discover together patterns and meaning in skip counting by 2s.
Another possible strategy might have been to pose a similar task and then pair each of those six students with AM, EW, AS, DN, CC and MK, whose work indicated strong conceptual understanding.

Although students had (and for the most part enjoyed) many opportunities to share their problem-solving strategies and learn from hearing and seeing others’ strategies, I wonder if they would have benefited from more direction—or at least discussion—of the criteria used to score work samples.

Finally, in the money data set, I think I ought to have persisted in using or finding some kind of a chant or song to help students learn coin values. After I realized the value of skip counting in unison, practicing double equations, chanting the days of the week and other repetitive learning strategies, I found a poem about coin values at a website for teachers. When I introduced it, CC and MK quite vocally denounced it as a “Barney song for babies!” In retrospect, I think enough students needed an easy-to-remember way to learn coin values that I either should have overridden their objections or found another, less objectionable vehicle.

“What’s missing?” – assessment data that would have been helpful to collect

In addition to reflecting on the assessment data I gathered, I examined my data sets for gaps—information that would have been useful in planning future instruction but was either incomplete or missing entirely. I find that the longer I engage in reflective thought and probing about my practice—especially if I periodically step away from the process and the data and then return with fresh eyes—the more examples and categories of useful-but-missing data I find. However, at present, these omissions seem the most glaring.

In the money data set, gathering information about which students could capably and comfortably show a certain value using more than one combination of coins would have provided guidance about which of the Bridges® Number Corner money lessons to emphasize.
The curriculum provides such a wealth of material that I found it easy to fall into the trap of covering the curriculum rather than teaching to build understanding. More careful and thorough assessment data collection might be one way out of that trap.

I could have been more effective in helping students build number sense and an understanding of operations if I’d used more thorough questioning about how they achieved the results they did or how they knew what they knew. One useful instructional strategy that would build on such questioning would be to follow up math learning games (what Bridges® calls “workplaces”) with a whole-group session in which students—with my help if needed—summarized certain aspects of their work, strategies and understandings. Not only would that strengthen math thinking and communication skills, such a technique would also provide needed closure to workplace sessions and built-in accountability for how students used their time. (This is something I wish I’d realized sooner!!)

During the penguin measurement unit I had planned—but unfortunately didn’t implement the plan—to informally interview a few students during each “lab” period to gain a sense of their understanding. Imagine the window into student thinking that would open with such questions as, “What do the inch marks on your measuring strip mean?” “What do these lines on the scale stand for?” “What does it mean when the red needle lines up with a different number as you add cans to the scale?” “What do the lines on the thermometer mean?” “What kind of clothes would you want to wear if the red line on the thermometer went to this number?” Even if such interviews never led to direct instruction sessions, they still would be guiding student thinking and inquiry—perhaps the best kind of instruction—as well as providing key assessment information.
As I evaluated the problem-solving data, it occurred to me that often the ways assessment data is collected favors learners adept with paper-and-pencil tasks. With reflection and retrospect, I see the need to be more intentional in using assessment methods that allow all students to show their abilities, regardless of learning modality or favored intelligence; e.g., creating performance assessment tasks with manipulatives for kinesthetic learners.

**The tip of the iceberg – what I learned and will learn**

To share the details of what I learned by doing, by failing to do and by reflecting on both would require multiple megabytes. The materials included in the appendices of this paper will provide further illumination for those so inclined; the forgoing glimpses of day-by-day experiences in a dynamic learning community illustrate the reflective analysis, the critical learning stance and the unwavering focus on the goal of student understanding that I believe are the heart of what I learned in this study and anticipate continuing to learn throughout my service in the education profession.

Finally, perhaps the most valuable outcome of this project involves what I did NOT do. By deliberately focusing on using assessment as an instructional tool rather than strictly as an end-of-term measure of understanding, I tried to avoid what appears to be an easy trap for new teachers: making curriculum coverage, rather than student understanding, the goal of instruction. As I especially found during my five weeks of primary teaching responsibility, the multitude of daily tasks and decisions required of the elementary classroom teacher require a tremendous amount of physical and mental energy. It’s tempting, especially when using as full and broad a curriculum package as Bridges® to plug certain lessons into certain time slots, to use the assessment vehicles provided at the end of each unit, to record student results and then to assume that you’ve taught math. While such an approach may effectively serve the students who fall
within a “normal bell curve,” that is not an approach that is consistent with reform curriculum principles—or with my values as a teacher committed to all students.
REFLECTIONS AND QUESTIONS

What did I learn?

Like most valuable experiences in life, the process of answering my research question has been as beneficial—if not more so—than the answers I discovered. However, if my end-of-study self were to travel back in time and post some road signs to guide the process they would say:

Pay attention to what students are telling you

Students—especially young learners—cannot help but communicate. My job is to learn to listen to what they communicate behaviorally as well as verbally and in response to a wide variety of learning tasks as well as in response to direct questions.

Ask the right questions

Asking “Can she do it?” or “Does he get it?” reveals some information about what additional instruction is needed. Asking questions like “How do you know?” “What does this mean?” and “How can we figure it out?” provides more information about what needs to be taught AND gives direction about how to teach it.

Both kinds of questions are necessary, not just for the classroom teacher, but for the other stakeholders in a child’s education. Questions like the first set allow the teacher to tell students and their parents whether or not a student is learning what he or she needs to be learning for this grade level, time of year, etc. Using the latter kind of questions equips the teacher to help students learn about the processes they use to learn, their unique ways of knowing, their individual areas of strength and opportunities for growth. Students with that kind of insight are well on their way to a lifelong pursuit of knowledge, not just passing standardized tests.

Both the forest and the trees matter!

The effective elementary math teacher needs to balance detailed assessment of individual strengths and weaknesses with a “mountain-top view” that monitors whole-class learning and progress toward important learning benchmarks. While I think that most direction setting probably occurs with annual curriculum mapping and planning, that map will always be in a
process of renegotiation as the effective teacher responds to individual and whole group
understanding, interests and aptitudes.

**Review, review, review**

Continual examination and re-examination of assessment data is vital. Reflect on what
happened last week. Compare and contrast it with last month’s findings. Go back again in
another month and look for trends, growth, gaps, etc. Try to view data as a running film, as well
as snapshots. Let what you know today help you determine what to look for next week.

**The bar can always be raised**

Repeated analysis and reflection provide never-ending implications for instruction—
every review of assessment data reveals a way to plan better, respond differently, provide
meaningful differentiation, build lessons about teamwork and group skills into the math
curriculum, and much, much more. Plus, effective assessment engenders even more effective
assessment. The more you learn about determining students’ understanding, the better you get at
knowing what kinds of questions to ask or tasks to pose to gain even more insight into what
students know and how they learn it.

**It’s not a loop until you close it**

The planning-instruction-assessment cycle isn’t a cycle until assessment informs
planning and instruction. I found this probably the most difficult concept to put into practice as I
juggled the demand of being organized and prepared each day with the equally valid demand of
adapting lessons to respond to students’ needs.

Building in responsiveness to assessment data tended to be easier for me when I was
evaluating specific skills. For example, when I planned a lesson on using coins to express certain
values, I also planned a time to provide follow-up instruction and additional practice time for
students who might need it. Observation of students at work on the coin value task and analysis
of the artifacts generated during the lesson quickly allowed me to identify which students were
struggling.

In contrast, I found it much more difficult to assimilate meaning from assessment of bigger concepts or more involved skills. Often by the time I had wrestled some degree of meaning from the data, the chance had passed to adapt instruction to specific needs.

Use the wheel, don’t reinvent it

Elementary math teachers are blessed with a tremendous wealth of resources—many of which are outlined in the literature review above. Judicious use of resources from curriculum, state and national math associations, internet collections, mentors and colleagues allows the teacher to focus on the planning-teaching-assessing cycle rather than spending so much time creating novel learning tasks that no time remains to plan for their optimum use or to assess their impact and effectiveness. Although I sought some insight from other teachers, my practice would have been stronger if I had established a strong collaboration with colleagues.

A cradle-to-grave strategy

Kindergartners through high school students benefit when teachers intentionally use assessment to learn as much as possible about what they know and what they need to know. That being said, I was fortunate to conduct this study in the first-grade classroom of a teacher who supported a constructivist approach to teaching math. Students who have not yet been steeped in multiple-choice and all-that-matters-is-the-right-answer forms of assessment don’t resist the kinds of alternative assessment described at length above. Also, given the self-confidence that 6-year-olds typically bring to the classroom, I generally had no problem persuading students that their thinking was valuable. In contrast, teachers of adolescents often must overcome significant resistance before empowering students to express and explore their mathematical thinking. I am convinced, however, that the insights I gained in this study will benefit students in any classroom at any grade level.
**When you’re out on a limb, you pay close attention**

When I viewed the curriculum as a guideline rather than a directive, I tended to be most effective in using assessment to guide instruction. Perhaps that’s due to the suspension of the “it’s published so it must be right” bias that at some level limited the rigor with which I scrutinized my teaching and student response when I stayed within the published curriculum. In contrast, when I implemented learning tasks that I designed or adapted from other sources, I assumed more responsibility for evaluating how well they accomplished what students needed.

That brings me to my main criticism of the Bridges® curriculum: it provides too little support and direction for effective day-to-day differentiation, especially for the mathematically advanced student. The philosophy underlying the curriculum seems to be that with enough opportunities for exposure and hands-on exploration, students will build understanding as they are developmentally ready. My cooperating teacher often referred to it as a “marinating process.” After six months of watching many of these first-graders explore, struggle and reach “ah-ha” moments, I now can support that philosophy from a practical, as well as theoretical, stance. However, because my goal is that all students achieve their highest learning potential, I want to design the most effective environment for exploring so that more students experience more “ah-ha” moments.

To extend the marinade metaphor—a master chef artfully blends the proper ingredients to enhance a particular cut of meat while Joe Barbecue pours on a bottle of supermarket special sauce. I believe students deserve a chef and the way to become one involves thoughtful adaptations based on careful assessment. Particular attention needs to given to students who excel in mathematics and are all too frequently left on the back burner while instruction focuses on students in the middle or struggling learners. My reading indicates that academically gifted students must remain challenged so that they become confident learning risk-takers.
What do I still wonder about?
Completing this almost-year-long process, two major questions stand out—one as I look back and one as I look forward.

Isn’t there a cleaner way to do this?
Due the nature of my research question (and no doubt also due to my complete lack of experience with action research), my research design provided very little guidance for the self-study aspects of this project. Essentially, the plan called for me to reflect regularly on how I had been using assessment to guide instruction and how I might do so in the future. Without diminishing the importance of thoughtful contemplation throughout the entire process of teaching, I think that in order to continue using the action research process in my practice, I will need to streamline it somewhat or the task will be too daunting. Initially at least, I am much more likely to use action research to design and test projects of a much smaller scope: “Do students respond well when peers take the lead in guided practice activities for learning in intermediate language arts lessons?” versus the “how do I become a teacher?” nature of this project. (I don’t regret the scope or topic of this study—it fit the circumstances and I had tremendous guidance and support in the process.)

One possibility that occurs to me for more effective self-study projects in the future is the idea of establishing certain benchmarks to shoot for or measure against. One such goal for this study might have been to show a certain number of examples per time period in each mathematical strand. A standard like that would have focused my attention across the content area and on quantity—even when I failed to reach the goal.

So what?
I’ve labored to sculpt detailed, three-dimensional representations of each student’s mathematical understanding, strengths and weaknesses, dominant intelligences and methods of processing, capturing clever and quirky individual nuances. The end of the term comes and that
complex understanding is reduced to a mark on a continuum, a number or letter on a scale, a few words of explanation. After three or four grading periods, that record accompanies each student into his or her new grade level with a new teacher who must repeat the process. That seems to waste a wealth of valuable insights and to do our students, our colleagues and ourselves a great disservice.

In actual practice, I hope to be able to send students on with more than a superficial progress report. I want to equip them with a depth of self-knowledge about their abilities and challenges that allows them to be their own best educational advocates—a tall order for a 7- or 8-year-old. I also want students to carry forward a portfolio that illustrates their growth and their areas of prowess. The portfolio needs to be theirs in every sense of the word—not teacher-selected samples placed in a folder that the student doesn’t even know exists, but a frequently-visited hall of fame with commentary by the author.

Even if I can successfully implement both of those steps, which seem within the scope of an individual classroom teacher’s realm of authority, it still seems that systemic changes are necessary to avoid squandering a tremendous amount of insight as we transition students from grade to grade.
REFERENCES


Stiggins, R.J., Ruben, E., and Quellmalz, E.S. (1988). Measuring thinking skills in the

Dear Parents,

What a delight it has been to join Mrs. G in teaching your child this fall! I am learning so much each day from both the students and Mrs. G.

Throughout the time I am student-teaching, I will be involved in a teaching-learning project to fulfill requirements for my classes at the University.

The benefits to your child will be instruction that is tailored specifically to his or her learning needs as I focus on applying recommendations from two national mathematics education associations to the way that I evaluate my mathematics teaching.

Part of my project involves a presentation to fellow university students. In that presentation, I will not include any student’s name or any other identifying information. Neither will I identify the actual classroom, school and even school district.

However, in order to make that presentation to my professors and fellow students, I must have your consent to include your child’s responses to specific teaching strategies. Your decision to provide or not provide consent will not influence your child’s instruction in any way. Please complete, sign and return the form below.

Thank you so much for your prompt attention!

Mrs.D.

Should you have questions, feel free to call me (XXX.XXX.XXXX, cell) or Mrs. (XXX.XXX.XXXX- school).

☐ Yes, my child’s responses to specific teaching strategies in mathematics may be used for Mrs.D.’s teaching-learning project. I understand that the data is being used to assist Mrs. Mrs.D. in becoming a better teacher of mathematics and to improve my child’s mathematics understanding. I also understand that fictitious names will be used in the final report and that I may request a final copy of the report.

☐ No, I do not consent to the inclusion of my child’s responses in this analysis.

Parent/Guardian Signature

Name of student
APPENDIX B

Problem-Solving Data Set

An example of one of four data sets referred to in the body of the paper
Problem-Solving Data Set

Friendly Number Problem-Solving

This information was collected on Nov. 18. It records my observations of student problem-solving strategies. The class was seated on the floor in a circle with individual white boards and markers. I read and showed three picture problems (featuring 10-petalled flowers and 5-lobed leaves) one by one; students solved problems and then I called on three or four to share their solutions and methods with the entire class. I then reinforced and/or clarified the strategy they used.

In analyzing this data set, I looked for students who fell at least twice at the lower or higher end of a continuum that showed problem-solving sophistication. Keeping in mind my research question (how can I use assessment to guide instruction), I used this data to plan heterogeneous groups for the next lesson, in which I encouraged students to seek help from peers with their problem-solving.

As I reviewed this data in light of my research question, I was able to identify the following ways that I used on-the-spot and past assessment data during this lesson:

- Based on past observations and evaluation, I had prepared Unifix® Cubes to have available for students who would benefit from manipulative use. Three of those students were sitting together (fortuitously), so I introduced and explained to all three how cubes could be used to stand for the petals in the flower/petal problem.
- By evaluating the strategies employed during the lesson, I chose to call on students who used different levels of problem-solving strategies. My goal was to validate all kinds of successful strategies, to encourage student mathematical confidence by having their method affirmed and to strengthen students’ math communication skills, which I believe also strengthens their conceptual understanding.
- Of the 17 students present that day, I had time to call on 10 of them to share. By recording that data, I then was able the next day to have the remaining students speak.

Assessment notes

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<th>equation</th>
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<td></td>
<td>AG</td>
<td></td>
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<tr>
<td></td>
<td>RW</td>
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called on to share: NW, MC, AS

flowers/petals problem
Nothing Counted by 1s Counted by 10s Equation

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<thead>
<tr>
<th>AL</th>
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<th>EW</th>
<th>CC</th>
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</thead>
<tbody>
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<td></td>
<td></td>
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<tr>
<td>DF</td>
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</table>

called on to share: AB, TT, EW, AM

When I realized that AL had just dropped out, I made it a point to work with AL on the next problem so the student could at least process it verbally so that writing it wouldn’t trigger student’s “shutting down” behavior.

leaves/lobes problem

called on to share: JF, RW, AG

RW equation read 3+3+3=15. I purposefully called on RW so that we could together figure out how to change what was written into what was intended. I felt like RS’s self-esteem and eagerness to learn warranted the exposure and would in some ways validate taking a risk and then learning.

On 11/19 had students solve on paper—should have created some kind of recording sheet for each problem that could easily be distinguished from the papers where they worked out their plan for their picture problems. Not only would that have helped with the huge mess of papers that I had to sort through, but also using a different recording sheet for each problem would have made analyzing and evaluating student work much easier.

Student-Created Friendly Number Festival Problems

Nov. 19 - Students created Picture Problems with 5-lobed leaves, 10-petalled flowers. I asked students to come up with a plan on scratch paper, then to work one-on-one with me to assemble the problem while I wrote out their question balloon. (Some students created problems that did not include 10-petalled flowers and 5-lobed leaves. They had to create a new one “on the spot,” as noted in table.)

<table>
<thead>
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<tr>
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<td>3</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>on the spot (99X99=?), eager to create, interested in others’ work, quite complex</td>
</tr>
<tr>
<td>AG</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>AL</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“I started but I got stuck” Able to verbalize idea, created quickly</td>
</tr>
<tr>
<td>AS</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>on the spot (bugs)</td>
</tr>
<tr>
<td>Student</td>
<td>Complexity</td>
<td>Guidance</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>AB</td>
<td>2</td>
<td>Tentative</td>
</tr>
<tr>
<td>CC</td>
<td>3</td>
<td>Modified from plan</td>
</tr>
<tr>
<td>DF</td>
<td>1</td>
<td>Modified from plan</td>
</tr>
<tr>
<td>DM</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>DN</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>EW</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>JF</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>JJ</td>
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</tr>
<tr>
<td>LW</td>
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<td>2</td>
</tr>
<tr>
<td>MC</td>
<td>1</td>
<td>3</td>
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<tr>
<td>MK</td>
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<td>3</td>
</tr>
<tr>
<td>NW</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>RW</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TJ</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>TT</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

3 – high complexity
2 – average complexity
1 – relatively simple
x – just like my example

3 – little or no guidance
2 – moderate guidance
1 – maximum guidance
Friendly Number/Maple Leaf Problems

On Dec. 4, I gave students an on-demand problem-solving prompt similar to a state assessment problem, except it also included pictures, which made it more like the kinds of picture problems the students had created the week before. (“Three flowers with 10 petals each were growing on a hill. A rabbit ate one of the flowers. How many petals were left? Show how you know.” The accompanying visual was of three flowers just like they had used for their own problems.)

Students worked at tables with “offices dividers” separating them. Four students were absent. The remaining 15 solved that problem. I had grouped together students who I expected to solve the problem quickly and as they finished gave them the challenge of creating a problem for me that was as hard as they wanted it to be. Seven students created or began a problem. Engagement was quite good, behavior problems very limited—students essentially worked quietly on their own for 35–40 minutes.

Three of those 7 early finishers plus four others also solved a second prompt that I had available about the number of lobes on 3 leaves.

Scoring for Friendly Number Problem, using Oregon scoring guide

<table>
<thead>
<tr>
<th>student</th>
<th>Conceptual Understanding</th>
<th>Processes &amp; Strategies</th>
<th>Verification</th>
<th>Communication</th>
<th>Accuracy</th>
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<tbody>
<tr>
<td>AM</td>
<td>Absent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>AL</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>AS</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>AB</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>CC</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>DF</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>DM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>DN</td>
<td>Absent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EW</td>
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<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>JF</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>JJ</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
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<tr>
<td>LW</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>MC</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5</td>
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<tr>
<td>MK</td>
<td>Absent</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NW</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>RW</td>
<td>Absent</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>TT</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>st.</td>
<td>ans</td>
<td>Process/Strategies</td>
<td>rating</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>------------------------------------------------------------------------------------</td>
<td>--------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>20</td>
<td>Redrew flowers &amp; crossed one out; 3-1=2</td>
<td>1</td>
<td>Flowers don’t show 10 petals each</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>21</td>
<td>Drew flowers (on hill), crossed one out; 10+10=21</td>
<td>1</td>
<td>Suspect student miscounted to 21, then wrote equation in response to “show how you know” directions</td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>20</td>
<td>Line between two flowers with 20 written on it; 10+10+10-10=20; 10+10=20; 1+1+1...+1=20</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>20</td>
<td>Crossed out one of printed flowers; direct model drawn of 2 flowers with petals, one without; 30-10=20</td>
<td>3</td>
<td>Assume student meant 30-10=20</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>20</td>
<td>1+2=3; 1+1+1=0; 3+0=3; 3+10=20; 0+3=20; 10+10=20</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>20</td>
<td>Drew flowers, crossed out one; 19+1=20, 20-0=20, 10-1+20</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>20</td>
<td>Crossed out one flower, numbered remaining petals 1-20; redrew flowers &amp; numbered petals</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EW</td>
<td>20</td>
<td>Redrew flowers, crossed out one, labeled one 10, other 20; tally marks to 20; each set labeled 5, 10, 15, 20</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JF</td>
<td>20</td>
<td>Crossed out one printed flower. “I caotid”</td>
<td>1</td>
<td>Sat a long time with nothing but answer; finally wrote “I counted” after speaking that phrase to me.</td>
<td></td>
</tr>
<tr>
<td>JJ</td>
<td>20</td>
<td>Drew flowers w/o 1:1 correspondence &amp; crossed out one. 13 hash marks with 3 x’d out</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LW</td>
<td>29</td>
<td>Three hash marks w/one x’d out; 3 flowers w/1 x’d out (no 1:1 petal corres.); drew hand w/3 fingers x’d out; 3-1=2, 30-11=28</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>20</td>
<td>Printed flowers show pencil mark on each petal (as if student counted); 3 flowers drawn w/1:1 petal corres., one x’d out; 3 hash marks</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NW</td>
<td>20</td>
<td>3-1=2; 30-10=20; three-one=two flowers</td>
<td>2-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td>20</td>
<td>Marked out one printed flower; 20+0=20; 30-30=20; 20-0=20; 40-40=20; 10+10=20</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT</td>
<td>20</td>
<td>I caytd the padls. I caytd by tas. It wus var ese.</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3—evidence of multiple strategies
2—evidence of one strategy besides counting by 1s
1—counting by ones seems to be only strategy tried

<table>
<thead>
<tr>
<th></th>
<th>leaves</th>
<th>lobes</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>1</td>
<td>5</td>
<td>Drew one leaf</td>
</tr>
<tr>
<td>AS</td>
<td>4, 2</td>
<td>4</td>
<td>Drew four leaves w/1:1 lobe corres., 2+1=3</td>
</tr>
<tr>
<td>CC</td>
<td>3</td>
<td>5</td>
<td>1+1+1=3; /+/+=///; 5+5+5=15; //++++++/+///+//////=/////////////</td>
</tr>
<tr>
<td>EW</td>
<td>15</td>
<td></td>
<td>Drew 3 leaves w/1:1 lobe corres., labeled 5, 10, 15</td>
</tr>
<tr>
<td>JJ</td>
<td>3</td>
<td>14</td>
<td>Drew 3 leaves, no corres.; four hash marks w/1 x’d out</td>
</tr>
<tr>
<td>MC</td>
<td>3</td>
<td>24</td>
<td>Drew ✦ ✦ ✦</td>
</tr>
<tr>
<td>NW</td>
<td>3</td>
<td>15</td>
<td>Drew leaves w/each lobe numbered (also drew kids!)</td>
</tr>
</tbody>
</table>

Student-created problems (12/4):

CC
for frindlea number fowwers and tow levs
how many petls an love
how meny stims

Four friendly number flowers and two leaves. How many petals and lobes? How many stems?

DM
thar ww 2 ladbzs
if you tuc awa 1 h man laz with
(did not have time to finish)

There were two lady bugs. If you took away one, how many legs will . . .

EW
Ter wr fif maplefs and three flawrs
ha mine lods and petals

There were five maple leaves and three flowers. How many lobes and petals?

NW
There were 5 ladea bugs and 2 fridlea nummbrs flowers. How miney petals and lags are left?

Three were five lady bugs and two friendly number flowers. How many petals and legs are there?

TJ
Thir wr to fawars
a bow pit a fawar
ha mane r laft

There were two flowers. A boy picked a flower. How many are left?

TT
Thear wr 5 flawrs
Haw mane padls wr thear

There were five flowers. How many petals were there?

Thar wr 7 lefs.
hw mane lobes wr thar

There were seven leaves. How many lobes were there?

Use in practice
During the next two weeks when I had time to work with students individually, I sat down with the student, his/her problem and a sticky note showing my solving strategies. I explained what I did, why I did it and the answer I came up with then asked if I was correct. (Amazingly enough I was, although on TJ’s problem I answered “one flower and 10 petals” to hedge my bets. 😊)
My purpose in doing this was to model problem-solving strategies and the complete communication path for students in a context that they were really invested in.

Data analysis
Students meeting benchmark Basic Problem: 11 out of 15
Students meeting benchmark Challenge Problem: 4 of 7 (one w/4 in accuracy)
Strategies Used:
  Multiple: 3–4
  One besides counting: 4–5
  Counting only: 7
Posed problems w/facts up to 10: 1
Posed problems w/facts >10: 4

Deconstruction
Method of gathering data about problem-solving favors kids who are good with paper-pencil tasks, penalizes those who are better at verbally communicating their thinking.

Problems posed by students are the most complex, challenging of any that I’ve gathered data on—perhaps due to challenge to create for me to solve, perhaps because opportunity extended only to kids of highest ability.
Snowman Picture Problems

Week of January 12

On the first day back after a three-week break, I did a lesson introducing snowman picture problems. During the winter break, I created problems using the printed prompts provided by my CT. The problems were quite simple—students’ conceptual understanding has grown considerably since October when CT last worked with students on problem-solving. When I presented the problems, I did not have out white boards, intending to present a problem and then pass out materials to have students solve.

I showed the first example: 5 snowmen, 3 melted; how many left? Instant choral response of 2 from vast majority of students.

Second problem: 4 snowmen, 2 eyes each, how many eyes all together—again instant choral response of 8 (although fewer voices). Asked how students knew—several responded they counted by 2s.

AG “I counted by 1s like this (pointed to snowmen) 1–2 3–4 5–6 7–8.”

Use in practice

After realizing how quickly students were able to solve those problems, I created two more for later in the week that were a little more complex and didn’t show all elements visually. My goal was to stimulate students to construct the picture—physically or mentally, even if their only solving strategy was counting.

Student-created problems

My CT and I provided students with a pre-printed sheet of six snowmen and construction paper to create picture problems. I met with students individually to write out their questions. In a few cases, I also needed to guide (and occasionally direct) a student’s thinking.

I did not present specific, clear criteria for this task, e.g., max. or min. number of snowmen. CT directed the use of the printed snowmen in this task; seemed like a good idea before implementing so that student focus would be on coming up with a mathematical question. In retrospect, I wonder if use of pre-printed snowmen may have limited mathematical thinking and engagement???
### Mathematics Assessment

<table>
<thead>
<tr>
<th>st</th>
<th>question</th>
<th>up to 10</th>
<th>&gt;10</th>
<th>guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>There were 2 snowmen. The sun came out and melted one. How many are left?</td>
<td>X</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>There were 6 snowmen. Each has 5 buttons. How many buttons all together?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN</td>
<td>There were 6 snowmen. Each had 3 balls. One ball on each snowman melted. How many balls were left?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>There were 6 snowmen and 2 ran away. How many are left?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>EW</td>
<td>There were 6 snowmen. The sun melted one arm off one of them. How many arms were left?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>There were 5 snowmen. They each have 5 buttons. How many buttons all together?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>There were 4 snowmen in the snow. How many snowballs all together?</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>There were 2 snowmen playing when a snowstorm came and covered them up. How many snowmen were left?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>LW</td>
<td>There are 3 snowmen and one went home. How many are left?</td>
<td>X</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>JF</td>
<td>There are 6 snowmen. Each has 5 buttons. How many buttons all together?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>TT</td>
<td>There were 6 snowmen. (He covered four of them.) How many buttons all together?</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>MK</td>
<td>There were 7 snowmen. Three melted. How many snowmen are left? (Started with question of how many were good, bad—interesting discussion about difference between moral, mathematical questions.)</td>
<td>X</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>NW</td>
<td>There were 2 snowmen who went to town. One snowman melted. How many hats were left?</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td>There were 4 snowmen. Each had 5 buttons. How many buttons all together? (Wanted to write 5+5+5+5=? rather than a word question.)</td>
<td>X</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>There were 2 snowmen. Two more came along. How many all together?</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>There were 5 snowmen. Two melted. How many are there left?</td>
<td>X</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>There were 6 snowmen. Three went away. How many buttons were left? How many eyes were left? How many carrots were left?</td>
<td>X</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

### Data Analysis
Problems posed with facts less than or equal to 10: 8 of 17
Problems posed with facts >10: 9 of 17
Two students (highlighted) posed questions unlike any of the problems modeled. (concerning arms and hats)
Students who needed no help posing question: 8
Needed some help: 4
Needed help posing or clarifying question: 5

Possible use in practice
Consider letting students pose and write their own questions in future picture problem creation tasks.

Penguin Picture Problem-Solving
Feb. 17-20

Background
I presented the problems in the order suggested by the curriculum. Originally, I’d sorted according to what I perceived as complexity, then noticed that the problems were numbered and decided to follow that order. I passed out the kids’ white boards, erasable markers and erasers then presented the problems by reading, asking students what the problem asked us to figure out and then having them show their thinking on their white boards. I circulated and made notes on student strategies, then called on 2–3 students per problem to share their strategy—looking for different degrees of abstraction and different methods. I tried to select different students to share for each problem, drawing on a range of abilities and striving for gender equity.

The students did problems 1–3 the morning of Feb. 17 and problems 4–6 the afternoon of Feb. 18. Student engagement was quite high; students listened well to classmates’ sharing and most were eager to be selected to share, regardless of their ability!

Before we began the problem-solving portion of the lesson, I introduced/reviewed the concepts of half as many and twice. I asked students for definitions, used examples (but not non-examples, which I wish I would have) and represented visually with circles, as follows.

\[
\begin{array}{c|c}
0 & \text{half} \\
0 & \text{twice as many}
\end{array}
\]

Reflection/evaluation

2/17

Observations:
AB  \[ 6 + 6 = 12, \ 12 + 6 = 6 \]
12 litl, 4 big
(student has a history of writing/speaking equations without using symbols correctly, e.g., “9+9+18” for 9+9=18 so I suspect he meant 12-6=6)
NW 12 – 6 = 6
LLLL 1 (tally marks)

AG o> o>

DF Mom & Baby?

DN 12/6 = 6

LW 8 8 8 (continued drawing, replicating picture)

JF verbalized answer quickly; when asked to show thinking, wrote “6 ar in 6 ar out” after lengthy pause.

Strategies as explained by students:
NW I wrote 12-6=6, which is subtraction because I knew that 6 and 6 is 12. I also used tally marks like this LLLL L – LLLL L = LLLL L.

AB There were 12 up there so I counted to 6.

Observations:

MC (: :) (: :) (: :) (: :) (: :) (: )

EW O O O O O O O O O
2 4 6 8 10 12 14 16 18

TJ 2+2+2+2+2+2+2+2=18

CC 1111 1111 1111

Strategies as explained by students:
EW I counted by 2s for each nest.
MC I drew two lines in each nest for the babies and then I counted 1 2 3 all the way to 18.
TJ I did 2+2+2+2+2+2+2+2=18. (How did you know it equaled 18?) Because I counted by 2s.

Observations:
MC  \  \  \  \  \  \  \  \\

JF  counted sub-vocally, looking at pix  1–2  3–4  5–6  7–8  9–10  11–12  13–14

AS  1111
    7 + 7 = 14

DN  7 x 2 = 14

DF  2  2  2  2  2  2  2
    1  2  3  4  5  6  7

CC  //  //  //  //  //  //  //  //
    2  4  6  8 10 12 14

RW  counted by 1s, 2 for each finger

DM  \  \  \  \\

Strategies as explained by students:
DM  I drew tally marks for each penguin and then I put feet on each one and then I counted them.
RW  I drew seven fingers for each penguin and then I counted while I drew the lines. I got mixed up and had to start over.
DN  I counted by 2s and then I wrote 7 x 2 which I knew was 14 because 7 twos is 14.
Observations:
EB seemed to have no understanding of what to do until I said I wanted AM (seated next to EB) to share, then began copying AM’s board

AM 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇

MK  /////##

Strategies as explained by students

AM I drew 12 circles for penguins then I showed how many were in the picture with a line. Then I counted how many were left.

MK I made a line for every penguin then I took away 5. (How did you know to take away 5?) Because I know that 7 and 5 makes 12.

Notes
I re-read this problem several times and stated it differently (You have 9 penguins. A certain number of them are babies and twice as many as that are grown-ups. How many grown-ups—or adults? How many babies?)

Observations

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>B</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>AB</td>
<td>2 bebies, 7 adults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>9+2=11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td>3 babies, 7 grown-ups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>9+9=18 9 babies, 18 adults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EW</td>
<td>3 6 OOOOO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT</td>
<td>1+8=9 10-1=9 11-2=9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>9 babies, 10 adults</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DN  6+3=9

JF  OoO  OoO  OoO (First had OOOOOOOOO)

Strategies shared by students
JF  I drew one baby between two grown-ups and counted until I got 9.
DM  I drew three penguins and made one a baby, then I did it two more times. Then I counted how many were babies.
DN  I wrote 6+3=9. (How did you know to write 6+3?) I looked at the number line: it goes 3+3+3=9—pointing to 3, 6 and 9 on number line.

As CC listened to peers present, realization of misinterpretation of problem dawned. Student readily announced mistake and reason for it. See problem student created below.

Observations
MK  6+6=12
    2 4 6 8 10 12
EW  O O O O O O
AL  ooo ooo ooo ooo
DM  ////  ////  ////
CC  Oo Oo Oo Oo Oo Oo
DN  6 x 2 = 12
AB  1+1+1+1+1+1=6
RW  ####  ####  //
TT  ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦
TJ  1+6=7  6+1=7

Strategies as explained by students
CC  I drew a big one for the one in the water and a little one for the one on the ice and I did it six times because you see there are six of them in the water.
AL  (Said he was too scared to talk—I described what he had drawn and asked if he drew six
for in the water and six more for out of the water.)
EW  I drew the ones in the water and then I counted by 2s.

Data Analysis
Strategies noted ranged from counting by 1s to multiplication. Most students used direct
modeling or combination of direct modeling and choosing an operation.

<table>
<thead>
<tr>
<th>Kinds of strategies used</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct modeling</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Count by 1s</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count by 2s</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Equations</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Words only</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

As I taught this material over two days I felt like it was some of the most thorough record-
keeping on student work/thinking that I had done. The analysis below bears that out.

<table>
<thead>
<tr>
<th>student</th>
<th># of observations recorded</th>
<th>called on to share</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>1</td>
<td>2/18</td>
</tr>
<tr>
<td>AL</td>
<td>1</td>
<td>2/18</td>
</tr>
<tr>
<td>AG</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>3</td>
<td>2/17</td>
</tr>
<tr>
<td>CC</td>
<td>5</td>
<td>2/18</td>
</tr>
<tr>
<td>DF</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>3</td>
<td>2/17, 2/18</td>
</tr>
<tr>
<td>DN</td>
<td>4</td>
<td>2/17, 2/18</td>
</tr>
<tr>
<td>EB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>EW</td>
<td>3</td>
<td>2/17, 2/18</td>
</tr>
<tr>
<td>JF</td>
<td>3</td>
<td>2/18</td>
</tr>
<tr>
<td>LW</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>2</td>
<td>2/17</td>
</tr>
<tr>
<td>MK</td>
<td>2</td>
<td>2/18</td>
</tr>
<tr>
<td>NW</td>
<td>1</td>
<td>2/17</td>
</tr>
<tr>
<td>RW</td>
<td>2</td>
<td>2/17</td>
</tr>
<tr>
<td>TJ</td>
<td>3</td>
<td>2/17</td>
</tr>
</tbody>
</table>
Deconstruction

In reviewing data, I realized that I tended mainly to record strategies that actually seemed to help students arrive at answers, so I missed noting some of the erroneous thinking and ineffective strategies that the students used. For the assessment to have been of most value, I would have noted who needed additional guidance and then planned times to provide it either in pairs, individually or in small groups.

Student-created problems

On Feb. 18, students created their penguin picture problem backgrounds. On Feb. 19, I gave them criteria for posing their problems:

- not too hard and not too easy
- at least 6 penguins
- no more than 18 penguins

I also asked them to try to write out their own problem, but told them I would help as needed. All but four students wrote out their own problems. (A few needed a little help refining wording so that they were asking what they meant to be asking.)

<table>
<thead>
<tr>
<th>student</th>
<th>question</th>
<th>comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>Detailed drawing, ready for me to write question but ran out of time</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>Drawing shows 7 on ice, 5 in water and two more in water under flap—needs question.</td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>There are 7 on top twice as many in water. Needs revision—drew 12 in water.</td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>Four penguins, one more in the water. How many all together? Needs re-worded to make clear that one more in water than on ice.</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>How many penguins are under the flap? Twice as many. Done—drew three above flap, six below.</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>18 penguins, twice as many adults. How many adults, how many babies? Done—building on prior misunderstanding!!</td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>There is 3. How many is under the flap? Ten to how many? Needs question revised. I tried to help her clarify her question during work time.</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>There were 6 penguins? How many beaks and feet all together? Done</td>
<td></td>
</tr>
<tr>
<td>DN</td>
<td>There are 10 penguins. 3 got washed away. How many are left? Made flap over group of 3, another over group of 7.</td>
<td></td>
</tr>
<tr>
<td>EB</td>
<td>Drew 3 on ice, 3 in water. Needs to finish</td>
<td></td>
</tr>
<tr>
<td>EW</td>
<td>There’s 17 penguins. Each penguin has two feet. Twice Sought me out to ask wording</td>
<td></td>
</tr>
</tbody>
</table>
as many. How many feet are there?  for twice as many.

<table>
<thead>
<tr>
<th>Student</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>JF</td>
<td>There is 18 penguins. How many flippers is there?</td>
<td>Done—very neat work, stayed totally on task!</td>
</tr>
<tr>
<td>LW</td>
<td>19+3=?? How many penguins?</td>
<td>Needs revision—criteria, wording a question</td>
</tr>
<tr>
<td>MC</td>
<td>There is 12 penguins. How many flippers?</td>
<td>Done—one of first to finish</td>
</tr>
<tr>
<td>MK</td>
<td>There were 6 penguins. How many flippers?</td>
<td>Done—showed two penguins, with four under flap.</td>
</tr>
<tr>
<td>NW</td>
<td>There were 2 penguins, half as many as in the water.</td>
<td>Four in water.</td>
</tr>
<tr>
<td>RW</td>
<td></td>
<td>Needs to finish—drew 2 on ice, 3 in water; review criteria</td>
</tr>
<tr>
<td>TJ</td>
<td>There are 6 penguins and the same number of adults. How many all together?</td>
<td>Needs revision—drew 3 on ice and 3 in water.</td>
</tr>
<tr>
<td>TT</td>
<td>There are 4 baby penguins swimming in the water?</td>
<td>Needs question revised.</td>
</tr>
</tbody>
</table>

Need to finish
Need simple wording revisions
Need 1-on-1 guidance to form question and/or correct mathematical misunderstandings.

Plan for use in practice

I set out problems and supplies for EB, AM, RW, AL, AS, TT to finish at beginning of day on Feb. 20. I also planned groups for problem-solving. I asked four students to work with me to do a fishbowl model of problem-solving on Feb. 20. I anticipated the help of a parent volunteer with whom I had worked previously. I intended to have all members of each group solve one problem, share strategies, solve the next, share those strategies, etc., working through 2–4 problems.

Actual use in practice

Two of those needing to finish/revise were absent, as well as one who had completed the picture problem. Some of the students who needed to finish did so during pre-session time. So, later on Feb. 20 I regrouped students as follows. Bold type indicates the student to whom I gave the role of leader.

**CC, AL, AB, EW**

**RW, DM, DN**

**MK, MC, NW, AS**

The remaining students were to work with me until their problem was done or revised. Then I planned to send them to work with groups, or if they finished at about the same time, to form their own group.

Of the five who worked with me (LW, TJ, AG, DF & EB) only TJ finished revising.

- EB posed her question verbally, but did not stay on-task well enough to finish in allotted time.
- LW did redraw problem to have only 18 penguins, as criteria stated. I was not able to work with student enough to help pose question.
- DF wanted to communicate that the penguins swimming in the water were in a 3 x 5 array, but again we ran out of time for personal attention to successfully guide student to creating a viable question.
• AG did not seem able to grasp that twice as many as 7 was 14, not 12. AG, LW, DF all needed concentrated, undivided assistance to finish and I was not able to provide it because I needed to monitor and redirect two of the three groups that were solving problems.

My fishbowl modeling and instructions were not clear and concrete enough for the students. Consequently, I had to do a lot of redirecting, reminding and some group behavior/conflict management. Students have had little or no experience or training in this kind of group-directed conversation; given that reality, having one in three groups function effectively is really pretty nice. Also, the parent helper I though was coming sent word that morning with her six-year-old that she would come the following week instead.
Reflections about problem-solving strategies data

In November’s friendly number picture problem-solving session, I pretty quickly moved from what the students did/said to my evaluation and interpretation of it. By late February, I found myself more interested in studying what students had said and done and less eager to overlay my judgment/interpretation over their expressions. While some of that MAY be because it’s easier just to record what students did or said, I think part of the change is due to my increasing respect for each student’s thinking and way of explaining his or her understanding. Actually, it’s not exactly easy to record detailed observations and capture fleeting student comments—at least not when compared to just looking at scores on tests or worksheets. Gathering the kind of assessment data that I did, I have a fuller, rounder description of each student and know better how to help most (if not all) grow even more.

However, still at the end of the term, all that nuanced, layered understanding gets reduced to a number or a symbol on a report card with maybe a few comments.

Student Created Problems – a synthesizing look at complexity

<table>
<thead>
<tr>
<th>Student</th>
<th>Nov. 19</th>
<th>Dec. 4</th>
<th>Jan. 12</th>
<th>Feb. 18</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>3</td>
<td></td>
<td>2</td>
<td>Unfinished</td>
<td>2.5</td>
</tr>
<tr>
<td>AG</td>
<td>2</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1.66</td>
</tr>
<tr>
<td>AL</td>
<td>1</td>
<td></td>
<td>2</td>
<td>2</td>
<td>1.66</td>
</tr>
<tr>
<td>AS</td>
<td>2</td>
<td></td>
<td>2</td>
<td>3</td>
<td>2.33</td>
</tr>
<tr>
<td>AB</td>
<td>2x</td>
<td></td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>CC</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>DF</td>
<td>2</td>
<td></td>
<td>1</td>
<td>Unfinished/ unclear</td>
<td>1.5</td>
</tr>
<tr>
<td>DM</td>
<td>Absent</td>
<td>unfinished</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>DN</td>
<td>3</td>
<td></td>
<td>3</td>
<td>1</td>
<td>2.33</td>
</tr>
<tr>
<td>EB</td>
<td>Not enrolled</td>
<td>Not enrolled</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>EW</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2.75</td>
</tr>
<tr>
<td>JF</td>
<td>2</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>JJ</td>
<td>2</td>
<td>w/drawn</td>
<td>w/drawn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LW</td>
<td>1</td>
<td></td>
<td>1</td>
<td>Unfinished</td>
<td>1</td>
</tr>
<tr>
<td>MC</td>
<td>1</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1.33</td>
</tr>
<tr>
<td>MK</td>
<td>3</td>
<td></td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>NW</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>RW</td>
<td>1</td>
<td></td>
<td>absent</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TJ</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>TT</td>
<td>2x</td>
<td>3</td>
<td>2</td>
<td>Unfinished/ unclear</td>
<td>2.33</td>
</tr>
</tbody>
</table>

1 – single operation, uses facts up to 10
2 – single operation, uses facts of more than 10

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Thoughts on interpretation
Not really enough examples for averages to be statistically significant, but they give one view of data. A ranking of the averages fairly closely matches performance measured by other indicators. Exceptions likely to be MK (lower than expected) and DM (higher than expected for math aptitude overall, but consistent with expectations for problem-solving, an area which DM excels in and enjoys).

Some evidence of growth in complexity: AL, AS, MC
Some evidence of maintaining med/high complexity: AG, DN, DM, EW, JF, TT
High degree of inconsistency: AB, CC, MK, NW, TJ
Consistently low complexity: DF, LW, RW
Inconclusive: AM

Instruction about complexity varied. Nov. 19 – no direction; Dec. 4 – as hard as you want to make it; Jan. 12 – no direction; Feb. 18 – not too hard, not too easy. I suspect that some students might have posed more complex problems if they’d received the message that I expected a certain degree of complexity. CC is a definite example: When complexity was mentioned, CC’s problems met that criteria; when it was not included in expectations, CC’s problems were quite simple. One thing that the data doesn’t show, but my interactions with students made clear to me, is that at least a few of the kids had in mind somewhat more complex concepts but had difficulty in expressing those—for example TJ, NW. EW on Feb. 18.
APPENDIX C

Example of Researcher’s Notebook Pages
Mathematics Assessment

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APPENDIX D

Example of Student-Created Story Problem

and My Solution

for frindle number
flowers and tow leus
pet lisa an love
how many
how many
Stim's
Above is the sticky note on which I showed my problem solving solution that I discussed with student who created the problem above.
APPENDIX E

Analysis of student worksheets

Counting by 2s and penguin pair

2/11
Counting by 2s Grid to Penguin Pairs Chart

The worksheet included two charts. The first was a 100s chart with only the even numbers. In the first rows the even numbers were present as dotted lines that the students were to trace over. Further down the chart fewer and fewer numbers were provided and students were to continue writing in only the even numbers. The second chart consisted of two columns; the first listed numbers 1–20. Students were to complete the second column by entering the number of penguins in 1 pair, 2 pair, 3 pair, etc. On the day before this worksheet was assigned, students had created a chart with a growing pattern of penguin pairs. The chart ended after row 8.

Observations from work time:
Seemed to have difficulty understanding that chart showed results of skip counting: EB, RW, LW; DM—did at beginning but seemingly struggled with concept until arrived at meaning.

Counting by 2s and Penguin Pairs worksheet

<table>
<thead>
<tr>
<th>Student</th>
<th>Status</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>Finished</td>
<td>Seemed to have good CU, skipped 16 on PP chart (# of penguins), asked st to review—pointing at specific error; self-corrected and changed that &amp; following incorrect answers.</td>
</tr>
<tr>
<td>AL</td>
<td>Did not finish</td>
<td>Small-motor fatigue evident; after 40, I alternated rows to write numbers; st. provided information; still only got to 70; did not get to pairs/penguin chart</td>
</tr>
<tr>
<td>AG</td>
<td>Did not finish</td>
<td>Ended at 84, did not do PP chart</td>
</tr>
<tr>
<td>AS</td>
<td>Finished</td>
<td>One of first finished, CU apparently strong as we reviewed together</td>
</tr>
<tr>
<td>AB</td>
<td>Did not finish</td>
<td>Ended at 88, did not do PP chart</td>
</tr>
<tr>
<td>CC</td>
<td>Finished</td>
<td>CU strong</td>
</tr>
<tr>
<td>DF</td>
<td>Finished</td>
<td>Evident difficulty with understanding at beginning, understanding seemed to emerge as work progressed; need 1:1 to check for understanding</td>
</tr>
<tr>
<td>DM</td>
<td>Finished</td>
<td>Solidified meaning as worked; complained of getting stuck at 16 on PP chart (student-created penguin chart went as far as 8 pairs), but worked through it to complete chart</td>
</tr>
<tr>
<td>DN</td>
<td>Finished</td>
<td>CU, evidence of self-correction</td>
</tr>
<tr>
<td>EB</td>
<td>Did not finish</td>
<td>Ended at 38, but traced only, did not fill in missing even numbers; did not do PP chart</td>
</tr>
<tr>
<td>EW</td>
<td>Finished</td>
<td>CU strong, finished quickly and completely accurate</td>
</tr>
<tr>
<td>JF</td>
<td>Did not finish</td>
<td>All of skip counting, did not do PP chart</td>
</tr>
<tr>
<td></td>
<td>Did not finish</td>
<td>Traced all numbers, did not fill in all missing evens; did write in some odds; did not do PP chart</td>
</tr>
<tr>
<td>---</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LW</td>
<td>Did not finish</td>
<td>Ended at 80, did not do PP</td>
</tr>
<tr>
<td>MC</td>
<td>Did not finish</td>
<td>CU, accurate</td>
</tr>
<tr>
<td>NW</td>
<td>Did not finish</td>
<td>All of skip counting, did not do PP chart</td>
</tr>
<tr>
<td>RW</td>
<td>Did not finish</td>
<td>Stopped at 76, did not do PP chart</td>
</tr>
<tr>
<td>TJ</td>
<td>Finished</td>
<td>Seemed to have CU, lots of reversals on PP chart</td>
</tr>
<tr>
<td>TT</td>
<td>Did not finish</td>
<td>All of skip counting, did not do PP chart</td>
</tr>
</tbody>
</table>