Building a Nurturing Visual Math-Talk Teaching-Learning Community to Support Learning by English Language Learners and Students from Backgrounds of Poverty

Karen C. Fuson
Northwestern University

Todd Atler
Sawyer School

Sheri Roedel
University of Chicago's Urban Teacher Education Program

Janet Zaccariello
CICS Irving Park School

New England Mathematics Journal, May 2009, XLI, 6-16.

We present critical components of a Nurturing Visual Math-Talk Teaching-Learning Community that can support the learning of ambitious mathematical content for students from backgrounds of poverty and English Language Learners as well as for student from other backgrounds. The importance of student math drawings that accompany explanations is outlined. Then the benefits of such a community for diverse students and for teachers, and key aspects of building and then developing such a community to higher levels, are summarized.

Students from backgrounds of poverty (SfrBP) and English language learners (ELLs) primarily have the same learning needs as do students from homes where families have higher levels of education: They need to understand math ideas, become fluent with core mathematical methods for representing and solving problems, and feel that they are capable mathematics learners. However, they also enter classrooms with less or even no knowledge of the English used in school, so their classrooms must enable them to learn to understand and to speak such English as well as meet the above mathematical goals. Often, schools and teachers have adapted to these additional needs by lowering the level of mathematics being taught and especially by focusing only on numerical methods rather than including word problems. We report here the alternative used in the 12-year Children's Math Worlds Research Project in which visual supports linked to explanations of thinking by students was a core feature of the classroom that enabled students to learn ambitious grade-level goals including solving different types of word problems. This was a powerful feature for all students, but it especially supported SfrBP and ELL students in learning to understand and to speak standard English including appropriate and ambitious mathematical vocabulary.

We call this on-going feature of the classroom a Nurturing Visual Math-Talk Teaching-Learning Community (a Visual Math-Talk Community, for short). The NCTM Process Standards (2000) come to life within such a community as students represent, problem solve, communicate, connect, and use reasoning and proof in age-appropriate ways. The authors of this paper worked together for a number of years to build such classrooms, to articulate features of such classrooms, and to work with many teachers to help them build such classrooms. Three of the authors began as classroom teachers and now are working with teachers in other capacities.

In working with teachers, we have found it to be effective to summarize various aspects of such classrooms in tables. Teachers have told us that they find it helpful to take these tables out periodically to review and make notes on because they notice different things at different times. This process helps them continue to build and refine their Visual Math-Talk Community. Space permits discussion only of the most important or least obvious points from the tables.

Math Drawings Support Thinking and Math Talk

A central result of our research project was the power of having students make math drawings and relate them to mathematical notation. Math drawings are simplified drawings that show quantities and relationships in simple ways, for example, drawing 238 as 2 hundreds-squares, 3 tens-sticks, 8 circles or showing an additive comparison word problem by drawing 6 dogs as 6 circles and 9 cats as 9 circles below these and matching them to find out how many fewer dogs than cats. Table 1 outlines all of the advantages we found through the years in having students and teachers make math drawings as visual supports for mathematical problem solving. The Visual Math-Talk Community then is an on-going process of building and relating these math drawing visuals and language. Students can begin working from their strength (visual or language), and the continuing connections enable them to develop the other aspect.

Benefits of Establishing a Visual Math-Talk Community

A Visual Math-Talk Community is culturally responsive and allows students to bring cultural solution methods and ways of thinking from home into the classroom for discussion, exploration, and linking to language and methods emphasized in the United States. All students can belong to the community and have their thinking acknowledged and supported. Table 2 summarizes benefits of establishing a Visual Math-Talk Community in the classroom.

Starting a Visual Math-Talk Community

Crucial aspects of starting a Math Talk Community are summarized in Table 3. These are: make it safe for students and for yourself, make the math thinking visible by using math drawings, emphasize and assist close and supportive listening, provide continual teacher assistance, and start simple and build up from there. Opening up the classroom to different ways of thinking mathematically will be empowering for everyone, but students need to feel that they will be supported and not ridiculed in order to participate.

Shifting to a Math Talk environment can be intimidating to a teacher. Teachers worry that they will not be able to understand students' methods or answer all of the questions that students raise. We have found that it is very important for teachers to know that at any time they can say, "We seem to be confused about this point. I think this is something that we all need time to consider. Let's all think about this, and we'll discuss it again tomorrow." This allows a teacher time to think at a later time and to consult others. This is **modeling actual longer-term problem solving** in which one does put aside a problem, ponder it when one has the attention to consider it carefully, and can consult others who might help. Students also frequently understand other student's methods and can clarify or answer questions even when the teacher cannot, so assistance for teachers is often present in their own classes if they will just redirect questions to students before trying to answer them.

Use a "Solve, Explain, Question, Justify" classroom structure: Once learned, this structure can be used all year and across many different math topics. As many students as possible go to the board because students love to do so, and it is easier for the teacher to watch student problem solving methods at the board than at student seats. Helpful interactions also frequently occur at the board and can easily be watched by the teacher, though of course they also occur at students' seats. Having two or three students explain their thinking allows different methods to be discussed and related. Occasionally more students can explain if the teacher knows there are more mathematically worthwhile methods. But students are usually more engaged if they all go on to solve a new problem rather than sit through more explanations. Students learn that over time everyone will get a chance to explain. Especially needy students may need to have their energies privately directed toward helping and higher-level questioning and learn to accept a brief nod or thumbs up from the teacher instead of a chance to explain. A vital step for SfrBP and ELL students is to have all students explain to a partner before the two or three explanations are given to the whole class. Early in a topic, it also helps to elicit choral practice of key explanatory steps so that students get practice saying key mathematical phrases or sentences, for example, *I grouped my ten ones to make one new ten.* With time, students become secure enough to use their own ways to say an explanation.

Emphasize and assist close and supportive listening and support students saying things in their own words. This is especially crucial early on to prevent non-attentive listening in which students just wait for their turn to talk without attending. Asking students to repeat what someone just said emphasizes this social norm, gives practice in English (or in math vocabulary), and gives participatory experience. Asking students to rephrase in their own words what someone just said does all of the above and extends everyone's vocabulary. When possible, crucial aspects of a problem situation or of a solution can be translated into another language and restated in English by language pairs. Gesturing at the drawings, and perhaps adding to them, can help clarify and extend everyone's verbal and non-verbal understanding. Posters of crucial vocabulary can be made in English and other languages.

Developing a Visual Math-Talk Community

Table 4 summarizes vital aspects of developing a Visual Math-Talk Community. There is not space to discuss all of these, but we would like to emphasize three. First, Math Talk is an **instructional conversation** with mathematical learning goals for all. It is not a meandering conversation that lacks direction from the teacher nor is it just turn-taking to give everyone a turn to talk. The teacher must monitor and orchestrate each instructional conversation with a learning path for the whole class in mind. The goal is to move everyone to more-advanced mathematically-general methods. Second, teachers tell us that **"bite your tongue" to allow students time to think and then talk** is a months-long but totally crucial step. Third, **moving to the side or back of the room** speeds up the process of students speaking to their classmates rather than just to the teacher by allowing students to look at their classmates as they look at you. Students, rather than the teacher, also begin to elicit and manage the questions from other students.

The teacher facilitates the movement to the higher levels described by Hufferd-Ackles, Fuson, and Sherin (2004) by asking questions that seek extended descriptions of multiple student strategies rather than just answers and by assisting students by probing, clarifying, and extending

their explanations without taking over the explanation over from the student. For example, a teacher might help a student connect the numbers in her word problem calculation to the problem situation by saying, "Tell us what your numbers are in the problem situation. Put a letter or a word by each number to remind us how it comes from the situation. Then explain how that told you that you needed to add those two numbers. You start and someone can help you if you get stuck." Even at the highest Level 3 with a considerable amount of student-to-student talk, the teacher must continue to lead the Visual Math-Talk Community by monitoring and directing the instructional conversation from the back of the classroom. But students become increasingly able to do higher-level questioning, explaining, and assisting of classmates.

Conclusion

Teachers tell us that students extend their Visual Math-Talk Community to other subject areas, asking questions and assisting others to learn. The benefits of deeper and more connected knowledge and increased language learning, and the resultant student empowerment, then begin to extend throughout the day. Once built, the Visual Math-Talk Community continues to enable students to nurture and assist each other in powerful ways. Students whose initial mathematical or language knowledge is particularly weak may need extra learning support in small groups with additional opportunities to solve and explain. But we have found that all students can make huge progress in a Visual Math-Talk Community. This was exemplified by the report from a school with many ELL and SfrBP students when outside interviewers from the state came to interview students not yet demonstrating proficiency in English. The interviewers met with some teachers over lunch and asked incredulously, "What are you doing in your math classrooms? Many of your students do not know the English words for head or hand, but they can explain subtracting with ungrouping." The teachers replied that all students were expected to explain their thinking in math class and that they were supported to do so with the help of math drawings linked to their numerical methods.

The authors wish to thank all of the teachers and students with whom they have worked in the classroom research underlying this paper. That classroom research was partially funded by National Science Foundation Grant Numbers RED935373 *and* REC-9806020. *Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the view of the National Science Foundation. The authors collaborated for many years first in the Children's Math Worlds Classroom Research Project and then using the published version of this NSF program, Math Expressions published by Houghton Mifflin Harcourt.*

References

Hufferd-Ackles, K., Fuson, K. & Sherin, M. G. (2004). Describing levels and components of a math-talk community. *Journal for Research in Mathematics Education, 35 (2)*, 81-116.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Table 1: Advantages of Student Math Drawings of Problem Situations and/or Solution Methods

Young children aged 2 through kindergarten benefit from using physical objects to show mathematical ideas. Manipulatives also are important for introducing some math ideas for older students (e.g., making fraction strips by folding unit fractions). But many ideas beginning in grade 1 benefit from having students make math drawings and relate them to the formal math symbols. Math drawings are simplified drawings that show quantities (e.g., 238 or 6 dogs) and relationships in simple ways (e.g., drawing 2 hundreds-squares, 3 tens-sticks, 8 circles and drawing 6 circles for the dogs).

Student math drawings of problem situations and/or solution methods enable students to explain their thinking more clearly and explicitly by pointing to parts of their drawing as they explain and enable listeners to understand because of the relating of language and visuals.

Students can relate parts of the drawing to the problem situation by labeling those parts.

Students can relate in the drawing (e.g., by using an arrow) a step with quantity drawings (e.g., making 1 new ten from ten ones) to that same step in the numerical method (e.g., writing the new 1 ten in the tens column).

Math drawings are *windows into the minds of students* that allow teachers to understand student approaches and errors on homework and classwork. They enable teachers to do continual assessment for instruction. Teachers can always follow up on a math drawing by asking a student to explain it, but this frequently is not even necessary to understand student thinking.

Math drawings are easier to manage than are manipulatives. They are not dropped on the floor, thrown at other students, lost, mixed up, taken from the school by last year's teacher, or lost during summer school.

Math drawings are cheaper than are manipulatives. Some drawings can be made on dry erase boards, sheet protestors, or on recycled paper from businesses.

Math drawings remain after the problem is solved. They can show the whole action, whereas actions with manipulatives may be over by the time the teacher gets to a particular group.

The teacher can collect all math drawings made on paper after class to reflect on student methods shown that day. This cannot happen with manipulatives.

Many students take pride in their math drawing creations and use care in making and in editing their drawings. They have a product at the end of their solution.

Low literacy students need experience with 2-D representations on paper (like math drawings) to help understanding pictures and drawings in books.

Table 2: Benefits of a Visual Math-Talk Community

Math becomes a time for **community building** through Math Talk as students help each other solve problems in partners, in small groups, and the whole class.

Speaking helps the **speaker** to **clarify his/her own thoughts**.

Listeners understand more by hearing another idea or an explanation; an explanation by a peer may be more adapted to their thinking than a teacher explanation.

Because Math Talk is communication to build understanding together, students are **more involved and engaged** in the class.

Students learn to **speak to a large group**: They speak loudly, clearly, and articulately and stand beside their work and point to parts of it with a pointer as they explain.

Listeners learn to **listen** attentively and thoughtfully, **prepare to assist** when needed, and **prepare to ask questions** (Good Thinker Questions) that support everyone's learning. Helping or asking good questions extends the thinking of the listeners as they adapt their thinking to that of a peer.

The Visual Math-Talk Community expects and enables students to become better **problem solvers and explainers** because peers and the teacher model this.

Students are **empowered** as they learn from each other, ask each other questions to clarify meaning, and have their own thinking valued in the community.

The classroom teacher orchestrates discussions but also directs attention, introduces new vocabulary and notation, models, clarifies and restates, probes and questions, extends, summarizes, and sets classroom expectations. These all **facilitate deeper and more relational learning** by the students (and by the teacher).

Assessment for instruction is on-going as the teacher hears student thinking expressed. This enables teachers and students to provide learning assistance as a student needs it.

Teachers deepen their understanding of math and of various aspects of student thinking about math as they listen, understand, and assist problem solving and explaining by the range of students in their class.

The Visual Math-Talk Community provides **differentiated instruction in the whole-class setting** because the methods explained by students range from less to more-advanced. Peers and the teacher help students move to more-advanced methods.

All of these features **support equity**—high expectations and strong support within an accepting teaching/learning community where everyone's thinking is valued.

Table 3: Starting a Visual Math-Talk Community

Make it safe: Emphasize that Math Talk is not a test. It is helping everyone learn more by talking about their thinking. Emphasize: No making fun of anyone ever.

> **Community assist:** The teacher can relieve pressure for an explainer who appears 'stuck' by asking the explainer if s/he would like help from the group or from a specific student. Students can then begin to ask for such assistance.
>
> **Explain with a helper**: Shy students can be helped by the presence of a friend with them at the board (the friend may or may not help explain).
>
> **Handling mistakes:** Emphasize that everyone makes mistakes. The important thing is to learn from our mistakes. Point out or describe your own mistakes and how you learn from them. If a student makes a mistake, you can thank them for helping everyone learn more by discussing that mistake.
>
> **Make it safe for the teacher:** Remember that you as well as students can say, "I need to think more about that. Let's talk about it tomorrow."

Make the math thinking visible: Children must make some kind of **math drawing** to show their thinking. This supports understanding by the listeners and promotes meaning. This is very important for equity: less-advanced students and English learners are helped by the math drawing linked to the explanation by pointing.

> **Use a "Solve, Explain, Question, Justify" structure:** As many as possible solve at the board; the rest solve at their seats. Only call on two or three to explain because attention spans for a single problem are limited. Students often explain to each other in pairs before the whole-class explanations and discussion.

Emphasize and assist close and supportive listening: Ask children to repeat what someone said either exactly or in their own words. Lots of rephrasing helps build and practice vocabulary and language.

Provide continual teacher assistance: Engage and involve, manage, and coach by using mixtures of modeling, clarifying, explaining, questioning (probing), and giving feedback. The goal is to help students move to being able to assist others by doing similar coaching in pairs, groups, or whole-class discussions.

Start simple and build up from there: Some students may start out with explaining only one part of their thinking using a few words. The teacher or other students can assist by asking about steps before or after that part and by expanding the sentence and then checking with the student to see that the expansion was correct. It is crucial for students to own their own thinking and to be validated for it.

Table 4: Developing a Visual Math-Talk Community

A Visual Math-Talk Community is an inquiry-based learning environment whose continual focus is on sense-making by all participants: Students are expected to understand what they are doing, come to be able to explain their thinking, understand the thinking of other students, learn to seek help when they need it, and help others who need it.

Math Talk is an instructional conversation about the math. It is not just taking turns talking. Teachers need to be sure that the mathematics is clear for everyone, and sometimes stimulate higher-level discussion such as discuss advantages and disadvantages of various methods or how methods are alike and different. Students can often help their peers understand better and can learn to do so even more.

"Bite your tongue" to provide enough wait time: Many students need time to think or develop questions. Many will ask a question or add a comment if you wait.

Help students speak to their classmates rather than to you: Maintain eye contact and attention while moving away to encourage louder speaking. **Move to the back of the room** so that as the explainer looks at you, and s/he will see and start looking at their classmates. Later, remind students to address each other (not the teacher). This can be done with a silent gesture so as not to interrupt.

Questioners may ask genuine questions they have; they may need assistance to make these clear enough. They may ask "Teacher-y Questions" whose response will help the explainer or the listeners (playing teacher). Or they may participate by asking questions they have heard others ask, either generic for any topic or specific for a topic. Create a "How to Ask Good Questions" Poster with the students and add to it as you go. Include generic questions and questions for particular topics.

Practice Math Talk in pairs/small groups before the whole-class explanations. Sometimes talk about what the room should look/sound like when good math talk is happening (it starts with good listening). Create a Math Talk Poster and add to it.

Post vocabulary: Post a list of relevant vocabulary words and core sentences (e.g., *I group ten ones to make one new ten.*) to prompt and focus students. **Practice reading and saying the words/sentences chorally and individually to build fluency.**

Expect and assist students to coach themselves and others by using mixtures of modeling, clarifying, explaining, questioning (probing), and giving feedback.

Students must speak and not just listen: Structure opportunities to explain to a partner and repeat what the partner says, if needed. Students eventually find their own words, but may need the security of saying an explanation they know is correct.