

# Mathematical Questioning Guide

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Many math teachers have encountered the exasperated student who says, “Just tell me how to solve the problem so I can get it right on the test!” And who hasn’t been in a classroom where math instruction focuses on the destination—that golden “right answer”—and not the journey? An emphasis on getting the answer, using recipe-like procedures, and learning algorithms has been a time-honored approach to teaching math, probably going back to Pythagoras.

Yet over the past few decades, the pedagogical thinking around math instruction has undergone a sea change. The model of math learning has shifted from learning a procedure or algorithm in order to “get the right answer” to focusing on the process and method of doing math, in order to discover many different ways to the same solution and understand the underlying principles more deeply.

Effective questioning by the teacher has been at the center of this shift, engaging students in the process, building their metacognition skills, and working to make math interesting, accessible, and meaningful. A math classroom where the teacher guides the learning through questioning strategies can be a rich learning environment where the students learn to articulate their thinking, engage in mathematical discourse, and pose questions themselves. Yet it doesn’t come easy: good questioning can result in unexpected responses, and the teacher must be prepared to go wherever those answers take the class.

In this article we’ll tackle some best practices around questioning, its challenges and pitfalls, and the use of questioning strategies within STEMscopes Math.

## How does effective questioning relate to math proficiency?

In the 2013 *Common Core State Standards for Mathematics*, the authors described a vision for mathematical proficiency that focused on deep understanding, and the ability to articulate math concepts rather than merely remembering how to perform mathematical procedures:

One hallmark of mathematical understanding is the ability to justify, in a way appropriate to the student's mathematical maturity, why a particular mathematical statement is true or where a mathematical rule comes from. There is a world of difference between a student who can summon a mnemonic device to expand a product such as  $(a + b)(x + y)$  and a student who can explain where the mnemonic comes from.<sup>1</sup>

In support of that vision, the document laid out a set of proficiencies that have been foundational for subsequent standards and teacher training programs in the years since. These are the skills that teachers should be developing in their students through the practice of teaching math.

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

It is clear that gaining comfort and proficiency with these skills requires scaffolding on the part of the teacher and practice on the part of the student, and that routine formative assessment of the student's progress must be an integral part of the process.

This is where questioning comes in. In general, there are several purposes to using good questioning strategies.

- They engage students in the work, whether discussing with the teacher or among themselves.
- They help the teacher assess students formatively throughout the lesson and over the course of many lessons.
- They enable the teacher to monitor individual and class-wide progress, and adjust subsequent lessons accordingly.

- They enable the teacher to differentiate instruction by student ability and learning style, asking questions that meet each student where they are and encourage them to move forward.
- They teach students not only the material itself but metacognition—the ability to observe their own thinking and learning process and, for instance, identify different approaches to the same problem.<sup>2</sup> Strengthening student metacognition in itself has a wide range of benefits. It increases students' ability to apply what they have learned to new contexts and problems. It gives students a better sense of their own strengths and weaknesses, competencies and areas of growth, so they can better determine how to improve or extend their skills, and maintain insight about their own abilities within a wide range of domains.

Giving students practice thinking about a problem, relating it to previous learning, discussing it, considering alternative approaches and tools, and understanding their own reasoning takes greater engagement than traditional orientation to teaching math procedures. Questioning is an integral part of eliciting that student thinking and response. Before we talk about the benefits of questioning, though, let's consider the all-important distinction between closed- and open-ended questions.

## Closed vs. open-ended questioning

While there are many techniques and nuances to effective questioning, there is one key practice common to all of them: asking open-ended questions. This is not to say that closed-ended questions are to be abandoned in math teaching: the best maintains a balance of both types of approaches. In a sense, the difference between open- and closed-ended questions mirrors the difference between formative and summative assessment. Closed-ended questions generally have one correct—and short—answer, a questioning technique that, as middle school assistant principal Samantha Piscopo puts it, “makes students reluctant to participate unless they can guarantee their correctness,”<sup>4</sup> and does not provide the teacher or the student insight into the process of approaching

1. Source: Common Core State Standards Initiative (2013). Common Core State Standards for Mathematics, p. 4. [https://www.mathedleadership.org/docs/ccss/itp/Introduction\\_Resources.pdf](https://www.mathedleadership.org/docs/ccss/itp/Introduction_Resources.pdf)

2. Plaisance, D. (2015). Quality questioning for effective mathematics teaching. NCTM 2015 Annual Meeting and Exposition. QUALITY QUESTIONING EFFECTIVE MATHEMATICS ...nctm.confex.com › nctm › Handout › Session31497

3. Source: Chick, N. (2013). Metacognition. Vanderbilt University Center for Teaching. <https://cft.vanderbilt.edu/guides-sub-pages/metacognition/>.

4. Piscopo, S. (2019). Questioning Strategies that Invite Math Participation. ASCD Express 14:19.

and solving problems using math. Examples of closed-ended questions are, “What are the coordinates where the two lines intersect?” “4 or 5: Which number is bigger?” and “What is the name of a shape with 4 sides where only 2 are parallel?”

In contrast, open-ended questions do not elicit short answers, but instead ask students to explain, compare, conjecture, describe, imagine, reason, or make connections with what they already know. Some examples are, “What might be a first step to solving this problem?”, “What skills have we learned in class that you could apply to this problem?”, “If you did *this* instead of *that*, what would be different?”, and “How did you think about this problem?” There are generally no wrong answers to open-ended questions.

## Benefits of teaching through questioning in mathematics

Over recent decades, teachers became increasingly interested in different types of formative assessment, rather than relying as heavily on summative assessment in math. As part of this movement, the NCTM proposed standards in 1991 that, among other things, highlighted the importance of posing open-ended questions to students as both a means of assessing their comprehension and deepening their understanding of mathematical concepts.

The teacher of mathematics should orchestrate discourse by posing questions and tasks that elicit, engage, and challenge each student thinking; listening carefully to students’ ideas; asking students to clarify their ideas orally and in writing. A teacher’s role is to be active in a different way from that in traditional classroom discourse. Instead of doing virtually all the talking, modeling, and explaining alone, teachers must encourage and expect students to do so. Teachers must do more listening and students more reasoning. For discourse to promote students learning teachers must orchestrate carefully.<sup>5</sup>

Today this approach to questioning is more and more the norm, and research into effective questioning over the past decades has contributed much to our understanding of good questioning technique in the context of teaching mathematics.

There are several benefits to using open-ended questions. They shift student thinking to the process of solving math problems rather than the outcome—that sought-after right answer. Open-ended questions are often the kick-off to a discussion that can draw in all the students and provide an

opportunity to explore different viewpoints and approaches, student questioning, and collaborative problem-solving. And they are inclusive: especially in the early stages of teaching a concept, questions can be structured so that they invite every student to participate. For example, the teacher can start with a question about the process that every student can answer, like “What are your first thoughts about how to approach this problem?” And teachers can call on quiet students with open-ended questions that do not put them on the spot, requiring that right answer. Subsequent questioning can become more specific and more complex. A follow-on question to this example might be, “How would you show this problem in a drawing?”

Because open-ended questions don’t focus on the answer, students don’t feel the same pressure to get things right the first time and are less likely to feel discouraged by their mistakes. For the teacher, the answers to open-ended questions give insights into misconceptions and provide a good overview on what students know. Finally, the metacognitive process of thinking through a problem or concept builds a student’s ability to absorb new approaches to problems and understand their own errors without judgment.

The teaching challenge of these open-ended questions is that they yield, in turn, a wider range of student responses—some unexpected—and can feel frustrating to teachers and students, as the process may feel slow and unproductive at first, until the classroom becomes comfortable with the format and develops normative behaviors that support constructive discussion and supportive behavioral norms. The process requires practice and patience on the part of teachers, who must learn to skillfully draw on a personal toolkit of pedagogical strategies and responses to make the discussion fruitful and relevant to everyone. Developing that toolkit can take teachers some time, reflection, and preparation, and even as early in the reform movement as 1991, the National Council of Teachers of Mathematics (NCTM) acknowledged that early-career teachers needed support to prepare them for this approach.

## Encouraging participation from students

Some of the most basic questioning skills are also the most difficult to master: they often require even new teachers to reflect on their own oral questioning skills and consciously change some reflexive listening and presenting habits. Some of these good basic skills include preparing the most important questions in advance, asking questions clearly,

5. Piscopo, S. (2019). Questioning Strategies that Invite Math Participation. ASCD Express 14:19.



concisely, and in multiple ways to promote understanding, choosing questions that stimulate thinking (usually open-ended questions), and giving students enough time to think about and formulate their responses.<sup>6</sup>

Here is a selection of other teaching practices that encourage student participation.

- a. Select topics and problems based on real-world issues that are relevant to students. As with any subject, integrating the topic into the students' own experience of the real world will increase their engagement and interest in the underlying concepts. Some examples include using money to buy things at a favorite store, comparing sports statistics for a local team, and making measurement comparisons between familiar local landmarks.
- b. Use different models for asking questions of students: invite volunteers, but sometimes call directly on particular students, differentiating questions based on level of understanding. Setting the expectation that this will happen routinely—while making sure to listen to responses carefully and responding without judgment—will create a positive classroom culture around questioning. Solicit other student feedback: directly ask for student input and ask them to comment on one another's work, opinions, and ideas appropriately, without fear of judgment. Break students into dyads and small work groups, who share their own answers and thinking about questions and then present each other's responses to the rest of the class.
- c. Celebrate differences in approach and thinking as learning opportunities. Champion new ideas, inviting the class to explore different ways of thinking about a problem, and encouraging them to articulate the differences in approaches and identify the strengths and shortcomings of each. Don't chastise students when they are wrong: the way the teacher models a response will set the pattern for how students react to each other's ideas and approaches to problem-solving when working together in small groups or dyads.
- d. Make math visible: start by making algorithms and equations into manipulatives and visuals in order to encourage open discussion and ease of understanding, and provide differentiated learning across students. As the lesson and students' level of sophistication progresses, ask students to relate what they understood visually or kinesthetically to more abstract concepts and representations in math. This approach forms the basis for STEMscopes' CRA (concrete-representational-abstract), which transitions students from hands-on instruction to symbolic math (more on this later).

- e. Ask students to explain their work and their thinking about a problem they have worked to solve on their own or with a partner or group. Ask probing questions, like "What decisions did you make as you drew this graph?" or "Can you tell us more about how you used the table to find the answer?" If a group struggled between different approaches, ask them to describe the differences and defend their choice of one over another.

## Pitfalls

Even the most well-intentioned teacher can struggle with the open-ended questioning process. Proponents of open-ended questioning strategies in math caution teachers to avoid several common pitfalls.

- a. **Funneling**, where the teacher disregards unexpected or unconventional student responses and focuses on the ones that will lead to the desired conclusion faster, or "pushes" students toward an answer with leading questions. Instead, ask questions that help students bring their own thinking into focus: ask what they notice, ask probing questions, encourage reflection and justification, and encourage them to communicate their thoughts clearly.
- b. **Re-interpreting** student responses to make them conform more readily to the expected answer. Rather than trying to interpret their reasoning and jumping to conclusions, ask them to clarify their thoughts further. This approach does slow the process down, but puts the student in the driver's seat and leads to greater comprehension, potentially among a number of students who are thinking along the same lines.
- c. **Excessive teacher talk**. It's easy for a teacher to dominate the conversation when there's silence... and hard to wait! Discipline yourself to accept silences as constructive, rather than rushing into the breach; use multiple ways to encourage participation, as described above; and develop a toolkit of formative open-ended questions that will elicit responses from everyone.
- d. **Wanting to provide the answer**. It's hard not to. But don't "save" students by just giving them the answer or—as in the case of the student who begs, "Just tell me how to do it!"—Teaching them the step-by-step procedure. It is a harder and sometimes more time-consuming approach, but remind yourself that valuing the process over the outcome will teach students an approach to mathematics that will yield benefits throughout their lives.

6. NCTM (1991). Professional Standards for Teaching Mathematics, pp. 35-36. Quoted in McCarthy et al.

## Questioning in STEMscopes Math

STEMscopes Math infuses the curriculum materials with questioning best practices and teacher questioning supports. You'll find both checks for understanding that are directed at quickly gauging student understanding, as well as open-ended questioning within activities such as My Math Thoughts and math PBL activities where students explore, debate, and question the ways we use math in the real world. Underlying these practices is the STEMscopes Math CRA model, which helps students transition from the physical and tangible to the symbolic math we use as adults, a transition that is gradual, scaffolded, and integrated into every lesson. It provides a strong foundational basis for asking questions at different levels of rigor and complexity while allowing students to discover that other students might solve problems in a different way. Those

differences in approach and method are a great questioning focal point between students, offering an opportunity to learn the math more deeply and focus on the process over just getting the "right" answer.

Going a step further, STEMscopes Math also contains foundational primers on mathematical process standards and communicating math ideas that will bring students to higher order thinking. Find out more and start a free preview by visiting [stemscopes.com/math](https://stemscopes.com/math).

### Conclusion

In the classic movie *Up the Down Staircase*, new teacher Sandy Dennis gazes with satisfaction around a classroom of inner-city students that she has successfully engaged in a heated discussion of *A Tale of Two Cities*—until her administrator steps in and chastises her for losing control of her class. Moving away from procedurally-based lesson plans and the use of closed-ended questions toward a more open-ended and unpredictable style of learning can feel challenging and uncomfortable to new teachers and veterans alike, not only pedagogically and intellectually, but also in terms of classroom management. Yet shifting to an effective questioning approach in math can elicit the engagement, lively discussions, and deep learning that will pave the way for student understanding of math concepts for years to come. And teaching an approach to problem solving that involves discussion, questioning, uncertainty, discovery, and metacognitive skills prepares students to tackle the complex challenges in their future, in both academia and real life.



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