Part 3 · Promoting Effective Classroom Interactions

"Teach all students as you would the brightest—with interdisciplinary curriculum, cooperative learning, hands-on activities, and a stronger focus on developing student's critical thinking skills."

Lynn & Wheelock, 1997

" Slowing down may be a way of speeding up."
Rowe, 1986

Increasing Wait Time

Background

In the late 1960s, Mary Budd Rowe analyzed instruction by teachers in a wide variety of settings. She found that teachers asked questions of students at the rate of two or three per minute. If student replies were not given within one second, the questions were repeated, rephrased, or answered by someone else. If students did respond quickly enough, the teacher then replied on average within nine-tenths of a second by asking another question or responding to the given answer (1978).

What Research Says

" Teachers who have learned to use silence report that children who do not ordinarily say much start talking and usually have exciting ideas."
Rowe, 1996

Rowe referred to the period of silence that follows teachers' questions as "wait time." She found that when wait times were increased to three seconds or longer the following aspects of children's and teachers' conversations increased as well:

- the length of student responses
- the number of unsolicited, relevant responses from students
- the number of student questions and the amount of speculative thinking
- student confidence
- the use of evidence in student responses
- the contributions by low-achieving students
- the creativity of responses

Increasing wait time also helped teachers to:

- ask more reflective and varied questions
- show more flexibility in responding to students
- decrease the total number of questions asked
- decrease disciplinary comments
- hold higher expectations for all students

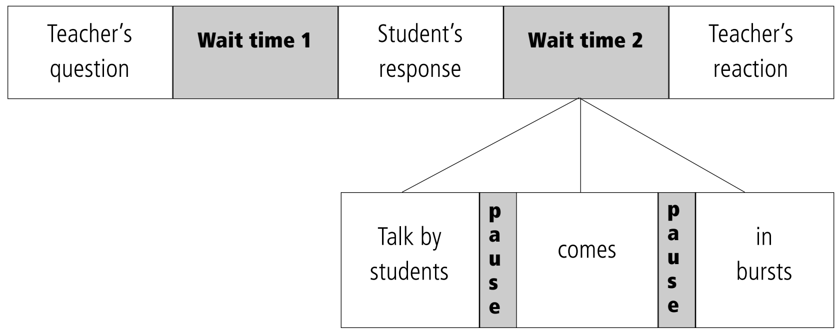
The research on wait time is very consistent. These findings hold across all disciplines as well as all levels, elementary through college.

Implications for the Classroom

There are several places during instruction when increasing wait time can have a positive effect on the level of discourse and thinking in the mathematics classroom:

- after the teacher asks an initial question and prior to calling on a student or group of students for a response (Wait time 1)
- after the response from a student or group of students to the initial question (Wait time 2)
- after receiving a student's question and prior to responding
- after asking a follow-up question

These opportunities can be identified in the following graphic (Rowe, 1978, p. 273):



"Wait time 2" is the term applied to the pause that follows a student's response. When a pause occurs here, the probability is higher that the students will continue a mathematical conversation among themselves.

Wait time is a key component in soliciting student responses to all forms of questions asked in class. Pausing has many purposes for the teacher and the students. For the teacher, pausing helps him/her focus on the student response and gives him/her time to understand the response and then to formulate appropriate follow-up questions. Additionally, if the teacher pauses, students are provided with time to understand the question or response and formulate their own thoughts, questions or elaborations. Equally important are the student pauses that indicate they are listening to other students' questions or responses. These wait times contribute to the growing of a community of mathematical thinkers rather than an audience dominated by a few fast thinkers.

"Optimal wait time may be dependent on the cognitive level of questions and the cognitive level of outcomes to be achieved."
Tobin, 1987

In practice, increasing wait time it is not always straightforward. There is a relationship between the amount of wait time and the level of the question asked. Lower level questions need shorter wait times than those requiring more thought from students. However, as wait time increases, the number of higher level cognitive questions that teachers ask increases as well. Since some students are ready to respond quickly, they should be acknowledged, but wait time should not be curtailed. This will give more students the opportunity to engage in mathematical thinking.

For Further Study

Rowe, M.B. (1986). "Wait time: Slowing down may be a way of speeding up." *Journal of Teacher Education*, 37(1), 43-50.

Rowe, M.B. (1996). "Science, silence and sanctions." *Science and Children*, 34(1), 35-37.

Tobin, K.G. (1987). "The role of wait time on higher level cognitive learning." *Review of Educational Research*, 57(1), 69-95.

"The notion that mathematics is a set of rules and formalisms invented by experts, which everyone else is to memorize and use to obtain unique, correct answers, must be changed."
Romberg, 1992

Questioning for Higher Order Thinking

Background

In the *Professional Standards for Teaching Mathematics*, NCTM (1991) indicates that classroom discourse, or "the ways of representing, thinking, talking, agreeing, and disagreeing" is central to helping students develop mathematical understanding and skills (p. 34). Teachers can "orchestrate discourse by posing questions and tasks that provoke and challenge students' thinking and by asking students to clarify and justify their ideas" (p. 37).

The development of higher order thinking cannot be achieved without teachers asking a variety of questions to challenge students' thinking—questions that require more than factual recall. Unfortunately, the research of Watson and Young found that teachers ask as many as 50,000 questions a year with at least 80 percent requiring only general recall of information (Vacc, 1993a, p.88).

In contrast, when teachers ask for explanations or follow-up responses, students have the opportunity to process and describe their own thinking. This not only provides necessary support for student learning but helps teachers assess student knowledge. Understanding student thinking provides necessary information for carefully planning follow-up questions and activities to move students' learning forward.

What Research Says

"Teachers' acceptance of student ideas is positively correlated with student learning gains."
Gall, 1984

Enough is known about questioning to establish that effective teacher questions contribute significantly to student learning. In their review, Prichard and Bingaman (1993, p. 220) report that achievement improves when students are asked more high level versus low level questions. Similarly, brain research findings show that those students who are asked to synthesize and report on their thinking increase their understanding and retention of new information by 75 percent (Wolfe, 1997). Student achievement increases for test questions that demand the use of higher cognitive level abilities. In general, student responses are more complex and at a higher cognitive level (Gabel, 1995, p. 127).

Research indicates that teachers must be conscious of their questioning practices in order to plan effective ways to stimulate and develop student thinking skills (Dantonio, 1990, p.16). Equally important to the level of the question is a well-designed sequence of questions with a focus on student responses.

Implications for the Classroom

"Improving the quality of teachers' questions is not sufficient. Students also need to learn the response requirement of different types of questions."
Gall, 1984

Several types of questions have the capacity to increase the cognitive level of student responses and shift the environment from one of "show and tell" to one of inquiry and discussion:

- Reasoning questions require students to construct logically organized information, e.g., "How do you know?", "What would happen if...?"
- Open questions allow for more than one acceptable answer, e.g., "Tell us everything you notice about...."
- Interpretive questions focus on applications, relationships, connections, or evaluations and lead students to analyze facts, e.g., "How would this be different if..."

In addition, certain techniques have proven valuable for increasing student participation and learning. *Think-pair-share* is a teaching strategy that gives students the opportunity to reflect individually before sharing their thinking with a partner or within a small group. The small group then shares its ideas with the whole group, listening to, paraphrasing, and comparing other group solutions to their own. This process complements the learning cycle, a method of organizing instruction that closely resembles the way people spontaneously construct knowledge (Lawson et al., 1989).

A *learning cycle* approach to instruction typically follows four stages. First, a teacher "launches" an investigation by introducing a rich task and asking questions that will pique student curiosity and motivate them. Next, students explore the problem alone, in pairs, or in small groups. The teacher then pulls the students back together to summarize their findings and attach labels/terms to the concepts involved in the lesson. Finally, students apply their learning to new situations.

"The authority for changing ideas comes from the results of experiments. Students have to learn to trust their ability to find answers. They have to feel safe in asking questions. They need time to think and a safe environment in which to speculate."

Rowe, 1978

Many new curriculum projects, in both mathematics and science, reinforce the learning cycle concept in their teacher support materials. The investigative nature of the tasks, supported by the questioning skills of the teacher, helps students develop and refine their thinking skills. Teachers are encouraged to pose questions which ensure worthwhile student activity and lead students to explore a concept or explain their thinking.

Facilitating questioning and thinking skills in the classroom is an art that, with effort, develops over time. The following strategies can help teachers improve the effectiveness of their questioning interactions with students:

- use precise language
- acknowledge all responses
- paraphrase student responses to acknowledge them
- rephrase questions rather than repeat them
- use non-specific praise sparingly
- acknowledge student performance by giving specific feedback
- ask students to "think about their thinking"
- encourage students to ask questions of you and other students
- consciously plan for productive interaction

For Further Study

Gall, M. (1984). "Synthesis of research on teachers' questioning." *Educational Leadership*, 42(3), 40-46.

Johnson, D.R. (1982). *Every minute counts: Making your math class work*. Palo Alto, CA: Dale Seymour Publications.

Vacc, N. (1993a). "Implementing the *Professional standards for teaching mathematics*: Questioning in the mathematics classroom." *Arithmetic Teacher*, 41(2), 88-91.

Structuring Collaborative Learning

Background

"What students can do with others today, they can do alone tomorrow."
Vygotsky, 1962

Quality teams, collaborative research teams, and project groups are common ways of organizing to get work done in the world outside school. There is a growing recognition that productive work groups require a variety of skills from their members, such as leading, following, listening, communicating, making decisions, negotiating, seeking feedback, and resolving conflicts.

Group learning has a long history in U.S. education and has always been a part of a skillful teacher's repertoire. Recent research and practice in cooperative learning stems from work by psychologist Morton Deutsch beginning in the late 1940s. Deutsch (1962) proposed three possible motivational goal structures for students: competitive, individualistic, and cooperative.

"Knowledge and skills are of no use if the student cannot apply them in cooperative interaction with other people."
Johnson et al., 1986

In competitive classrooms, students compete with one another to see who is best; their perception is that there are clear winners and losers. In classrooms that promote individualistic interactions, students work independently and the achievement of other students is irrelevant. In cooperative learning situations, student achievement is interdependent and individual students can achieve their learning goals only if other students also achieve their goals.

Cooperative learning differs from traditional small group instruction in that groups are structured to be heterogeneous, to have shared leadership, and to have both group and individual accountability for learning the material. Group tasks are developed to promote student dependence on each other in order to accomplish the learning goal. These factors provide incentives for students to help each other to learn (Slavin in Grouws, 1995).

In a typical cooperative learning situation in mathematics, students work on a problem in groups of two to five. They exchange views, discuss different approaches and solutions, and persuade each other of the soundness of their arguments. By explaining their ideas to others, students clarify their reasoning, order their thoughts, revise their strategies, and expand their conceptual understanding.

What Research Says

"Cooperative learning is a powerful tool for increasing self-confidence as a learner and for fostering true integration among diverse student populations."
Davidson, 1990a

The effectiveness of cooperative learning is well established in research. One research review reports that 72 percent of cooperative learning studies showed higher achievement for students involved in cooperative learning (Good et al., 1992). Reports on studies comparing the achievement of high-, middle-, and low-achieving students in competitive, individualistic, and cooperative learning situations show that cooperative learning experiences tend to produce higher results. This is true for "all ages, subject areas, and for tasks involving concept attainment, verbal problem solving, categorization, spatial problem solving, retention and memory, motor performance, and guessing-judging-predicting. For rote-decoding and correcting tasks, cooperation seems to be equally as effective as competitive and individualistic learning procedures" (Johnson et al., 1986, p. 24).

Cooperative group structures provide many learning opportunities that do not typically occur in traditional classrooms including opportunities to resolve conflicting points of view (Yackel, Cobb & Wood, 1991). They also result in greater self-confidence, better group relations, more cross-cultural integration, improved acceptance of mainstreamed children, and enhanced social skills (Kober, 1991).

Research suggests that flexible grouping that mixes students of different achievement levels, genders, and races/ethnicities better stimulates achievement gains for all students. Comparisons between high-achievers working in heterogeneous cooperative groups versus individualized set-

"The key lesson from research is to keep groups flexible and rearrange [them] periodically."
Kober, 1991

tings show that those in cooperative groups match or exceed their peers on traditional achievement scores. The cognitive processes involved in having to talk through and explain new material enhances scores on retention tests and promotes the development of higher quality reasoning strategies (Johnson et al., 1986).

Implications for the classroom

Teachers establish the guidelines and expectations for working cooperatively, and must directly teach group processing and interpersonal skills. Kober (1991, p. 14) suggests that teachers play a critical role in collaborative learning by forming groups, observing and interacting with groups, answering and clarifying questions, and moderating and helping students to tie ideas together.

Johnson and Johnson (1991, pp. 279-281) suggest the following requirements for effectively structured cooperative lessons:

- positive interdependence—students must recognize that they need one another to complete the task, often summarized as, "We sink or swim together."
- face to face promotive interaction among group members
- interpersonal and small-group skills
- reflection on group processes
- individual accountability

One of the concerns in the use of groups is the so-called "hitchhiker" problem where certain students do the majority of the work. Teachers who spend time explaining the reasons for cooperative group work and who do not grade on a curve encounter the hitchhiker problem less often.

While cooperative learning is well-suited to a variety of instructional purposes, tasks that require multiple abilities and contributions for goal completion are likely to promote better cooperative activity and collaboration by all students in a group (Cohen et al., 1982).

Research suggests that, for all students, cooperative, heterogeneous, and flexible groupings for instruction are more effective for stimulating and improving achievement than the traditional independent learner approach. Slavin (in Yackel et al., 1990) suggests that the teacher is instrumental in structuring "a pervasive norm in the classroom that helping one's peers to learn is not a marginal activity, but is a central element of students' roles" (p. 20).

For Further Study

Davidson, N. (Ed.). (1990a). *Cooperative learning in mathematics: A handbook for teachers*. Menlo Park, CA: Addison Wesley.

Davidson, N. (1990b). "Small-group cooperative learning in mathematics" In T.J. Cooney (Ed.), *Teaching and learning mathematics in the 1990's: 1990 yearbook*. Reston, VA: NCTM.

Johnson, D.W. & Johnson, R.T. (1990). "Social skills for successful group work." *Educational Leadership*, 47(4), 29-33.

"It boils down to this—if you can't talk about math, you are unlikely to do it well."
NCSM, 1997

Incorporating Oral and Written Communication

Background

Learning is predominately a social process. It involves checking against personal experience and negotiation with peers and teachers. Constructing meaning is an active process that includes hands-on learning with the materials and tools of mathematics and a focus on interpretation and explanation of student findings. What was once referred to as discussion must now become a classroom conversation among peers. Ideas are shared, respected, and available for reflection, discussion, and revision.

Oral and written communications influence students' reasoning ability, construction of mathematical knowledge, problem-solving abilities, self-confidence, and social skills acquisition (Lappan & Schram, 1989). Group discussions encourage students to apply previously-learned knowledge to new situations. Performing a writing task requires students to reflect on, analyze, and synthesize the material being studied in a thoughtful and precise way (Davison & Pearce, 1988). Conversations and writing exercises help students identify gaps in their own understanding and support students' construction of knowledge.

"Teachers who listen to students, and who plan instruction based on what they learn from listening, transform student learning."
NCSM, 1997

Communication is also a necessary component of assessment. Listening to students explain their thinking provides information for planning follow-up questions and activities. Through student writing, teachers have access to a unique source of information which is typically underutilized as an assessment resource in mathematics classrooms. By responding to student communications, either individually or before the whole class, teachers engage in a unique and continuous dialogue that can contribute to the whole process of teaching and learning (Miller, 1992).

What Research Says

Research indicates that student communication positively influences learning. Piagetian research shows that children develop language and logical thinking ability through an exchange of viewpoints. Studies also show that time spent in content-oriented interactions with peers and teachers enhances classroom performance and achievement. As students synthesize their thoughts to share them with or teach another student, their ability to retain new information improves by 75 percent (Wolfe, 1997).

"The nature of the activity and talk in the classroom shapes each student's opportunities to learn about particular topics as well as to develop their abilities to reason and communicate about those topics."
NCTM, 1991

In studies where levels of student talk were structured and measured, increased levels of "on task" student talk were related to increased achievement. Achievement was significantly higher for groups in which student talk was equal to or half as much as teacher talk compared to groups with no student talk (Dessart & Suydam, 1983).

Research studies on problem solving have shown that expository writing is an effective and practical tool for enhancing learning (Miller, 1991). Improved mastery of mathematics concepts and skills is possible if students are asked to write about their understanding.

Implications for the Classroom

Facilitating emerging mathematical ideas and conversations requires skill and patience. Responsibility for initiating discussion and maintaining focus is generally assumed by the teacher, especially with younger children. Thus it becomes very important that teachers strengthen their skills in facilitating discourse.

"The teacher's role is to create an environment where students feel free to:

- *share their beliefs and opinions*
- *ask what, how, and why questions*
- *take risks*
- *hypothesize*
- *make mistakes"*

Vacc, 1993b

Teachers can reinforce classroom communication skills and help students understand the value of focused writing and conversation when they:

- teach what is expected by sharing the norms and routines of communication
- pose questions and tasks that elicit, engage, and challenge each student's thinking
- listen carefully to students' ideas
- arrange seating so that students can easily see classmates as they speak
- encourage and monitor each student's communication and participation

Creating environments in which students can safely communicate their own mathematical thinking is a central teaching strategy and a crucial element in developing students' mathematical power. Students learn about the nature of mathematical knowledge as they justify their choices from among different strategies and solutions. As their ideas become the focus of critical examination, a different view of mathematics is created—a view that mathematics is dynamic, growing, and created by people.

Promoting classroom discourse often demands that teachers think quickly on their feet and make minute by minute decisions regarding:

- when to join a group quietly without comment
- when to elaborate, provide information, clarify an issue, or model a problem
- when to let a student/group struggle with a difficulty
- when and how to attach appropriate mathematical notation and language to students' ideas

Students in the classroom should be involved in communication in which they:

- clarify and justify their ideas orally and in writing
- think about a focus question individually before discussing it in class
- provide an audience for their peers, speaking to, questioning, and listening to one another
- write or discuss ideas with a partner before sharing with the whole group
- seek clarification when they don't understand a question or statement

Students learn mathematics by talking, writing, reasoning, and reflecting about mathematics. They are able to develop proficiency in the language of mathematics through active use of that language in meaningful contexts (Santiago & Spanos, 1993, p. 134).

Mathematics classrooms must promote students' ability to ask questions, share ideas, and communicate thinking in a dynamic environment of learning. Students who talk and write about mathematics as a way of making sense of the world are more likely to be able to use their own questions in the future to direct their learning and their work.

For Further Study

Lappan, G. & Schram, P.W. (1989). "Communication and reasoning: Critical dimensions of sense making in mathematics." In P. Trafton & A. Schulte (Eds.), *New directions for elementary school mathematics: 1989 yearbook.* Reston, VA: NCTM.

Mokros, J., Russell, S.J., & Economopoulos, K. (1995). *Beyond arithmetic: Changing mathematics in the elementary classroom*. Palo Alto, CA: Dale Seymour Publications.

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