Process Standards

The five fundamental processes that characterize “doing” mathematics are problem solving, communication, reasoning and proof, representation, and connections.

(Elementary Mathematics is Anything but Elementary p. 5)

Problem Solving

Problem solving in math means “becoming involved in a task for which the solution method is not known in advance. To find a solution, students must use previously acquired knowledge and, through this process, gain new mathematical understandings” (Bahr & Garcia, 2010). Problem solving should be an integral part of daily math. Problems can be drawn from real life experiences and applications. The problems selected should be carefully analyzed so the teacher can predict the mathematical ideas that will underscore students’ problem solving efforts.

To promote problem solving, students must feel safe in their learning environment. They need to know they are free to explore, take risks, share, and argue strategies with one another. This type of environment will also allow them to confidently work through problems and challenges, and view themselves as capable mathematical thinkers. Specific problem solving strategies, or heuristics, is also a focus of the teacher. This includes things like simplifying the complexity of a
problem, drawing a diagram or picture of a problem, seeing patterns, guessing and checking, and working backwards.

Problem solving also has a metacognitive component. Teachers can promote this level of thoughtfulness by asking questions:

- What do we know from the information in this problem?
- What information does it ask for?
- Is there any missing information that might make solving the problem easier?
- What should we do first, second, etc.?
- Are we getting closer to the solution?
- Should we try something else?
- Why is that true?

These types of questions places the responsibility for success on the students.

**Communication**

Mathematics communication is both a means of transmission and a component of what it means to “do” mathematics. Teacher have to provide an environment in which students can risk expressing their beginning efforts to communicate their thinking. Teachers must be patient while students begin to do this, because communicating in math doesn’t come naturally to students.

The NCTM standards provide a complete list of standards in communication and the benefits of communicating in math.

When students share, they should genuinely listen to one another, compare it to their own ideas, evaluate it, then share their own opinions. Teachers can use probing and prompting questions during discussions as scaffolding. In older grades, students should be encouraged to elaborate more.

Writing in math is also beneficial to deepening mathematical understanding. In the primary grades, they rely more on pictures and as they get older will be able to form more complete sentences and thoughts. Writing in math also allows them to practice using mathematical vocabulary and symbols. Their writing skills are consequently enhanced as they practice justifying and writing in this expository form. Just like writing in any other content area, the teacher will have to model how this should be done effectively.

**Reasoning and Proof**

Reasoning is a habit and should provide a context for developing important mathematical ideas. Questioning is the key! Ask WHY? Mathematics involves discovery, so invite students to make conjectures and create, refine, and evaluate them. Also, allow students to explore and explain their own reasoning. It’s often best to start students off with what they know, and then build from there.
This is where students can take advantage of manipulatives and using technology to solve problems and explore their conjectures. Several virtual manipulative websites exist to get the same practice with manipulatives while utilizing technology, especially if the manipulatives in the classroom are limited. Using manipulatives will help reinforce concepts to all students, especially students with learning disabilities and English language learners.

Sometimes younger children need a discrepant or contradictory event to verify their reasoning. They tend to overgeneralize an idea, which means they may apply reasoning from one context to a context where the same reasoning does not really apply. Through enough exploration and discovery the students will be able to accommodate and assimilate the new mathematical reasoning into the correct schema.

Also encourage students to look for patterns. These patterns can be spatial, temporal, logical, and sequential.

**Representation**

This is asking students to show a mathematical idea in more than one way. There are five ways to represent thinking:

1) manipulative models  
2) static pictures  
3) written symbols  
4) spoken/written language  
5) real-world situations or contexts

Real-life situations are very valuable to the students because it gives them something more concrete to work with, and they begin to see the real purpose and meaning behind using the mathematical concept. Because adults think in symbols and children do not, children support their thinking with examples they have seen in the real world.

Representations are used by children first to display the problem, then to find a solution, and finally use tools to solve similar problems. This will especially be useful to special needs children and English language learners to use situations they are familiar with.
The following are examples of solving problems using models, pictures, numbers and words.

Connections

“Connecting is the experience of mentally relating one object to another” (Bahr & Garcia, 2010). *Elementary Mathematics is Anything but Elementary* (2010) identifies six types of connections distinguished by what types of thoughts are being connected:

1) representations

2) problem solving strategies or conjectures

3) prior and current math learning

4) mathematical topics

5) mathematics and other subjects

6) mathematics and real-life situations
If you encourage these connections, it will increase your students’ mathematical reasoning abilities. One of the roles of teachers is to compare strategies students share and help students see the connections between those strategies. It is essential to make these connections with prior math learning, so the learning is logical and builds from what students know. Just when you build a structure, you need to have a firm foundation before you can start building the structure. The same is true in math. When students make connections between math concepts it’s like they have formed a neighborhood of strong buildings and can see how the neighborhood works and functions together, instead of each building functioning or existing on its own. Children learn about the world in connected ways, so balanced math instruction will help children do this.

Integrating other subjects with math has to be meaningful. Therefore, if you simply read a book with a math concept in it, that is not successful integration. Here is also a website that has successful ways to integrate math with literature, history, geography, health, art, and music.

“When mathematics is consistently used to solve problems in other subject area contexts, connections, to real life occur consistently” (Bahr & Garcia, 2010).

References
