HOW TO CREATE OPEN-ENDED QUESTIONS

GENERAL TECHNIQUES

Creating open-ended questions may be even harder than answering them. However, as with most things, the more you do it the better you will become. Another appropriate aphorism is that two heads are better than one, so encourage a colleague to engage in the endeavor with you or to offer feedback on questions you create. Be sure to answer the questions in writing yourself to gauge the difficulty that students will have in framing a response and to capture some of the criteria you will use to evaluate students' work.

Keep in mind that the reason to use open-ended questions is to inspire much more than just fact recall or skills practice. Rather, you are looking for what students know and why they believe it to be valid. As a matter of fact, adding "How do you know your answer is true?" to any closed question is one of the easiest ways to open up student thinking and assessment opportunities. The following are other techniques that can be employed to create open-ended questions.

JEOPARDY

As in the game show of the same name, you give students an answer that is appropriate for a question from the topic they are studying and then invite them to create statements or questions that would yield such an answer. This should produce multiple responses and the opportunity to observe how each student is able to apply ideas from recent work.

Example

Twenty-five cents is the answer. What could the question be?

Student responses might include:

How much is two dimes and a nickel?
Which coin is greater than a dime?
13¢ and 12¢ = ?
How much money do you have?

Example

The probability is ¼. What could the question be?

Student responses might include:

What is the probability of spinning blue on a color wheel divided into four equal sections with one colored blue?

[Source: Open-Ended Questions in Elementary Mathematics: Instruction & Assessment, Eye on Education]
by Mary Kay Dyer & Christine Moynihan

What is the probability of getting two heads when tossing two coins?
What is the probability of picking a month that begins with a J?

Such solutions have many possible questions. If students are encouraged to give multiple responses and to think expansively, much can be gleaned about the range of their thinking and their ability to make connections between ideas.

RESOLVING A DISAGREEMENT AND CORRECTING MISTAKES

You might take the fodder for these types of questions directly from students' papers. Choose the erroneous work of one or two students as a point for discussion. Be sure to change the names or ask the authors' permission first.

Example

John believes the answer to 24 + 37 is 51, but Katrina is almost positive it must be 511. Who is correct? Explain your thinking in writing.

Although offering two incorrect solutions may seem like a trick question to the students, it is a particularly effective method for finding other students who have misconceptions as they try to defend one of the positions. It is also helpful for identifying students who are able to explain to their peers why both solutions are incorrect.

A classic geometric misconception is used next in a similar fashion.

Example

Maria tells Toni she has five rectangles in her pattern block design. Toni says she is wrong because she sees three rectangles and two squares. What will you say to resolve the disagreement?

Along similar lines, one teacher asked a class of fourth graders to identify all the different types of mistakes one could make in a specific two-digit by two-digit multiplication problem. A long list was created by combining the ideas from all the students. Besides being a great open-ended question, it helped students learn to reflect on their own errors. Often students have difficulty identifying their own mistakes. It is important to help them develop explicit techniques for checking their solutions for reasonableness and for error analysis.

FROM THE REAL WORLD

We always tell students that mathematics is everywhere, but do we create an environment that validates this perspective? Look for things in your home or the school that will entice students to find many different solutions as well as real-world applications. Menus, sales flyers, or magazines are good sources.

[Source: Open-Ended Questions in Elementary Mathematics: Instruction & Assessment, Eye on Education]
by Mary Kay Dyer & Christine Moynihan

Example

- **If school lunches came from this restaurant, what might they be and how much would they cost?**
- **What are the possibilities for spending between $5 and $10 at this store?**
- **What can you say about the relationship of space devoted to articles and to advertisements in magazines.**

You may want to encourage students to bring in props or make drawings for their reports on a number, measure, or shape treasure hunt such as the following:

Example

- **Where can you see mathematics at work on your way home?**
- **What shapes are in the room, and how are they used?**
- **What units of measure are in your cupboards at home, and why were they selected for those particular products?**
- **What mathematics do others in your family do during their day? Is it like any work you have done?**

These types of questions can be used to evoke interest in new mathematical ideas as well as to assess what the students have already learned. For example, if individual students did not find all the different measuring units identified by other students, they are likely to want to be introduced to those they may have never noticed.

TELL ME ALL

One of the teachers we worked with began her open-ended question odyssey by simply asking students to write about what they knew relating to a topic before and after a unit of instruction. She related that it was slow going at first, but by the end of the year, the students were quite proficient, usually filling more than one page. She also commented that with this approach, she knew more about her students' abilities than she ever thought possible.

With questions this open, it is often effective to give or elicit vocabulary words that could be included in the response. Graphic organizers might also be used to help students capture all their ideas well.

[Source: Open-Ended Questions in Elementary Mathematics: Instruction & Assessment, Eye on Education]
by Mary Kay Dyer & Christine Moynihan

Example

What things do you know about fractions?

Fifth graders tried this question. The words and phrases they brainstormed initially only included: thirds, fourths, numerator, denominator, part of, whole, shading. Their first attempt at writing about fractions highlighted their misconceptions and confusion but was helpful in planning follow-up experiences. By the end of the unit, the students' responses were much richer, and they were pleased to see their own growth in knowledge.

Younger children can do similar work by offering pictures as well as words. These can be used by the class in writing a story about the mathematics they explored during a week.

Example

One teacher read from and made available several books about shapes so that students had models. She engaged the students in several hands-on experiences with pattern blocks. As a nice connection among literature, art, and geometry, she had pairs of students work together to create a story.

With some students it might be necessary to begin to learn how to respond to a tell-all question by asking for stories about a single day.

Example

Write and illustrate a story involving pattern blocks.

The tell-all type of question helps students learn to reflect on and synthesize the mathematical ideas that they have been experiencing. If students are to become lifelong, independent learners of mathematics, these skills of reflection and synthesis should be a major focus in the schooling experience. Work with them should begin at a young age and be fostered each year.

ADAPTATIONS FROM TEXT QUESTIONS

CHANGE THE WORDING

If the goal of using open-ended and open-response questions is to examine students' thinking, then we must choose words that inspire thinking. Mathematics textbook problems are usually prefaced with words that only suggest performing a learned routine: add, multiply, solve, and so on. Change the text experience with words you may have associated with thinking skills in other disciplines.

[Source: Open-Ended Questions in Elementary Mathematics: Instruction & Assessment, Eye on Education]
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Example

- **With "3 + 4 = ?", ask students to *draw* a picture that proves the answer is 7.**
- **With "round 23 to the nearest 10", have them *explain* when it might be advantageous to**

use 20 and when rounding to 30 might be more advantageous.

- **With a page of division problems, ask students to *predict* which will have quotients greater than 10 and to *explain* why they have chosen particular examples.**
- **With a whole page of varied problems, ask students to explain how some problems are *alike and some are different*.**
- **With word problems, have students *restate the problem differently*.**
- **With number sentences, have students make them meaningful by *creating word problems* that might spawn such number sentences.**
- **With any problem, ask students to *generate other problems* that would yield the same answer.**

Sometimes you will find ideas for open-ended questions embedded in the teacher hints or dialogues on the side of the lesson pages. Rather than telling what is suggested, pose a question that will have a similar effect but will be more thought provoking.

Example

- **Text: "Remind students that multiplication is repeated addition."**
  - **Question: In what ways are addition and multiplication alike?**
- **Text: "Tell students that 44 means 4 tens and 4 ones."**
  - **Question: How are the fours in 44 different?**

FROM ILLUSTRATIONS

A picture may not elicit a thousand words from a young student, but it may be worth more than a typical textbook question. Look for an illustration and consider how it could relate to questions other than the one being asked. Here are some questions that help students to see a collection of squares from many different perspectives and to make connections across several different mathematical domains.

[Source: Open-Ended Questions in Elementary Mathematics: Instruction & Assessment, Eye on Education]
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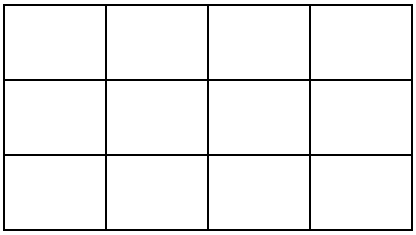
Example



- **Show all the different rectangles you can create by folding along one of the line segments of this rectangle.**
- **Explain to someone how to make this drawing.**
- **Draw pictures to show the ways you can shade one-third of this figure.**
- **This is one of the shapes in a pattern of growing grids. What might come before and after it? Describe the pattern.**
- **What other ways could these tiles be arranged to make a rectangle? How does this change the area and perimeter?**

Most commercial mathematics programs do require adaptations to make their questions more open-ended. To insure that there is sufficient instructional time for all the areas of mathematics offered by commercial texts and open-ended adaptations, consider reducing the amount of time your students spend working with "naked numbers;" that is, exercises that come without a context and yield only one right answer. Students need meaningful experiences to make sense of the mathematics they do. It is important that we help them understand "when and how they will use this stuff."

FROM GOAL STATEMENTS AND STANDARDS

Writing open-ended questions from goals can seem difficult because goal statements are more abstract than day-to-day experiences. Perhaps this is why the NCTM created *Addenda Books* (NCTM, 1992). You will find many examples in the seven-grade level and four topic-specific books in this series that relate directly to the *Curriculum and Evaluation Standards* (NCTM, 1989).

Many states have produced documents relating to their statewide assessment programs that include samples of open-ended questions. You can often download such documents by connecting to the state education office through the Internet. Information about some of these documents is contained in Chapter 6, "Where Open-Ended Questions Are Found."

To create open-ended questions from your district's goals, start from a broad goal statement rather than from each individual behavior or skill. Next, consider a few behaviors that you think will show students' grasp of the idea(s) in the goal statement. Then think of an open-response task that would afford you the opportunity of assessing how students used the behaviors to find a solution.

[Source: Open-Ended Questions in Elementary Mathematics: Instruction & Assessment, Eye on Education]
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Example

- **Goal**
  - **Students will exhibit understanding of the place value system.**
- **Behaviors**
  - **Students can represent the digit values.**
  - **Students can name the places up to a million.**
  - **Students can order numbers.**
  - **Students can identify real-world uses for numbers.**
- **Task**
  - **Look through the newspaper during the next week. Find three examples of dollar amounts that are greater than $1,000. List them in order from smallest to largest. Explain what each amount would look like as a collection of bills. Also include an explanation of why the amount was cited in the newspaper;**

OR

  - **If you have one of every coin, what are the four different things you could afford? Order the amounts from most to least expensive. Draw pictures and show the amounts in coins.**

Both are fairly simple tasks that allow children to exhibit their knowledge of numbers in the world as well as several numeration concepts. As you can see from the example, one of the bounties of using open-ended questions is assessing several behaviors with only one question.

STUDENT-CREATED QUESTIONS

Much can be learned about students' knowledge by the types of questions they choose to offer. Some teachers review for tests by having students create questions that they themselves think should be asked. Students typically offer closed questions but may be able to create more open versions if they have had opportunities to respond to different types of questions. Students may be inspired by using techniques similar to those shown in this chapter. Students can be given a solution and a goal of the unit, say "18 inches" and "understanding subtraction."

Example

Use the "jeopardy" model and create a question that would have the answer 18 inches and that must require some thinking about subtraction.

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SAMPLE SOLUTIONS

A sample closed question is, "What is the difference between 36 inches and 18 inches?" A related open question would be, "Name two things in the room that are different in length by about 18 inches." Though both questions show a good understanding of the concept of difference, the capability to find the correct answer, and the ability to reason backwards from a solution, the more open question addresses several of the standards in *Assessment Standards for School Mathematics* (NCTM, 1995, p.18):

3. Mathematics as Reasoning
5. Estimation
7. Concepts of Whole Number Operations
8. Whole Number Computation
10. Measurement

Research indicates that students who create problems perform better on tests of problem solving than other students who have not had the experience. Even those who have had explicit training in techniques of problem solving do not perform as well as students who have problem-creating experiences. Also, students enjoy solving problems created by their peers. Consider using student-created questions on homework and tests.

QUALITY CONTROL

Sometimes it is hard to know whether a question you have constructed will be a valuable assessment tool. Many of the sample questions in this chapter are stated very simply but yield a wealth of responses if students are encouraged to find many possibilities. You could argue that both of the following questions are open, but the latter will expose more of the students' thinking.

Example

- **Name some of the even numbers.**

versus

- **What are some different ways to find all the even numbers on the hundred chart and the number line?**

Collison (1992) offers the following questions to help you evaluate whether you have asked a question that is likely to yield rich responses. Does the question:

- Focus on essential curriculum concepts?
- Lead to other questions?
- Tap real-world situations (if possible)?

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- Allow students to work together to pose solutions?
- Allow for multiple pathways to a solution or multiple solutions?

You will probably get more robust answers to questions if they are intriguing to students. Be sure a question offers a new perspective or challenge, especially if it relates to work that has been ongoing in the classroom or was done last year. As an alternative, consider asking the question before students have learned the appropriate skills. This can stimulate their interest in the topic and provide you the opportunity to observe their problem-solving skills.

Example

- **About how many breaths have you taken in your life?**
- **How long is the hall?**

These questions could be used to encourage students to learn about and use different units of measure while they are practicing measuring and computing skills. The large numbers the investigations produce will provide a challenge and an incentive to learn about conversion between units.

If students are confused and unable to get started with a question, it can be a message to you that they are not quite sure what is being asked. The difficulty may not rest with the quality of the question but in the students' understanding of the parameters of the response that will be acceptable. Questions of only a few words may be easy for all students to read but may warrant coaching. Here are a few tips:

- Start students with a title sentence or even a list of words to include in their response.
- Check to be sure students have an understanding of the content of the question. Ask them to restate the task in their own words.
- If the task is very open, one or two examples may be needed to help students frame their responses.

Example

- **What are different ways to show 20?**
- **What are different ways to show ¼?**

SAMPLE SOLUTIONS

20 can be made by:
1 + 19
2 Base Ten rods

¼ on the calculator looks like .25
¼ is 2 shaded squares out of 8

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- Suggest where to find important information. For example, "You may use calculators and blocks to help you think about possibilities."
- Give a sense of the scope of the expected response.

"There are many possible answers. Work by yourself to think of a few and then make a list of everything your group has thought of together."

- Post a rubric of what you value in a response.

For more tips about how to help students become comfortable with open-ended questions, read Chapter 4, "How to Establish and Support an Open-Ended Question Environment."

SUMMARY

Like many things, creating open-ended questions improves with experience. The first few attempts may be a struggle for both the teacher and the students, but persistence will be rewarded with significant information about students' knowledge and process skills. Creating open-ended questions is easily accomplished by changing the wording of closed questions in texts or asking students to relate a closed question to a real-world situation. Having students describe errors in a piece of work or explain a process for finding the correct answer also produces multiple solutions.

When we do real-world mathematics, we must often use several different skills, including reflection about and synthesis of things done previously. Open-ended questions that can be used to assess several things at once are time efficient and better reflect why we learn about mathematics. A few open-ended questions that incorporate most of the skills in a unit can inform the teacher about student progress and motivate the students to investigate new ideas. Such questions can be as simple as "tell me what you know about ___ _____."

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