Linking Literacy and Mathematics:

The Support for Common Core Standards for Mathematical Practice

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Abstract

In a new era of Common Core State Standards (CCSS), teachers are expected to provide more rigorous, coherent, and focused curriculum at every grade level. To respond to the call for higher expectations across the curriculum and certainly within reading, writing, and mathematics, educators should work closely together to create mathematically proficient students who actively look for relevance and purpose, think critically, and question when uncertain. Mathematics literacy experiences during the elementary school years provide a powerful opportunity to interject context students must know and deeply understand. As described by the Standards for Mathematical Practice, Common Core State Standards suggest teachers not only focus on content but also on process. Historically less attention has been given to the process than the content itself.. Given the importance of these standards and the focus on process, this article proposes children's books and other literacy materials to be used by practitioners to enhance the purpose of each of the eight Standards for Mathematical Practice. These standards include: 1. Make sense of problems and persevere in solving them; 2. Reason abstractly and quantitatively; 3. Construct viable arguments and critique the reasoning of others; 4. Model with mathematics; 5. Use appropriate tools strategically; 6. Attend to precision; 7. Look for and make use of structure; and 8. Look for and express regularity in repeated reasoning. The many literacy resources included in this article have been thoughtfully selected from an extensive literature review of resources recognized for their potential to support the Standards for Mathematical Practice. As described by the CCSS framework, practitioners must provide experiences to encompass not only Standards for Mathematical Content but also Standards for Mathematical Practice. These critical eight practices provide the foundation upon which mathematics content must be accessed and embraced by students. Knowing different ways in which literacy materials can be used to support mathematics is a good starting point and having a list of classroom ready resources becomes the catalyst by which teachers of elementary students begin to address the call for higher expectations in mathematics. The instructional implications of CCSS call for teachers to challenge students to think and reason in mathematics and to communicate to others by using literacy resources. The success of Common Core State Standards (CCSS) for Mathematics depends more on how practitioners teach than on what they teach. Elementary school educators must become aware of more and better ways to support the process by which students embrace the mathematics they are required to know. This article is a collection of resources to be used by teachers in support of the Standards for Mathematical Practice. The bibliography lists the literacy resources.

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While Mrs. Comfort spends a relaxing afternoon tending the lettuce patch in her vegetable garden and Mr. Comfort reclines on a bench nearby reading a favorite cookbook, they decide to host a family reunion and serve their famous spaghetti and meatball dinner. As Mrs. Comfort makes plans to rent tables and chairs to seat the guests, a mathematical adventure begins. Author Marilyn Burns (1997) in *Spaghetti and Meatballs for All* describes a series of mishaps, the results of rearranging the seating capacity in the dining room, which invite the reader to investigate the relationship between area and perimeter through an authentic problem solving situation. Certainly the story concludes with a happy ending and all of Mr. and Mrs. Comfort's family enjoy the meal, but how the conclusion emerges leaves the reader creatively pondering measurement situations that occur throughout the family reunion. The hopeful outcome is the reader makes connections between the story and real world measurement situations that emerge each day.

In a new era of Common Core State Standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), the need to blend literacy and mathematics becomes increasingly important as deeper, conceptual mathematics learning is expected at every grade level. Books similar to *Spaghetti and Meatballs for All* help practitioners connect mathematics and literacy while establishing context and bringing relevance to each subject. Earlier standards focused primarily on mathematics content and now Common Core State Standards imply a blending of mathematical processes with grade level content objectives. Linking literacy experiences with mathematics becomes a powerful tool by which mathematical processes nurture and support content objectives. The important emphasis on the

Standards for Mathematical Practices creates the foundation for everything else. The authors of CCSS explain,

> The Standards for Mathematical Practice describes ways in which developing student practitioners of the discipline of mathematics increasingly ought to engage with the subject matter as they grow in mathematical maturity and expertise throughout the elementary, middle and high school years. (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010, p. 8)

The Standards for Mathematical Practices, then, provide the process for accessing and strengthening content. In a new era of Common Core State Standards, students will be held accountable for both their knowledge of mathematical processes and content. Meaningful literacy experiences support the relationship between process and content. Given the importance of the Standards for Mathematical Practice, this article proposes children's books and other literacy materials which may be used by practitioners to support the purpose of each of the eight practices. These practices include:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

A starting point for blending literacy materials with mathematics in order to support Common Core State Standards for Mathematical Practice is knowing the multiple ways in which literacy materials support mathematics. Some books and materials refer explicitly about mathematics while other refer to mathematics in more subtle ways. Rosamond Welchman-Tischler in *How to Use Children's Literature to Teach Mathematics* (2000, p. 2), describes seven distinctly different uses:

1. To provide a context or model for an activity with mathematical content
2. To introduce manipulative that will be used in varied ways (not necessarily as in the story)
3. To inspire a creative mathematics experience for children
4. To pose an interesting problem
5. To prepare for a mathematics concept or skill
6. To develop or explain a mathematics concept or skill
7. To review a mathematics concept or skill.

When one or more of these literacy practices supports mathematics learning, higher order thinking skills develop and the subject becomes authentic, energized, and purposeful.

Other helpful information for meaningfully blending literacy materials with mathematics in order to support Common Core State Standards for Mathematical Practice focuses on the awareness of guidelines for making literacy selections. In *New Visions for Linking Literature and Mathematics,* Whitin and Whitin (2004) suggest the following criteria for selecting math-related books.

1. Does the book have mathematical integrity?
2. Is there potential for varied responses?

3. Does the book have an aesthetic dimension?

4. What messages does the book send about racial, cultural, and gender inclusiveness and is the book free from bias?

These guiding selection questions given by Whitin and Whiten and the different ways of using literature to teach mathematics suggested by Welchman-Tischler (2000) provide a general framework for now examining each of the standards for mathematical practice with specific book suggestions to follow. In addition to book suggestions, other types of literacy materials are included which follow the same guidelines as well.

Standards of Mathematical Practice 1: Make sense of problems and persevere in solving them.

Mathematically proficient students actively talk to themselves about the mathematical challenges facing them. They break down the integral parts looking for key words, identifying the main points, analyzing possible effective strategies and procedures, and identifying bridges to span from the mundane into the creative math applications.

The success of the problem solving procedure depends on the building of connections and demonstrating proficiency. The students practice multiple and varied experiences to effectively answer the question, "Does this make sense?" Problem solving procedures have evolved through the years. For effective problem solving in mathematics, in 1945 Polya suggests students proceed through a four step process. The first step gathers the data and analyzes looking to understand the problem. Then the students devise plans by making connections from previously solved problems and experiences and look for additional and reasonable ways to solve this problem. Then the students test the plan and finally look back to determine reasonable results and consider the effectiveness and feasibility of the method. The students evaluate if the results answers the original question.

J. W. Forgan (2003) adds additional steps and suggests when teaching problem solving using literature, in particular, the process is I SOLVE: I: identify the problem; S: solutions are brainstormed; O: obstacles are identified; L: look at the solutions again; V: validate the solutions by trying it; and E: evaluate how well the solutions worked. This acronym identifies clearly the steps.

Buehl (2011) writes students need to think like a mathematician and apply the enriched six steps of Bloom's taxonomy into the math domain. The steps are remembering, understanding, applying, analyzing, evaluating and creating. In remembering, the lowest level, facts form the foundation and this level starts with knowing vocabulary and the symbols, connecting to prior knowledge, and asks "What are the steps?" and "What did the author or problem say?" Then the second level of comprehension looks to explain the problem, understand the math vocabulary and terms, as well as use visuals and conversation to help describe the concept. The third level of applying describes and explains the concept by using examples from the real world as well as taking the information into the world outside of the classroom. Questions are "Where will I find this concept in the real world?" and "How can I apply this in a similar situation?" The fourth level analyzes the characteristics and relationships to other mathematical concepts and asks "What logical reasons or justifications can I use to the parts of this concept?" "If A can equal B, does B equal A?" The fifth step focuses on the value of the concept and asks questions as "What kind of problems can I solve?" and "Does the solutions or the procedures make sense?" The last level creates a new situation and application and asks "What do I understand now and how can I use this information to apply to other mathematical concepts?" Thinking mathematically combines both the procedures and the different levels of questioning and thinking to construct new knowledge.

Problem solving involves the use of obvious experiences with the use of multiple strategies and visuals like graphs, charts, tables, and diagrams to solve arithmetically the problem. Other experiences have not been implemented as often. These activities which add creativity to problem solving might be drawing a math story, using a strategy like Sketch to Stretch, using manipulatives, and making models. Literacy activities as reading math mysteries, math riddles, *Math-erpieces: The Art of Problem Solving* (Tang & Paprocki, 2003), *The Greedy Triangle* (Burns, 2008) and *G is for Google* (Schwartz, 1998) develop conversations to help students express innovative and creative ideas. Writing activities as math notebooks, Think-Share-Write (Gofalatrishnan, 2004), math note strategy (Silver, String, & Perini, 1999), 7 steps of Math Keys (Buehl, 2011), note making, math blogs, shared writing, math concept stories, and class books provide opportunities to share math ideas with others. Of course, the digital world offers multiple formats for applying problem solving in a game-like format. *Kids Math Games* and other interactive sites allow students to field test problem solving ideas without any pressure.

This Common Core mathematical practice emphasizes through multiple experiences in problem solving, proficient math thinkers know the possibilities of multiple answers for the same problem solving activity and the complexity and differences only adds interest to the possibilities. .

Standards of Mathematical Practice 2. Reason abstractly and quantitatively

Marilyn Burns (2012, p. 43) explains, "The Common Core Standards for Mathematical Practice will require teachers to strengthen students' numerical reasoning and mental math skills." Mathematically proficient students not only think logically, sequentially and in structured ways, but they move beyond examples of observation and math relationships to create valid and different proofs to see the world in multiple perspectives. Activities, which foster reasoning abilities, expand those abilities to represent mathematical information in multiple symbolic and graphical examples as well as encourage students to seek patterns to identify, describe, and extend representation of math concepts form the foundation of reasoning. These investigations of number sense start early with preschoolers playing around with the nursery rhymes and rhythm to experiment with size, volume, data, and number concepts.

Then as the students look to decontextualize the mathematical relationships, they desire to discover ways to represent this information into new situations. Opportunities to experience or learn about new situations come from books like *One Grain of Rice: A Mathematical Folktale* (Demi, 1997) or *Spaghetti and Meatballs for All! A Mathematical Story* (Burns, 2008). Procedural understanding comes from mental gymnastics and math detectives. Logical thought develops from strategies similar to poster proofs, convince me, questioning, and math talks. Digital sites offer multiple experiences. *Math Maven's Mysteries* contains 27 easy, medium and difficult math mystery stories to challenge the procedural and logical thinking of any student. *Math Discourse* has nine starters to start a conversation on a math concept. *Gamequarium*'s three links to logic problems, verbal reasoning, and patterns provide activities for different levels of students for reasoning practice. Another site of *Mathwire K -8* focuses on reasoning by providing differentiated real-world tasks to aid in problem solving and communication. The author, Greg Tang, writes multiple math riddles, math fables, and math stories to challenge students' thinking. *The Multiplying Jar* (Anno, 1999), one of M. Anno's books introducing math concepts, interestingly presents factorials to young readers. Each exposure to these creative and interesting literacy texts provide a context or model from which the student explores a mathematical experience and experiences an interesting solution.

Standards of Mathematical Practice 3. Construct viable arguments and critique the reasoning of others.

Mathematically proficient students examine a complex and multifaceted concept, apply the context into real life situations and then explore the multiple changes in content. These students not only think, tell, draw, write, but also reason and share their knowledge in logical and convincing arguments. They look to see if the solution is true in all cases, if there are counter examples and then explain the possible variety of proofs. This procedure, the sense of accuracy and creation of verbal models, are vital to build comprehension of a topic. The students also listen to others and look for the strengths in their arguments and help improve the solutions. Think-Pair-Share (Lyman, 1981) provides an opportunity to try the thinking on another person for feedback prior to sharing with a larger group. Arguments can be demonstrated through manipulatives, movement, and products as foldables or other graphic organizers. Using *The* D*oorbell Rang* (Hutchins, 1989), for example, students explore and manipulative concrete objects into patterns based on multiplication and division situations. Other books using humor or mysteries are *Arithmetickle: An Even Number of Odd Riddle-Rhymes* (Lewis, 2002), *40 Fabulous Math Mysteries* (Miller & Lee, 2001), and *The Book of Perfectly Perilous Math* (Connoly, 2012).

Standards of Mathematical Practice 4: Model with mathematics

Mathematically proficient students possess a conceptual understanding to transfer mathematical thinking and products into everyday life, society, and workplace situations. Early these students work with number sentences and later these students make additional assumptions looking for a deeper and different understanding of the concept. Mathematics modeling crosses all curricular domains. One of the many tools for mathematics can be found in music and rhythm and, for example, the Kodaly Method asks participants to clap, drum, chant, and move to represent musical notation to learn fractions (Courey & Balogh, n.d). Silly songs, raps, or any other activity enriches the math concept. Communication orally and with gestures provides multi-learning styles engagement. For example, Simon Says: Geometry starts with an explanation of math terminology and then go to the physical representation of a line (two arms outstretched) and other terms. Other visual literacy tools enhance the modeling of mathematics. Art and drawing provide a powerful way to engage students to represent math thinking and concepts and the Internet provides multiple experiences. Symmetrical patterns can be cloned or flipped in the digital sites of *Inkscape* and *Google Sketchup* creates 3-D space and geometric objects. *Scratch* moves angles and changes geometric shapes. *Many Eyes,* a free visual model visualizing tool, provides visuals for representing any type of data from bar charts, diagram, word clouds, and more. A drawing visual, using the math poster format, asks for pictures and text for these six ideas: I can write in numbers, I can draw a picture, I can write it in words, I can model it using it, I can explain it for another, and I can make real-world connections. The extension of math vocabulary continues by using these steps: define the word, provide student generated pictures and examples, and identify real world connections. Concept or spider maps demonstrate the relationship of the math problem and its parts. Books as *Spaghetti and Meatballs For All: A Mathematical Story* (Burns, 1997) model the shapes and perimeter mathematical concepts into another societal format. These meaningful representations of visuals and other literacy acts provide motivating activities to engage and produce models of mathematics

Standards of Mathematical Practice 5: Use appropriate tools strategically

Mathematically proficient students possess multiple tools to solve mathematical problems. These students not only have the literacy tools needed to comprehend and construct knowledge but are flexible, inquiring, and choose the appropriate tool. Some tools are simple like in the pencil/pen and paper format and others will be more complex and need special digital formats. *Read it, Draw it, Solve it* (Dale Seymour, 2000) increases young children's understanding of mathematical concepts through direct visual involvement. Students demonstrate their understanding of the concept by creating a drawing before providing the answer.

Others like the digital site of Khan Academy which provides another perspective to math instruction. Gaming, a regular part of students' lives (Marzano, 2010), targets essential academic content as well as enhances student achievement. *Lure of Labyrinth*, a digital math strand game designed by MIT, asks students to solve math and logic problems on three levels. *Dimension*, an online game company, wants students to play math games. *Absurb Math*, an interactive digital problem solving game, takes the player on a mission into a strange world where the ultimate power consists of mathematical knowledge and skills. Free mathematic apps as *Math Ref Free* has over 600-1300 formulas, figures, tips and examples while a 99 cent app *Graphing Calculator* is the equivalent to the graphing calculator, TI-83, a seventy dollar calculator, and has over 100 math functions. Books as *The Librarian Who Measured the Earth* (Lasky, 1994), a non-fiction book, tells the life and world of Eratosthenes who calculated the circumference of the earth within 200 miles of today's figure. *Actual Size* (Jenkins, 2004), another non-fiction book, uses torn paper illustrations to represent life size pictures of real objects compared to the actual size of an eye of a squid. These math tools extend, represent, practice, and provide a different perspective, as well as fun, for students.

Standards of Mathematical Practice 6: Attend to precision.

Mathematically proficient students communicate precisely to each other in words and representations. Math fluency activities like math strings, errorless math activities with answer keys, individual checklists identifying past specific error patterns, peer or collaborative sharing, cooperative learning, game formats, mass practice and reciprocal learning strategy help provide practice in mathematics. These activities not only require thinking in the head or on paper but also extend the math discipline into world knowledge and particularly word knowledge. Teaching academic vocabulary is an essential part to effective math instruction because math vocabulary is precise and compact. Specific terms differentiate the multiple meanings between the math definitions as well as the word use in other domains. A rich study of the history, definition, and Latin/Greek word parts of vocabulary terms clarifies the concepts and builds background knowledge. For example, many mathematic words have different meanings across the curriculum. Many mathematic words can be understood through the study of the word parts. Since seventy percent of English language derives from Latin, Greek or French derivatives and 22 percent comes from German, knowledge of the word parts aids in exact definitions. Some vocabulary strategies especially appropriate for the math domain are vocabulary knowledge rating scale, list-group-label, Frayer model, concept definition map, and concept circles

Writing procedures and explanations share the thoughts behind the concept but also communicate appropriate accuracy. Thinking about math can be shared in math journals or math challenges. The regular use of writing activities clarifies knowledge of math concepts and problem strategies. The student explains, articulates, connects, and uses words, symbols, drawings of the math concepts, thoughts, and understandings to illustrate concepts. Making visual cues or graphic representations highlight key terms and concepts. Drawing clarifies the information and also shows the teacher how the student visualizes and solves the problem. Using manipulatives and foldables to demonstrate the concept shows tactilely how the concept can be arranged. Technology as calculators, SmartBoard, online resources and programs give practice and opportunities to look for precision. *Math is Fun*, an Internet resource, offers game-like opportunities to practice math. Text resources as *Great Estimation* (Goldstone, 2010) helps with estimation which also gives a foundation for accuracy. Other resources as *Millions to Measure* (Schwartz, 2003) and *Measuring Penny (*Leedy, 2000) apply the concept of measurement creatively and realistically.

Exposure to multiple literacies broadens the knowledge and vocabulary so the students extend precise language into a new situation. *Challenge 24*, an app for 99 cents, helps learn flexibility by asking the participant to make 24 by adding, subtracting, multiplying and dividing. An adaptation of this program can easily be used in the classroom as an individual or group activity. The digital *Dimension M* provides exciting scenarios to engage students in algebra, problems solving and when precise, the students move to increasing difficult goals.

Standards of Mathematical Practice 7: Look for and make use of structure.

Mathematically proficient students look for patterns and structure within math concepts to organize their thoughts and ideas into a defined concept. To see conceptual understanding, these students need effective practice and engagement in flexibility and multiple formats. Literature enriches the extension of math from the classroom to the real world. The classic *Caps for Sale* (Slobodkina, 1987) besides providing practice in counting, also develops the concepts of patterns and attribute classification of size, shape, color and thickness. *Amanda Bean's Amazing Dream* (Neushwander, 1998) introduces the concept of multiplication when Amanda counts anything and everything by ones, twos, fives and tens. Other children literature for young readers shares math in different shape hunt books, *How Do Octopi Eat Pizza: Pizza Math*

(Kagan, 1994a), *Play Ball*: *Sports Math* (Kagan, 1993), *The Case of the Missing Zebra Stripes: Zoo Math* (Daniels, 1993) and *Right in Your Own Backyard: Nature Math* (Kagan, 1994b). Older children's books like *Math Curse* (Scieszka, 1995) and *The Great Number Rumble: A Story of Math in Surprising Places* (Lee & O'Reilly, 2007) focus on the fun behind math. Books like *By Nature's Design* (Murphy, 1993) demonstrate the beauty of fractals in nature as well as other symmetry in the natural world. *Circles, Triangles, and Squares* (Hoban, 1974) uses photographs of common objects to explore color, shape and size. One Internet resource for teachers and students, *A Mathematical Mystery Tour: Higher-Thinking Math Tasks (*Wahl, 1988), provides information about famous people, terms, concepts, etc. and challenges the readers to learn and think more about a topic. *Grandfather Tang's Story: A Tale Told with Tangrams* (Tompert, 1997) uses different arrangements of tangrams for illustrations. These literacy resources represent mathematical knowledge visually

Standards of Mathematical Practice 8: Look for and express regularity in repeated reasoning.

Mathematically proficient students possess a disposition to express mathematics as sensible, useful, and worthwhile. This habitual inclination pairs with a belief in diligence and their own efficacy. The preparation for this trait starts with independent tasks requiring students to apply what they have learned to different situations and look for reasonability and patterns. The arts and math, the movies and math, the literature and math, the puzzles in math, as well as junior architectural or engineering projects give opportunities for students to repeatedly use math in real life ways. Literature looks at the life of *Leonardo da Vinci for Kids and His Life* (Herbert. 1998), M. C. Escher, and Paul Nylander to view math in the arts. Computer programs as

Geometry and Math Art demonstrate and provide experiences with tessellations, fractals, polyhedrons, and crop circles. The National Geographic book, *Animal Architects*(1994), illustrates patterns in nature. Movies as *Donald in MathMAGICLAND (*Disney, 1959), *Phantom Tollbooth* (MCM, 1970), and television show as *Numb3rs* show mathematics in new lights. Digital games as *Fun Brain: Soccer Shootout* give repeated game-like practice. *Math in Daily Life* provides thought provoking scenarios with an activity to look at probability, credit cards and debts exponential growth, geometry and ratios/proportions. Short math activities like magic math, creative writing with calculators, minute math, and math strings provide quick practice in a way that motivates students to want to learn more. Each time the students view a new perspective on a math concept, then students are more apt to express the concept with more depth.

Conclusion

In a new era of Common Core State Standards, practitioners provide experiences to encompass not only Standards for Mathematical Content but also Standards for Mathematical Practice. These critical eight practices provide the foundation upon which mathematics content must be accessed and strengthened. This article proposes children's books and other literacy materials which may be used by practitioners to support the purpose of each of these Common Core practices. Knowing different ways in which literacy materials can be used to support mathematics is a good starting point. Rosamond Welchman-Tischler (2000) describes seven distinctly different uses of literacy materials. Other helpful resources include suggestions by

Whitin and Whitin (2004) who provide criteria to consider when making literacy selections for classroom use.

With thoughtful decisions in place about which literacy resources to use in support of a specific Standard for Mathematical Practice, mathematics becomes purposeful and relevant. In *Spaghetti and Meatball for All*, Marilyn Burns (1997) creatively approaches the concepts of perimeter and area by positioning these often abstract and confusing content objectives in a real world context. The reader is encouraged to make sense of a problem and persevere to the end, reason, construct viable arguments, and critique the reasoning of others. The story intentionally invites readers to explore shapes with the same area but different perimeters. However, the potential for what comes next is especially intriguing. The stage is set for the reader to wonder about how shapes with the same perimeter have different areas or to question why the number linked with an area unit of measure may be smaller than the number given with a perimeter unit of measure. When students are discovering, questioning, and wondering, mathematics is made relevant and meaningful and all of these processes begin with carefully chosen literacy materials.

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