Classroom Talk and Mathematical Thinking

Talk permeates almost all of our activities in early years and primary classrooms. The nature of the talk that is occurring is important to consider:

- ✓ Who is asking questions?
- ✓ Who is giving the mathematical explanations?
- ✓ Do children discuss their mathematical thinking or just their answers?
- ✓ Do they make connections between their own thinking and other children's ideas?

These issues are important if we want classroom talk to support children in developing robust mathematical understandings and to experience key mathematical processes, e.g., connecting, communicating, reasoning, argumentation, justifying and problem-solving.

Language plays a key role in developing thinking. Research carried out with preschool children has shown that the mathematical language used by adults can have an impact on children's mathematical knowledge. Language relating to spatial concepts appears to be particularly important in developing children's understanding of this topic, but observations of preschool settings have shown a tendency to focus more on number rather than the full range of mathematical topics (See NCCA Research report 17, chapter 3).

Learning mathematical vocabulary is only part of the story however. Children must also learn:

- ✓ ways of thinking
- ✓ how to express their thinking.

They must be supported in developing explanations, justifications and argumentation. Teachers' expectations for children's engagement in these processes should be relative to the child's age, but even very young children can be encouraged to engage in justification and provide warrants for their arguments e.g. "I think the shape (hidden in the bag) is a triangle because I can feel three sharp corners."

If you create opportunities for children to discuss their ideas it will allow you, the teacher, along with the children, to engage in sustained interaction that may deepen and extend the child's thinking.

Research on the *Thinking Together* programme, an interventional teaching programme designed to enable children to talk and reason together effectively, provides evidence that talk-based group activities can help the development of individuals' mathematical reasoning, understanding and problem-solving. Such talk also opens up opportunities for the teacher to engage in formative assessment.

Changing how talk is set up in classrooms can challenge our assumptions about our role as teachers. It is useful to keep in mind the following suggested goals for classroom discussions:

1. Helping individual children share their own thoughts
2. Helping children orient to and listen to each other
3. Helping children deepen their reasoning
4. Helping children engage with each other's reasoning.

Anderson, N., Chapin, S., & O'Connor, C. (2011). *Classroom Discussions: Seeing Math Discourse in Action, Grades K-6*. Math Solutions. 150 Gate 5 Road, Sausalito, CA 94965.

Norms for Classroom Talk

In this section, we will address norms for productive talk; changing from traditional teacher-directed approaches and also offer practical strategies for improving talk.

It has long been recognised that many conversations have a particular three-part structure:

1. a question or invitation
2. followed by a response
3. followed by some feedback.

As the teacher, you are likely to know the answer to many of the questions that you ask during a teaching activity. In contrast to questions we ask beyond the classroom, questioning during teaching can become more about testing children's knowledge rather than seeking information. This type of questioning places the teacher in a position to evaluate all contributions as right or wrong.

Assessment and evaluation by teachers is important, but children must also have opportunities to make their own judgements about the correctness of mathematical ideas. Sharing this 'power' with children is an important way of developing their own sense of agency and mathematical authority.

A first step towards this may be to postpone the 'feedback' or evaluative teacher response and instead to open up opportunities and allow further time for children to engage in deeper thinking about and evaluation of the mathematical ideas.

Real Life	Typical Class	An Alternative
What time is it, Denise? It's half past ten Thanks.	What time is it, Denise? It's half past ten Very good.	What time is it, Denise? It's half past ten. Do the rest of you agree with Denise? Why/Why not? I think she's about right because I'm getting hungry so it must be nearly break. I think it's just gone past half ten because the long hand is a bit past the six

For further ideas, see:

Mehan, H. (1979). 'What time is it, Denise?": Asking known information questions in classroom discourse. *Theory into practice*, 18(4), 285-294.

Parks, Amy Noelle. "Can Teacher Questions Be Too Open?" *Teaching Children Mathematics*, vol. 15, no. 7, 2009, pp. 424–428. *JSTOR*, www.jstor.org/stable/41199319.

Sussman, Annie, et al. "Questions to Elicit Students' Mathematical Ideas." *Teaching Children Mathematics*, vol. 25, no. 5, 2019, pp. 306–312. *JSTOR*, www.jstor.org/stable/10.5951/teacchilmath.25.5.0306.

Research recognises the effort and expertise that teachers bring to developing and sustaining norms for productive classroom talk. Teachers begin this work by **modelling** different forms of discussion and by questioning, probing, and leading conversations.
For example, see some of the teacher 'talk moves' described in the next section. Over time, children can be expected to carry out similar discussions amongst themselves.

You could establish '**Ground Rules for Talk'** with your class. These ground rules should involve more than just emphasising the importance of taking turns. Many children will happily wait their turn but not actually listen to what their peers are saying. Instead, ground rules should:

- ✓ involve making children aware that they should be actively listening and trying to understand the contributions of others
- ✓ ensure that children are supported to ask clarifying questions or to disagree with an idea and provide a reason why
- ✓ direct children's attention to the mathematical content of discussions. The teacher should aim to create an expectation of clear explanations and justifications.

In other words, there should be accountability to the learning community, to accurate mathematical knowledge, and to rigorous thinking. See Accountable Talk SourceBook: For Classroom Conversation that works.

Sample Ground Rules for Talk
Discuss ideas and ask questions Include everyone's ideas Ask what people think and what their reasons are Co-operate to work together Listen to each other Make an agreement before deciding
Mercer and Sams (2006, p. 9-10) Mercer, N., & Sams, C. (2006). Teaching children how to use language to solve maths problems. *Language and Education*, *20*(6), 507-528.

Moving From Traditional Approaches

Changing the model: Deciding when to 'tell'

Traditional models of teaching often begin with 'teacher telling' where the teacher explains mathematical facts or methods, then children practice this and the teacher may question them on their understanding or use of procedures.

Other models of teaching that aim to promote children's agency and authority may start with an open-ended problem where children attempt to come up with their own solutions. The teacher's role in this second model of teaching is quite different. Here the teacher is challenged with eliciting and working with children's thinking in a more dynamic way. The teacher must build bridges between children's informal methods and ideas and the formal facts and procedures of conventional mathematics. The timing of 'teacher telling' in this model of teaching is quite different. A teacher might only introduce formal mathematical facts and/or procedures after children have spent some time thinking about a problem and developing their own ideas.

Sample Inquiry or Problem-Solving Cycle	
1. The children begin with a challenging problem that can be solved in different ways	See section on Tasks.
2. Children work independently or in small groups. The teacher supports by helping children to help themselves. The teacher notes the different solution strategies and decides which solutions should be discussed with the whole class.	Teacher actions should aim to maintain cognitive demand of tasks. Opportunities for formative assessment.
3. A selection of children present their solutions. These solutions are compared and discussed.	The solutions which are presented to the class should be chosen purposefully by the teacher with the aim of exposing key mathematical ideas and moving children toward more efficient solutions.
4. The teacher summarises the results and possibly introduces new concepts or presents a more formal version of the ideas children have shared.	This might be understood as formal 'teacher telling'. At this point in a lesson, children have had time to consider the key ideas and are ready to hear more formal approaches. The teacher has also had time to consider children's own ideas and can draw connections between these and the more formal mathematics. Then the cycle begins anew.
See: Fibonacci Project Inquiry in Mathematics Education Smith, M, Hughes, E., Engle, R., & Stein, M. (2009). Orchestrating Discussions. *Mathematics Teaching in the Middle School,* 14(9), 548- 556	

Math-Talk Learning Communities

NCCA Research Report 18 identifies the promotion of math talk as central to effective teaching and learning. This can be understood as children talking about their mathematical thinking.

This happens surprisingly rarely in classrooms where the emphasis is often on answers or methods rather than the thinking involved in producing these e.g., "I got eight" vs. "I added five and three to get eight" vs. "I think you have to add five and three together because first there were five sweets and then he got three more."

Hufferd Ackles, Fuson and Sherin (2004) describe a math-talk learning community as a community where learners help each other learn mathematics by engaging in meaningful mathematical discussion. They describe four levels of discussion talk in classrooms and very helpfully describe action trajectories for teachers and children's actions as a classroom community moves toward becoming a math-talk learning community.

The key components and areas for action are:

- ✓ questioning
- ✓ explaining mathematical thinking
- ✓ source of mathematical ideas
- ✓ responsibility for learning.

This is explained in broad terms on the table below.
For further details of how this might look in practice, see the practical strategies for improving classroom talk below.

Levels of the Math Talk Learning Community			
Level 1: Traditional teacher-directed classroom with brief answer responses from children.	***Level 2:*** Teacher beginning to pursue children's mathematical thinking. Teacher plays a central role (e.g. questioning, explaining, evaluating) in the math-talk community.	***Level 3:*** Teacher modelling and helping children build new roles (e.g. asks children to comment on each other's work). Some co-teaching and co-learning begins as student-to-student talk increases.	***Level 4:*** Teacher as co-teacher and co-learner with children. Rich mathematical discussions between children with little support from teacher though teacher monitors all that occurs, still fully engaged. Teacher is ready to assist, but now in more peripheral and monitoring role (orchestrating, coaching, assisting).
Key Components and changes as the community moves to a Math Talk Learning Community			
Questioning:	***Explaining Mathematical Thinking:***	***Source of Mathematical Ideas:***	***Responsibility for Learning:***
Shift from teacher as questioner to children and teacher as questioners. Children ask 'why' questions, i.e. questions requiring justification.	Teacher begins to elicit children's thinking and sets expectations for complete and thorough explanations. Children increasingly explain and articulate their mathematical ideas.	Shift from teacher as the source of all mathematical ideas to children's ideas also influencing the direction of lesson. Children retain 'ownership' of their ideas. They spontaneously compare, contrast and build on ideas.	Children increasingly take responsibility for learning and evaluation of others and self. They assist each other in understanding and correcting errors. The teacher supports children as they help one another sort out misconceptions. 'Math sense' becomes the criterion for evaluating what is mathematically correct.

Adapted from Hufferd Ackles, Fuson & Sherin (2004, p. 88- 90)

Hufferd-Ackles, K., Fuson, K. C., & Sherin, M. G. (2004). Describing levels and components of a math-talk learning community. *Journal for research in mathematics education*, 81-116.

For an overview of the research paper see edugains.ca

Practical Strategies for Improving Talk

Classroom norms develop over time. Even the most committed, expert teacher will have to work at developing expectations and routines for productive classroom talk.

This section addresses some practical steps that can be taken as you work towards developing productive discussions in your classroom.

Teacher Questions

A number of principles for effective questioning in problem-solving lessons have been developed by the The Mathematics Assessment Resource Service and Shell Centre. These are:

1. **Plan to use questions that encourage thinking and reasoning**
   These questions might encourage children to consider what is known about a problem situation, what needs to be figured out and how they might do this. Good questions should also support children in reflecting on and evaluating their methods.
2. **Ask questions in ways that include everyone**
   A 'no-hands up' rule is recommended so that all children feel responsible for trying to come up with an answer and to continue to develop their thinking as other children suggest ideas. Open questions such as 'what do you notice about ..?' allow more children opportunities to contribute than closed questions seeking a single particular answer. It can also be productive to ask children to comment on or extend other children's contributions.
3. **Give children time to think**
   Developing your own practice to include more 'wait time' can be beneficial. It can also be helpful to explain to children that are allowing them time to think and to incorporate different strategies for this such as 'think-pair-share'
4. **Avoid judging children's responses**
   Even positive responses have been shown to inhibit children' willingness to contribute (e.g., if they feel their ideas are different to those being praised). It is recommended that teachers respond to children's ideas in ways which do not close off other alternatives (e.g., "That's really interesting. Does anyone have any other ideas?')
5. **Follow up and responses in ways that encourage deeper thinking.**
   Some ideas for how this might be done are included in the next section.

These principles connect to some of the ideas already presented. In particular, the idea of focussing on thinking rather than 'answers' and avoiding judgment of children's responses to create some space for them to think more deeply about the mathematics under discussion.

The Mathematics Assessment Resource Service and Shell Centre professional development module on Improving Learning through Questioning also details common mistakes that teachers make when posing questions and it lists questions you might use at different stages of a problem-solving lesson.
Common mistakes include:

- ✓ not giving children time to think
- ✓ not giving time to individuals/groups to discuss before responding
- ✓ simplifying the question when children do not immediately respond
- ✓ asking closed questions with only one right/wrong possible answer that limit children's opportunities to succeed.

Talk Moves

The questions that teachers ask require certain responses from children. Teacher talk moves can be thought about in exactly the same way, i.e., a move (statement, question etc.) made by the teacher intended to provoke a particular kind of response from the child. These are important because they can determine the nature of the interaction and whether sustained meaningful dialogue about mathematics occurs or not. The moves described below generally aim to elicit children's reasoning, clarify their ideas and/or encourage them to apply their reasoning to other people's ideas.

Talk Move	**Purpose**	**Example**
Revoicing Repeat what the child said and ask them to verify that what you said is correct	To ensure that you and other class members understand the thinking and to ensure the child retains ownership of his/her idea.	"So you think…., is that correct?
Say More Prompting children to say more	To encourage the child to expand on his/her explanation; To ensure that you and other class members understand the thinking.	"Can you say more about that?" "What do you mean when you say…?"
Repeating Asking children to restate someone else's explanation/thinking	To make children accountable for actively listening to peers; To ensure other children have understood; To make children engage with ideas of others.	"Can you repeat what he just said in your own words?" "What did your partner say?"
Adding On Prompting children for further participation and engagement with the mathematics already presented.	To encourage children to build on each other's ideas.	"Would someone like to add something more about this?"
Requesting reasoning Asking explicitly for reasoning	To elicit reasoning.	"Why do you think that...?" "How did you figure that out?"
Request reasoning about someone else's thinking This moves beyond simple repetition and asks children to attempt to explain and justify another person's thinking.	To create opportunities for children to engage with the mathematical ideas of others; To encourage a sense-making atmosphere with a focus on explanations and justifications. Compare and contrast solutions and make connections across different methods/ways of thinking.	"Why do you think Seán said that?" "Can you explain how Síle solved the problem?" "Did someone think of the problem in a different way?" "Do you agree or disagree, and why?" "Explain how your answer is the same or different than ___?"

Michaels, S., O'Connor, M. C., Hall, M. W., & Resnick, L. B. (2010). Accountable talk sourcebook: For classroom conversation that works. Pittsburgh, PA: University of Pittsburgh Institute for Learning.

Chapin, S. H., O'Connor, C., O'Connor, M. C., & Anderson, N. C. (2009). Classroom discussions: Using math talk to help students learn, Grades K-6. Math Solutions.

Analyse and Reflect 1

- What norms for classroom talk are present in your own classroom? Do children share their mathematical thinking in addition to their 'answers?' Do children actively listen and try to understand when other children speak about their ideas?
- What level of the Math-Talk Learning Community Framework (2004) best describes your practice? Do you have strengths or areas for improvement in any of the components (questioning, explaining mathematical thinking, source of mathematical ideas and responsibility for learning)?
- Consider if you allow sufficient 'wait time' for children to engage in thinking. You can experiment with increasing wait time by counting silently in your head after you pose a question. Also experiment with silent wait time where individuals think about the question you have posed and other approaches which introduce elements of pair or group work such as 'think-pair-share'.
- Look at the question categories described by Boaler and Brodie (2004) and consider your own practice. Are there particular question types that you use more than others? Are there question categories that you would like to choose more often? If so, write some sample questions for whatever topic you plan to teach next.
- Look at the talk moves on the list. Are any of these part of your practice already? Are there some in particular you think you would like to start using?

Analyse and Reflect 2

View the available videos to investigate how talk was used by children and teachers. Before you view the videos, it is important that you have read the guidelines for Learning from Video.

We have also created a number of prompts based on the Teaching for Robust Understanding (TRU) observation guide for mathematics. The particular prompts have been chosen from the full range of dimensions of the TRU framework. These prompt questions might also be useful as you reflect on recent or memorable experiences of teaching mathematics and consider ways to develop your own practice.

Prompts for thinking about the talk used by teachers and children	
Child Lens	**Teacher Lens**
• Do children (have opportunities to) explain their reasoning processes as well as their answers? • Are children comfortable sharing partial or incorrect work as part of a whole class discussion? • Do children actively listen to others and build on their ideas/support other children developing understandings? • Do children hold classmates and themselves accountable for justifying their positions, through the use of evidence and/or elaborating on their reasoning? • Do children see errors as opportunities for new learning? • Do children see their classmates as resources for their own learning?	• Does the teacher create safe climates in which children feel free to express their ideas and understandings? • Does the teacher provide time for children to develop and express mathematical ideas and reasoning? • Does the teacher support the purposeful use of academic language and of representations e.g. tables, symbols as central to mathematics? • Does the teacher position children as sense-makers who can make sense of key conceptual ideas? • Does the teacher build and maintain classroom norms that support every child's engagement? • Does the teacher expect and support meaningful mathematical engagement from all children, helping them to contribute and build on contributions from others? • Does the teacher employ a range of techniques that attribute ideas to children, to build children's ownership and identity?

General questions:

Each activity will have a specific mathematical goal but more generally, the *mathematical goal* can be understood as orchestrating opportunities for all children to work on core mathematical issues in ways that enable them to develop conceptual understandings, develop reasoning and problem solving skills, and use mathematical concepts, tools, methods and representations in relevant contexts.
Was this goal met? If so, how?

In relation to *Cognitive Demand*, the goal can be understood as orchestrating opportunities for all children to make their own sense of important mathematical ideas, developing deeper understandings by building on what they know. Was this goal met? If so, how?

In relation to *Equitable Access to Content*, the goal can be understood as supporting the diverse range of learners in engaging meaningfully in mathematical activity. Was this goal met? If so, how?

In relation to *Agency, Ownerhip and Identity*, the goal can be understood to be ensuring that every child has opportunities to explore, conjecture, reason and explain in ways that contribute to the development of agency, ownership of the mathematics and positive mathematical identities. Was this goal met? If so, how?

In relation to *Formative Assessment*, the goal can be understood as eliciting children's thinking and orchestrating subsequent interactions (between teacher and child or amongst children) in responsive ways. Was this goal met? If so, how?

Adapted from:
Schoenfeld, A. H., and the Teaching for Robust Understanding Project. (2016). The Teaching for Robust Understanding (TRU) observation guide for mathematics: A tool for teachers, coaches, administrators, and professional learning communities. Berkeley, CA: Graduate School of Education, University of California, Berkeley. Retrieved from: http://map.mathshell.org/

Key ideas about planning for productive talk:

- Deliberately cultivate norms and ground rules for talk so that children are clear what is expected of them - to talk about their mathematical thinking, to listen to others and try to understand their thinking and to work collaboratively to come to a solution.
- The key components of a math-talk learning community are questioning, explaining mathematical thinking, source of mathematical ideas and responsibility for learning. Creating a math-talk learning community involves devolving some mathematical authority to children in each of these areas, i.e., supporting them to ask questions, to explain their mathematical thinking, become the source of mathematical ideas and demonstrate responsibility for their own learning and that of their peers as they evaluate what is mathematically correct. Aim to share the responsibility for evaluating what is mathematically correct or incorrect with children.
- Experiment with increasing wait-time by counting silently in your head after you pose a question. Also experiment with silent wait-time where individuals think about the question you have posed and other approaches which introduce elements of pair or group work such as ‘think-pair-share’.
- There are different types of questions and talk moves that you can use to elicit children’s ideas, to help extend their reasoning and to encourage them to listen to and engage with the reasoning of other children.