Dimension 5: Constructing Knowledge

INSTRUCTIONAL APPROACHES

Students come to the mathematics classroom with a set of conceptions about the world that provides a framework for their learning. We now recognize that this pre-existing knowledge comes into play as students construct their own knowledge. This theory of learning is referred to as constructivist learning.

Whether the teacher consciously thinks about teaching with a "constructivist approach" or not, students will inevitably bring prior knowledge to bear in any task they undertake.

The skilled teacher not only recognizes that prior knowledge will play a role in a new learning situation, but takes advantage of it by asking for student input to "cement" the new knowledge in a solid structure. The teacher can do this through setting up appropriate tasks, monitoring students' exploration, and negotiating meaning and understanding with students through effective questioning. Through good questioning techniques, the teacher guides the direction of student inquiry and encourages new patterns in thinking. In classrooms where constructivism is the predominant approach, students see themselves as mathematicians and take more responsibility for their learning.

Dr. Olive Chapman of the University of Calgary has described three approaches to mathematics teaching: skills, conceptual, and constructivist. A teacher using a constructivist approach is more deliberate in recognizing the role of prior knowledge and using it to frame new knowledge than a teacher using either a skills or conceptual approach. A teacher using a conceptual approach is still intent on providing opportunities for students to make sense of the mathematics they are learning, but is more likely to tell than ask questions to promote mathematical thinking. A teacher using a skills approach is more focused on clarifying procedures or skills in a fairly uniformed way.

For easy comparison, aspects of these approaches are displayed in the chart below.

This child is using her own prior knowledge to come to terms with this new problem.

	Skills Approach	Conceptual Approach	Constructivist Approach
Goal	• Mastery of basic skills • Memorization of facts, rules, formulas, and algorithms	• Meaningful learning • Understanding of facts, rules, formulas, and algorithms	• Development of mathematical thinking • Use of mathematical processes
Focus	• Procedures and application • Symbolic representations, paper-and-pencil work	• Concepts and relationships • Why? What does ... mean?	• Process of inquiry • Investigating, problem solving, reasoning, communicating
Roles	• Teacher-directed • Student passive	• Teacher-guided • Student active	• Teacher-facilitated through questioning • Student active
Process	• Direct instruction • Mainly teacher talk • Drill and practice activities • Entails breaking subject matter into small steps	• Demonstration and guided discovery of meaning • Discovery learning activities	• Student exploration and discussion of open-ended problems • Solution strategies • Application of concepts

There is no one right way to teach *every* student in *every* circumstance as there are many factors that determine a desirable approach in a particular circumstance: the student's needs, the content and processes involved, the resources available, and the teacher's ability and comfort level. In fact, a good teacher may call on all three approaches within a given lesson. Even within a program that predominantly follows a constructivist approach, teachers will use a skills approach on an as-needed basis, perhaps to teach a conventional procedure, practice, or vocabulary, for example, the names of the metric prefixes.

What is important is that teachers recognize that the constructivist approach should be the foundation of the mathematics program for all students, including low-achieving students. With a constructivist approach, students often follow unexpected and unconventional paths to construct their own learning in more open-ended inquiry-style tasks. It is helpful for teachers to have resources and professional development that will support this approach to teaching mathematics.

QUESTIONING

Good questioning can help students construct knowledge.

Good questioning is an essential element of a constructivist approach. Good questioning involves the nature of the questions asked, as well as how a teacher reacts when a student has the right answer or when a student is struggling with a task. Good questioning also involves listening and reacting effectively to students' responses.

Good questioning

- initiates discussion and mathematical thinking
- builds on what students already know
- helps focus and guide students' thinking
- focuses more on the process than getting the answer right
- encourages reflection and communication
- helps assess students' understanding
- encourages students to self-assess

Questioning Techniques

WAIT TIME

One simple questioning technique that encourages more mathematical thinking and more elaborate responses from students is allowing sufficient wait time after the question has been asked before accepting a response. Without time to think about a question fully and perhaps prepare a response mentally, students may not have the opportunity to show what they really understand. Teachers should avoid putting too much pressure on a student to respond if it is obvious that the student is not prepared or is uncomfortable. Instead, the teacher might say, "Here is my question... . I am going to ask some other students while you take the time you need to think. I will come back to you later."

DELAYING REACTION

Related to wait time is the technique of delaying reaction to or evaluation of a student response by probing to elicit more mathematical thinking. For example, a student asks the teacher if his or her answer is correct. Whether the student's answer is correct or incorrect, the teacher can elicit more mathematical thinking by asking a question such as, "Do you think it's correct? Tell me why."

QUESTIONING TECHNIQUES

- allow wait time after asking the question
- delay reaction to student responses
- rephrase questions
- reward the act of responding
- carefully sequence questions
- ask questions that relate to students' experiences
- be aware of the effect of tone and body language
- allow students to respond in different ways

Some examples of questions that can be used to delay reaction to a student's response and elicit more mathematical thinking follow:

- Why do you think that...?
- Would it also be true if...?
- Could there be a different answer?
- How did you figure that out?
- What was the hardest part of...?
- What strategies did you use to...?
- Why did you decide to...?

OTHER QUESTIONING TECHNIQUES

Besides allowing sufficient wait time and delaying reaction to a student response, teachers should

- be prepared to rephrase a question after a reasonable wait time
- be aware that their tone and body language in reaction to a student response can affect the outcome
- sequence questions to build on prior knowledge
- ask questions that relate to students' own experiences
- allow students to respond in a form that is comfortable for them, such as drawing a diagram or demonstrating with manipulatives

Teachers should reward the act of responding rather than the response (right or wrong).

HOW THE ADMINISTRATOR CAN SUPPORT THE TEACHER

The administrator can help the teacher in this dimension by

- encouraging and supporting professional development activities and resources that are focused on a constructivist approach and on questioning techniques
- offering to monitor questioning during a class session, keeping track of the kinds of questions the teacher asks, the amount of wait time, and the nature of the teacher's responses
- providing access to videos showing teachers who are good at questioning, particularly in mathematics situations
- providing opportunities for teachers to share some of their successful questioning techniques

LINKING THE NCTM PRINCIPLES AND STANDARDS

This dimension links most strongly to the following NCTM principles and standards (see pages 4–7 in Section 1):

- *Equity* by providing opportunities, through effective questioning techniques, for all students (even the more reticent ones) to fully participate
- *Teaching* by understanding what students know and by allowing for approaches that are adaptable, and through questioning, challenging, and supporting students to learn
- *Learning* by allowing students to construct knowledge by building on prior experience and knowledge and through effective questioning
- *Assessment* by determining what students know through diagnostic assessment techniques, and then building on this prior knowledge
- *Connections* by allowing students to construct knowledge by using appropriate questioning to connect new learning to prior knowledge