I-THINK I Can Problem Solve

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Imagine a middle school classroom in which students are working in cooperative groups and explaining their thinking about solving math problems. Do you see a *specific* cooperative-learning group structure, or do you see some students copying work from group members, others working on the task, and yet others socializing? When provided with a structured cooperative group setting that promotes explanation and justification, research has shown that students have a greater potential for understanding connections among mathematical concepts that underlie problems and understanding connections between different procedures used to solve problems (Cobb et al. 1997). NCTM's Communication Standard (2000) and the Common Core State Standards for Mathematics (CCSSM) (CCSSI 2010) call for instruction that engages students in communicating mathematical ideas while problem solving, making connections among multiple representations of mathematical concepts and procedures, and justifying solutions.

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Many teachers recognize the usefulness of cooperative learning during problem solving but struggle to implement it in the classroom. This article describes my experience (Sararose D. Lynch) with two different cooperative group instructional strategies that promote reflective discourse, think-pair-share (Kagan 1994), and THINK (Thomas 2006). Both strategies promote communication during problem solving and can be implemented easily in any math classroom.

The think-pair-share model is familiar to many. Students first complete their mathematics problem individually, pair with another student to verbally communicate their reasoning and solution, and then share one of their explanations with other pairs. For years, this was the main cooperative learning framework I used in my fifth-grade through eighth-grade classes.

However, I wanted my students to continue to communicate their mathematical thinking while developing stronger metacognitive skills, so I initially began using the THINK framework (Thomas 2006). The THINK framework is a cooperative grouping strategy that is guided by the following prompts:

- Talk about the problem.
- How can it be solved?
- Identify a strategy to solve the problem.
- Notice how your strategy helped you solve the problem.
- Keep thinking about the problem. Does it make sense? Is there another way to solve it?

Students who used THINK displayed greater improvement in mathematical problem-solving skills as compared with those who did not (Thomas 2006).

Thomas then suggested that future research modify THINK to I-THINK, the "I" referring to students' independently thinking about the problem before group work commences. I then implemented the I-THINK problem-solving framework (see the **sidebar** on p. 11), which encourages students to analyze a problem individually and cooperatively, consider solution strategies, monitor their efforts, and justify their solution. It promotes verbal and written discourse (guided

The I-THINK Problem-Solving Framework

Individually think about the problem.

Talk about the problem.

How can it be solved?

Identify a strategy to solve the problem.

Notice how your strategy helped you solve the problem.

Keep thinking about the problem. Does it make sense? Is there another way to solve it?

by a graphic organizer) for students working in groups. I-THINK differs from think-pair-share because it incorporates cooperative learning and metacognitive instruction to help students be aware of, evaluate, and regulate their mathematical thinking (Wilson and Clarke 2004).

Figure 1 provides examples of student responses from a problem-solving assessment comparing students who regularly used I-THINK and those who did not. The I-THINK student clearly described his metacognitive processes throughout his problem solving by stating why he used certain operations, such as multiplication. Unlike the student from the other class, he evaluated the reasoning behind his solution strategies and justified his solution when he stated, "This makes sense because the greater time has more miles." This process supports research indicating that students who are exposed to metacognitive instruction through cooperative learning outperform other students who have not received this type of instruction (Kramarski, Mevarech, and Arami 2002). This article describes the I-THINK framework and addresses how it supports metacognition and mathematical communication. It also provides implementation strategies.

IMPLEMENTING I-THINK WITH YOUR STUDENTS

Mathematical discourse, both written and spoken mathematical communication that occurs in a classroom, is a supportive tool that helps students monitor their thinking while constructing new mathematical understandings (Lynch and Bolyard 2012). As part of an introduction to the I-THINK framework, teachers need to help students understand the importance of written and verbal discourse and develop a plan for engaging students in small-group and whole-class discourse.

One way to begin is to have a class discussion on "thinking about your thinking." This exercise should emphasize to students the importance of knowing how they solved a problem, why they solved it in a specific manner, and how to communicate their processes. Then students can be given a problem. Finding a solution is not the only focus. They will also learn to focus on explicitly thinking about how they solved a problem, why their solution worked, and how to communicate these ideas during discussion. The teacher should choose a problem scenario that students can identify with. One example is the following:

> Izzy has $10.00 and wants to do something with friends on Friday evening. Originally, she planned to go to the football game with two friends, but another friend asked her to go to a movie on Friday evening. Student admission to the football game is $5.00, a regular Friday night movie ticket costs $8.50, and a Friday night "Free Food" movie ticket (including admission and a small popcorn) costs $10.00. What should Izzy do and why?

Begin by having students work individually on the problem for a few

Fig. 1 Two student responses from the same problem highlight the differences between the thinking of those who regularly use I-THINK and those who do not.

Question

The Johnsons are driving at about 60 miles per hour. At that rate—

a. how far will they drive in 1/2 hour?
b. how far will they drive in 3 hours?

Directions

To the best of your ability, clearly identify the following:

1. What the problem wants you to find
2. What important information the problem gave you
3. What strategy or strategies you used to solve the problem
4. How you would tell someone else to solve the problem
5. Why your answer makes sense

(a) The problem

The problem wants me to find how many miles the Johnsons will drive in 30 min. (half hour) and in 180 min. (3 hours). The Johnsons are going 60 miles per hour (mph). I would tell someone to multiply, divide and subtract. I subtracted 30 from 60 because a half an hour is 30 min. and the Johnsons were going 60 miles per hour. I multiplied 60 by 3 because the Johnsons were going 60 mph and it wanted to know how far they could go in 3 hours, which is three sets of 60 miles. This makes sense because the greater time has more miles.

(b) From an I-THINK class

Half Hour <u>1800</u>
3 Hours <u>3600</u>
$60 \times 30 = \underline{1800}$
$1800 \times 2 = \underline{3600}$

1. How many miles.
2. 60 mph.
3. Multiplying.
4. Multiply the mph by the time.
5. Because my multiplication is right.

(c) From a non-I-THINK class

minutes. Class discussion should focus on identifying Izzy's dilemma; factors in her decision; her options; and students' suggestions for how to solve the problem, including why their suggestions make sense. Most students will recognize mathematically that she can afford all three options. Students may also consider the amount of money that Izzy will have remaining after her evening and use this as a determining factor in deciding what option she selects.

Following this discussion, the teacher can introduce the I-THINK framework and discuss how students will explicitly use the framework during cooperative group problem solving. Visual aids that can help students engage in metacognitive thinking include the following:

- A poster with the I-THINK steps (see the **sidebar**) explicitly stated
- Student note cards with an expanded description of the prompts on the I-THINK poster (see **fig. 2**)
- A graphic organizer to elicit students' thinking and participation during the use of I-THINK in teacher-assigned two- to four-person groups.

Note cards can elaborate on the poster prompts by providing self-monitoring questions for students during different steps of I-THINK. These "how" and "why" questions specifically address students' metacognitive skill development and promote student reflection. The graphic organizer allows students to record—

1. their individual thoughts about the problem;
2. the problem's main question;
3. potential solution methods;
4. their mathematical work; and
5. a final response, with a justifying statement of why their response makes sense.

Fig. 2 This problem-solving card contains the I-THINK steps.

Problem Solving with I-THINK
Individually think about the problem.
Talk about the problem.

SELF-MONITORING:
What did you do that helped you understand the problem?
Did you find any numbers or information you did not need? How did you know?
How can it be solved?
Identify a strategy to solve the problem.
Notice how your strategy helped you solve the problem.

SELF-MONITORING:
Did you try something that did not work? How did you figure out it was not going to work out?
Keep thinking about the problem. Does it make sense? Is there another way to solve it?

SELF-MONITORING:
Did you think about your answer after you got it?
How did you decide your answer was correct?

Source: Adapted from Van de Walle, Karp, and Bay-Williams (2010, p. 47)

SIXTH-GRADE CLASS EXAMPLE

The Jeff's Blocks task below is typically assigned to my sixth graders early in the school year. Before using this problem, the I-THINK framework and what it entails has already been introduced. Students sit in their assigned groups with a graphic organizer, an I-THINK note card, and some type of counting manipulative (Unifix® cubes, integer chips, and so on).

> Jeff had fewer than 500 blocks. When he made 5 equal rows, he had 1 block leftover; with 4 equal rows, he had 1 block leftover; and with 9 equal rows, he had no blocks leftover. How many blocks did Jeff have?

When introducing the Jeff's Blocks task, I asked students to take 22 counters and organize the counters into 2 equal rows and then into 3 equal rows. Next, we discussed what happened when they organized the counters in 2 equal rows as compared with 3 equal rows to orient students to what Jeff would be doing with blocks. After collecting the blocks, I read the problem aloud while it was being projected with the document projector. As I distributed a copy of the task to each group, students began the first step of I-THINK. They recorded their individual thoughts about the problem on the graphic organizer. After working individually, they then shared their thoughts with their small group.

I moved around the classroom, observing group interactions and addressing students' misconceptions and questions. I did not give them the solution. My questions encouraged students to analyze others' ideas and use prior knowledge of similar problems to identify solution strategies. For example, many student responses included a description of guess and check using multiples of 9 to see if they are divisible by 4 or 5. One student stated that the group had used guess and check to answer a problem during the "H" stage of I-THINK. I inquired how that group guessed and checked and asked them

Table 1 An I-THINK scoring rubric lists levels of understanding and their point values.

	4 Points	3 Points	2 Points	1 Point
Understand	Response indicates insight and complete understanding of the problem.	Response indicates understanding of the problem.	Response indicates partial understanding of the problem.	Response indicates misunderstanding of the problem.
Plan	Makes original and creative plan to solve the problem. Organizes data concisely and with insight. Uses one or more strategies to solve problem.	Shows workable plan to solve the problem. Organizes data appropriately. Chooses a strategy to solve the problem.	Shows a plan that will not solve the problem. Partially organizes data. Chooses an inappropriate strategy to solve the problem.	Produces unworkable plan. Does not organize data. Chooses no strategy or an incorrect strategy.
Solve	Shows a clear, well-organized implementation of the plan. Clearly shows logical processes used in implementation. Uses data that fit the information given in the problem.	Shows correct implementation of the plan. Shows some evidence of processes used. Makes few or no errors in data.	Shows partially correct implementation of the plan. Shows little evidence of processes used. Produces work having many errors.	Shows incorrect implementation of the plan. Produces work that is unrelated to the problem.
Check	Attains clear, reasonable solution that is meaningful to the problem. Clearly labels all parts. Gives clear, insightful reasons to explain the accuracy of the solution. If solution is not reasonable, shows evidence of choosing another strategy.	Finds reasonable, acceptable solution. Labels most parts. Gives an explanation for the solution. If solution is not reasonable, shows some evidence of redoing the problem.	Produces partially acceptable solution. Labels no parts or few parts. Gives incomplete or unclear explanation for the solution. If solution is not reasonable, shows no evidence of redoing the problem.	Attains unreasonable solution that is unrelated to the problem. Uses no labels. Gives no explanation for the solution.

Source: Thomas (2006)

to clearly explain what that meant in this problem's context. This type of questioning encouraged students to reflect on their thinking and mathematical reasoning, or metacognition. It helped them to be able to articulate what they tried and why during problem solving.

If a student told me that he or she knew that the answer was a multiple of 9, not 4 or 5, but did not know how to find the answer, I asked, "What do you know about multiples of 5?" This typically elicited a student reciting multiples of 5. Then I asked a different group member, "What do those numbers have in common?" These questions helped the students identify a method they could use to solve the problem. If a student stated, "Jeff had 81 blocks because that number fits the criteria," I asked what was meant by "fits the criteria" to elicit a more precise description of why the response made sense. Encouraging students to describe why their answer made sense allowed me to verbally model a self-monitoring question that they should always ask themselves when solving problems. After finding a solution, students explained their problem-solving understanding in their math journal before we discussed the problem as a class.

TIPS TO SUPPORT I-THINK IN THE CLASSROOM

The following suggestions can help a teacher facilitate I-THINK in a math class:

- Plan how often explicit I-THINK tasks will be facilitated.
- Consider student grouping.
- Identify mathematical problems to use.
- Identify visual supports that will be provided.
- Develop a routine for introducing problems.
- Determine how students' problem solutions will be discussed and assessed.

It is important for the teacher to work through the chosen problems in advance and consider how students might solve them. A key role of the teacher during the group work phase is to ask questions that will engage students in metacognition. The questions that accompany the I-THINK steps in **figure 2** will aid this process. However, identifying questions in advance that are specific to the task, such as those shared in the Jeff's Blocks example, are important when planning discussions with students.

I typically used I-THINK once a week with groups of two to four students. I pre-assigned these groups, using two different methods. Some weeks, I would assign mixed ability groups containing one above average, one below average, and one to two average students. Other weeks, I grouped students with similar interests and mathematical abilities. The problems came from either curriculum materials or from "Solve It!" (a department in this journal). I always allowed students to use the three main visual aids—a graphic organizer, the note card, and the poster prompt.

To assess students' solutions, I asked them to summarize their solution and thinking during I-THINK by writing in a mathematics response journal. Then we had a whole-class discussion in which students presented their solutions using a document camera and explained how they found their conclusion. I collected their journal entries and scored them using the rubric in **table 1**. This article's description of how I regularly facilitated I-THINK is only one example. Your students' needs and the requirements of your district will ultimately determine how best to facilitate I-THINK in your classroom.

THE POWER OF THE FRAMEWORK

Instruction should provide many opportunities for students to develop their ability to communicate their mathematical thinking and reasoning (CCSSI 2010; NCTM 2000). The I-THINK framework supports encouraging a thorough consideration of a problem's context, posing explicit questions about mathematical processes, and reasoning through cooperative groups. When students' metacognition is identified and developed through mathematical discourse, teachers can facilitate a learning environment that directly addresses students' mathematical problem-solving needs (Kramarski, Mevarech, and Arami 2002).

CCSSM calls for a classroom environment in which *all* students engage in meaningful mathematical discourse. The use of I-THINK can meet these needs by giving students opportunities to (1) develop greater problem-solving and metacognitive skills and (2) make mathematical connections while they question, share, and analyze ideas in cooperative groups.

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