In Search of Understanding: The Case for Constructivist Classrooms, Revised Edition

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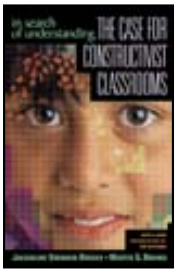

Chapter 9. Becoming a Constructivist Teacher

Most teachers with whom we've met, regardless of the approaches they have used in the past, view constructivism as the way they've "always known people learn." Most of these teachers believe that they have been prevented from teaching in accord with that knowledge by a combination of rigid curriculums, unsupportive administrators, and inadequate preservice and inservice educational experiences. Once offered the opportunity to study and consider the role of constructivism in educational practice, they tend to view the inclusion of such teaching practices as natural and growth producing. Once teachers are exposed to these practices, they enthusiastically experiment with constructivist pedagogy until it becomes part of the very fabric of their classrooms.

Still, some teachers resist constructivist pedagogy. They usually do so for one of three reasons —commitment to their present instructional approach, concern about student learning, or concern about classroom control. Some teachers have told us that, although they are compelled by the power and promise of constructivist teaching, they are too deeply into their teaching careers to consider tearing down and rebuilding their instructional practices. Others see no reason to change because their current approaches seem to work well for their students; that is, their students take comprehensive notes and pass important tests; perform well on worksheets; complete assignments neatly and on time; write well-structured and well-researched individual or group reports; and receive good grades for their work. Still other teachers, while focused to varying degrees on how well they perceive their approaches have worked for students, are more concerned about how well their approaches have worked for them. These teachers tend to be more concerned with behavior management issues than with student learning, and they are fearful that the constructivist approach to teaching will erode some of their control. When a teacher arranges classroom dynamics so that she is the sole determiner of what is "right" in the classroom, most students learn to conform to expectations without critique, to refrain from questioning teacher directives, to seek permission from the teacher to move about the room, and to look to the teacher for judgmental and evaluative feedback. The rest disengage. Empowering students to construct their own understandings, therefore, is perceived by these teachers as a threatening break from the unwritten but widely understood hierarchical covenant that binds teachers and students.

Becoming a teacher who helps students to search rather than follow *is* challenging and, in many ways, frightening. Teachers who resist constructivist pedagogy do so for understandable reasons: most were not themselves educated in these settings nor trained to teach in these ways. The shift, therefore, seems enormous. And, if current instructional practices are

perceived to be working, there is little incentive to experiment with new methodologies—even if the pedagogy undergirding the new methodologies is appealing.

But becoming a constructivist teacher is not as overwhelming as many teachers think. We have found that the following set of descriptors of constructivist teaching behaviors provides a useable framework within which teachers can experiment with this new approach. This set of descriptors presents teachers as mediators of students and environments, not simply as givers of information and managers of behavior. It is based on our own interactions with students and observations in the classrooms of many other teachers. The development of these descriptors has also been informed by the work of several researchers and theoreticians, including Sigel, Elkind, Kuhn, and Arlin (see bibliography).

1. **Constructivist teachers encourage and accept student autonomy and initiative.**

   While the philosophies and mission statements of many schools purport to want students to be thinking, exploring individuals who generate hypotheses and test them out, the organizational and management structures of most schools militate against these goals. So, if autonomy, initiative, and leadership are to be nurtured, it must be done in individual classrooms.

   Autonomy and initiative prompt students' pursuit of connections among ideas and concepts. Students who frame questions and issues and then go about answering and analyzing them take responsibility for their own learning and become problem solvers and, perhaps more important, problem finders. These students—in pursuit of new understandings—are led by their own ideas and informed by the ideas of others. These students ask for, if not demand, the freedom to play with ideas, explore issues, and encounter new information.

   The way a teacher frames an assignment usually determines the degree to which students may be autonomous and display initiative. For example, students in a 12th grade English class read *Oedipus Rex*. The teacher asked the students to write an essay describing the book as Oliver Stone, the controversial film director, might think about it, and then to compare that interpretation to their understandings of Sophocles' views. To twig their interest, the teacher asked one group of students if they could find proof in the text that Oedipus had actually slept with his mother. After poring over the text, this group concluded that, according to the chronology of events, Oedipus could not possibly have done so. The students then wrote essays defending their positions and retold the story as they imagined Oliver Stone might have.

   Conscientious students who are acculturated to receiving information passively and awaiting directions before acting will study and memorize what their teachers tell them is important. Robbing students of the opportunity to discern for themselves importance from trivia can evoke the conditions of a well-managed classroom at the expense of a transformation-seeking classroom.

2. **Constructivist teachers use raw data and primary sources, along with manipulative, interactive, and physical materials.**

   Concepts, theorems, algorithms, laws, and guidelines are abstractions that the human

mind generates through interaction with ideas. These abstractions emerge from the world of phenomena such as falling stars, nations at war, decomposing organic matter, gymnasts who can hurl their bodies through space, and all the other diverse happenings that describe our world. The constructivist approach to teaching presents these real-world possibilities to students, then helps the students generate the abstractions that bind these phenomena together. When teachers present to students the unusual and the commonplace and ask students to describe the difference, they encourage students to analyze, synthesize, and evaluate. Learning becomes the result of research related to real problems—and is this not what schools strive to engender in their students?

For example, students can read historical accounts of the effects of the social policies of the early 1980s on the economic and educational profile of the African-American population in the United States. Or, students can be taught to read the census reports and allowed to generate their own inferences about social policies. The former relies on the authority of a stranger. The latter relies on the ingenuity of the individual student. Lists of figures and pages of charts are probably not the first images evoked when the terms "hands on" or "manipulative" are heard. But the census data can tell a loud story if the right pages and lists are highlighted in the context of a good question.

3. **When framing tasks, constructivist teachers use cognitive terminology such as "classify," "analyze," "predict," and "create."**

   The words we hear and use in our everyday lives affect our way of thinking and, ultimately, our actions. The teacher who asks students to select a story's main idea from a list of four possibilities on a multiple-choice test is presenting to the students a very different task than the teacher who asks students to analyze the relationships among three of the story's characters or predict how the story might have proceeded had certain events in the story not occurred. Analyzing, interpreting, predicting, and synthesizing are mental activities that require students to make connections, delve deeply into texts and contexts, and create new understandings.

   In a 3rd grade classroom, a teacher read a story to her students about three children who became lost in a forest. After struggling mightily, yet unsuccessfully, to find their way, one of the three children, a brave and daring youngster, volunteers to go off alone in search of help while the other two wait in a clearing. At this point, the teacher stopped and asked the students to predict how the story is likely to end and to reveal the reasons behind their predictions: if a student predicts that help will be found and the other two children rescued, she is asked to indicate why. The overwhelming majority of students predicted just that—that all three would be rescued—and they explained their predictions by pointing to the competence of the child who went off in search of help. The students use information and impressions garnered from the text to predict how the story was likely to end. Framing tasks around cognitive activities such as analysis, interpretation, and prediction—and explicitly using those terms with students—fosters the construction of new understandings.

4. **Constructivist teachers allow student responses to drive lessons, shift instructional strategies, and alter content.**

This descriptor does *not* mean that students' initial interest, or lack of interest, in a topic determines whether the topic gets taught, nor does it mean that whole sections of the curriculum are to be jettisoned if students wish to discuss other issues. However, students' knowledge, experiences, and interests occasionally do coalesce around an urgent theme. Such was the case during the Persian Gulf War. Students at all grade levels were compelled by the images they saw, the reports they heard, and the fears they experienced. The social studies teacher attempting to continue discussions on the Renaissance, the science teacher moving ahead with the Krebs Cycle, and the art teacher in the middle of a unit on symmetry all experienced a similar phenomenon—the students were preoccupied with the war. When magnetic events occur that exert an irresistible pull on students' minds, continuing with preplanned lessons is often fruitless.

This descriptor *does* address the notion of "teachable moments" throughout the school year. As educators, we have each experienced moments of excitement in the classroom, moments when the students' enthusiasm, interest, prior knowledge, and motivation have intersected in ways that made a particular lesson transcendental and enabled us to think with pride about that lesson for weeks. We recall the gleam in our students' eyes, their excitement about the tasks and discussions, and their extraordinary ability to attend to the task for long periods of time and with great commitment. If we were fortunate, we encountered a handful of these experiences each year, and wondered why they did not occur more frequently.

It's unfortunate that much of what we seek to teach our students is of little interest to them at that particular point in their lives. Curriculums and syllabi developed by publishers or state-level specialists are based on adult notions of what students of different ages need to know. Even when the topics are of interest to students, the recommended methodologies for teaching the topics sometimes are not. Little wonder, then, why more of those magnificent moments don't occur.

Although some teachers may not have much latitude regarding content, all generally have a good deal of autonomy in determining the ways in which the content is taught. For example, a certain elementary science curriculum called for students to begin learning about the "scientific method" and to conduct some rudimentary experiments using this method: ask a question (develop an hypothesis), figure out a way to answer the question (set up an experiment), tell what happens (record your observations), and answer the question (support or refute the initial hypothesis). One 5th grade teacher asked her students, in preparation for this assignment, to talk about their favorite things at home. One student, Jane, spoke about her cat. A classmate, Eric, discussed his house plants. Capitalizing on their responses, the teacher asked Jane and Eric to think of questions each had about the cat and the plants. Jane wanted to know if her cat would like other cat foods as much as he liked the brand he normally ate. Eric wanted to know how plants grow.

Through the teacher's mediation, Jane organized an experiment to answer her question about cat food. She arranged four different brands of cat food in four different bowls and placed them on the floor. When the cat entered the room, she observed which bowl he

went to initially and from which bowl he ate. Jane changed the positions of the bowls and tried the experiment again. Ultimately, she concluded that her cat preferred one brand over the others.

With his teacher's mediation, Eric focused his question: Does the human voice affect the growth of a plant? Eric planted four bean seeds in four different pots and placed them all on the same shelf near a window. Each day he took each pot, one at a time, into another room. He spoke daily to one of the bean plants. He sang daily to a second plant. He yelled daily at a third plant. And he completely ignored the fourth. He recorded his observations over four weeks and concluded that the plants to which he spoke and sang grew the most.

The students' thinking drove these experiments, and the teacher's mediation framed the processes that followed. The curriculum content—exploration of the scientific method—was addressed faithfully in a different manner for each student.

5. **Constructivist teachers inquire about students' understandings of concepts before sharing their own understandings of those concepts.**

   When teachers share their ideas and theories before students have an opportunity to develop their own, students' *questioning* of their own theories is essentially eliminated. Students assume that teachers know more than they do. Consequently, most students stop thinking about a concept or theory once they hear "the correct answer" from the teacher.

   It's hard for many teachers to withhold their theories and ideas. First, teachers *do* often have a "correct answer" that they want to share with students. Second, students themselves are often impatient. Some students don't want to "waste their time" developing theories and exploring ideas if the teacher already knows that they are "on the wrong track." So teachers sometimes feel great pressure from students to offer the "right" answer. Third, some teachers adhere to the old saw about knowledge being power. Teachers struggling for control of their classes may use their knowledge as a behavior management device: when they share their ideas, the students are likely to be quiet and more attentive. And fourth, time is a serious consideration in many classrooms. The curriculum must be covered, and teachers' theories and ideas typically bring closure to discussions and move the class on to the next topic.

   Constructivist teachers, the caveats presented in the preceding paragraph notwithstanding, withhold their notions and encourage students to develop their own thoughts. Approximated (or invented) spelling is a good example of this approach. As very young students are learning how to put words into writing, they begin to approximate the conventional spellings of words. A kindergarten student titled a sign language book she had illustrated by writing on the cover "My sin lnge bk." The teacher chose not to correct her spelling but, instead, to permit her to continue approximating the spelling of words. Interestingly, when reading the book at home to her parents only one day after writing this title, the girl said, "Oh, I left the two *o*'s out of book." No one told the girl that her spelling was incorrect. She reformulated her own work in the process of sharing it. Her reformulation was a self-regulated event. The teacher's plan to

share her understanding of the conventional spelling, in this case, became unnecessary.

6. **Constructivist teachers encourage students to engage in dialogue, both with the teacher and with one another.**

   One very powerful way students come to change or reinforce conceptions is through social discourse. Having an opportunity to present one's own ideas, as well as being permitted to hear and reflect on the ideas of others, is an empowering experience. The benefit of discourse with others, particularly with peers, facilitates the meaning-making process.

   Over the years, most students come to expect their teachers to differentiate between "good" and "bad" ideas, to indicate when responses are "right" and "wrong," and to transmit these messages in a fairly straightforward fashion. Dialogue is not a tile in the mosaic of school experienced by most students.

   Consequently, most students learn to offer brief responses to questions, and to speak only when they are reasonably certain that they are supporting either a "good" idea or the "right" answer. These classroom sound bytes may assist teachers in moving speedily through the curriculum, but they don't help students construct new understandings or reflect on old ones.

   A group of 8th grade teachers decided they wanted to offer a wider literature selection to their students and to engage the students in more thorough analyses of important ideas. They organized a series of Booktalks. In a Booktalk, a group of about eight students and an adult read and discuss the same book. The students select the book they wish to read from a master list compiled by the teachers, and the school's schedule is altered so that the groups can meet twice for 45 minutes during a three-week period. During the first meeting, the adult distributes the books to the students, sets the context for the book by asking questions about students' prior experiences that relate to the storyline, and begins to read the book aloud to the students. The second meeting is devoted to a discussion about the book.

   In one Booktalk, students had read Steinbeck's *Of Mice and Men*. The issues raised by students during the post-reading discussion, issues generated by questions and contradictions posed by the teacher, included treatment of people with disabilities, sexism, the distribution of wealth and power in our nation, friendship, and death. The teacher orchestrated the discussion so that quiet students also had a chance to speak, but the ideas that drove the discussion belonged to the students and were fueled by student-to-student dialogue.

   Student-to-student dialogue is the foundation upon which cooperative learning (Slavin 1990) is structured. Reports state that cooperative learning experiences have promoted interpersonal attraction among initially prejudiced peers (Cooper et al. 1980), and such experiences have promoted interethnic interaction in both instructional and free-time activities (Johnson et al. 1981).

   The benefits of peer-to-peer dialogue among teachers reinforces its potential for students. Preservice teachers in one science methods course were asked to design, in

cooperative learning groups, a system for a family to generate electricity for its home, using windmills. The stipulation that no batteries could be used was included in the instructions. During a whole-class discussion of each group's work-in-progress, the issue of energy storage led quickly to a discussion of batteries. Most students defined "battery" in terms of what one typically purchases in a store: an electrolytic cell such as the type used in toys and flashlights, or larger cells such as those used to power automobiles. Three students, however, demurred, and defined a battery as any device that can store energy, such as an expanded balloon or a tank of hot water. The dialogues that ensued resulted in, for some students, the transformation of perspectives and, for others, the onset of reflection on a new topic.

Two weeks later, while this same class grappled with another, seemingly simple problem —how to redraw silhouettes in half the original size—one student, after much consideration of the question, declared: "Now we're trying to figure out what `hal' really means. I still want to know: What is a battery!" In each of these sessions, the students addressed their questions and statements to one another. The teacher clarified the questions they raised of one another and demanded accuracy of word choice, but the communication currents were between and among the students and led to deeper understandings of the topics at hand.

7. **Constructivist teachers encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other.**

   If we want students to value inquiry, we, as educators, must also value it. If teachers pose questions with the orientation that there is only one correct response, how can students be expected to develop either the interest in or the analytic skills necessary for more diverse modes of inquiry? Schools too often present students with one perspective: Columbus was a courageous explorer who discovered America (What does that imply about the Native Americans here when he came ashore?); and *Pi* = 3.14 (But C/d—circumference/diameter—yields another number; and if *Pi* is computed as the quotient of two integers, how can it be considered irrational?).

   Complex, thoughtful questions challenge students to look beyond the apparent, to delve into issues deeply and broadly, and to form their own understandings of events and phenomena. Knowing, for example, that Columbus' ships carried with them diseases for which Native Americans had no antibodies and that Columbus and his men enslaved Native Americans for the return voyage home enables students to view the historical development of our nation in terms of Columbus' calculated and uncalculated risks, and the Native Americans' subsequent oppression. Similarly, knowing that there are different ways to compute with and conceptualize *Pi*, and that the search for *Pi*'s precise value has influenced modern research relating to the science of chaos, enables students to form important questions that may lead to deeper understanding of geometry and mathematical functions. Fostering appreciation for a multiplicity of truths and options is the "real" mission of education because "real" problems are rarely unidimensional.

   In one 3rd grade classroom, a teacher formed "consultant groups." Each student became a consultant on a self-selected topic and was responsible for keeping the rest of the

class informed about that topic. Each consultant belonged to a small group of students who were charged with questioning each other in order to learn about the chosen topics.

One student became quite knowledgeable about volcanoes—so much so, in fact, that he gave "lectures" on the topic to other classes. One day, the student was describing to his group how volcanoes develop in certain regions. As his group members considered this new information, one student asked him about whether a volcano could be developing underneath the school. If it were possible, he wanted to know how they would know if one were developing. The student-consultant carefully pondered this question and said, "I don't think that volcanoes could develop here, but I'm not sure. But, I think we would know if a volcano were developing here."

"How?" one of the other students asked.

"Well," the student-consultant responded, "if a volcano were under the school, the grass would be turning brown from the heat. As long as the grass is green, I think we're safe."

Discourse with one's peer group is a critical factor in learning and development. Schools need to create settings that foster such interaction.

8. **Constructivist teachers seek elaboration of students' initial responses.**

   Initial responses are just that—*initial* responses. Students' first thoughts about issues are not necessarily their final thoughts nor their best thoughts. Through elaboration, students often reconceptualize and assess their own errors. For example, one middle school mathematics teacher assigned his class problems in a textbook. A student, looking quite confused, asked the teacher if her approach to solving one of the problems was appropriate. The teacher asked the student to explain what she had done. As she was explaining her approach in a step-by-step manner, she recognized her own procedural error. She smiled and said, "I forgot to multiply *both* sides of the equation by "*x*." The teacher based his responses to the student on the premise that he could learn more about what teaching steps to take in subsequent lessons with the student than he could learn from simply fixing the mistake for her.

   Occasionally, perhaps often, the adult filter through which teachers hear student responses fails to capture the students' meanings. Student elaboration enables adults to understand more clearly how students do and do not think about a concept. For example, a colleague of ours was having a discussion with his five-year-old daughter about the relative merits of living in the suburbs versus New York City. Their family had visited New York several times, and the young girl was curious about who lived there. After a few minutes, she mentioned that 42nd Street was in New York. Her father agreed, and asked her if she could name other streets in New York. She mentioned 52nd Street and 62nd Street. Her father asked her what street was above 62nd Street.

   "72nd Street," she replied. Then 82nd Street, 92nd Street, and 102nd Street. Her father was now convinced that his daughter was able to count by tens, and he asked her what was below 42nd Street.

   "The subway," she replied.

Students and teachers often discover how disparate their perspectives sometimes are. It's only through that discovery that individuals can engage in the process of trying to reconcile the two.

9. **Constructivist teachers engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion.**

   Cognitive growth occurs when an individual revisits and reformulates a current perspective. Therefore, constructivist teachers engage students in experiences that might engender contradictions to students' current hypotheses. They then encourage discussions of hypotheses and perspectives. Contradictions are constructed by learners. Teachers cannot know what will be perceived as a contradiction by students; this is an internal process.

   But teachers can and must challenge students' present conceptions, knowing that the challenge only exists if the students *perceive* a contradiction. Teachers must, therefore, use information about the students' present conceptions, or points of view, to help them understand which notions students may accept or reject as contradictory.

   Students of all ages develop and refine ideas about phenomena and then tenaciously hold onto these ideas as eternal truths. Even in the face of "authoritative" intervention and "hard" data that challenge their views, students typically adhere staunchly to their original notions. Through experiences that might engender contradictions, the frameworks for these notions weaken, causing students to rethink their perspectives and form new understandings. Consider the following example:

   During an 11th grade discussion about the causes of World War I, one student contended with great conviction that the assassination of the Archduke Ferdinand of Austria caused the war. The teacher then asked, "If the Archduke had not been assassinated, can you tell us what would have happened with the economy and politics of the region?"

   After a moment's thought, the student said, "I guess they wouldn't have changed that much."

   The teacher then asked, "Would anything else have changed? How about Germany's quest to rule Europe?"

   The student replied, "I can't think of anything that would have changed, except that maybe the Archduke would still be alive."

   "Then," continued the teacher, "what was it that made this event the cause of the war?"

   The student, now quite enmeshed in thought, said, "I guess that maybe it [the war] could have happened anyway. But, the killing of Austria's Archduke gave the Germans an excuse to begin their plan to conquer all of Europe. When Russia and France jumped in to help Serbia, the Germans declared war on them, too. But, I think I see what you mean. It was probably going to happen anyway. It just happened sooner."

   Note that this elaborate explanation didn't come from the teacher. It came from the student. Note also that the student said, "I think I see what you mean," as if the

meaning came from the teacher. But it did not. The meaning was constructed by the student who was ready and able to understand a different point of view. When the student revealed his original perspective, the teacher was presented with the opportunity to intervene; but the contradiction was constructed by the student.

In this example, the teacher challenged the student's thinking with questions. The questions provided a mechanism for the student to reveal very sophisticated understandings of the events and political subcurrents. The teacher never directly told the student to look at the assassination as a catalyst rather than a cause. She simply wanted to present a way for the student to consider this perspective as an option. The student quickly embraced this view. Some other students in the class didn't distinguish between a catalytic event and a causal event. They didn't construct the same "contradiction" that this student constructed. The teacher then directed the class discussion to other students with subsequent questions such as: "Who also thinks that war would have just happened sooner?" "Why?" "Who disagrees?" "For what reason?" Without acknowledging one answer as better than another, everyone can participate and listen to others.

10. **Constructivist teachers allow wait time after posing questions.**

    Several years ago, as part of its professional development efforts, a school district hired a graduate student to tapescript lessons in individual classrooms. The project was organized to provide feedback to teachers about their instructional practices: several one-minute snippets were tape recorded during a lesson, and then transcribed into writing for the teachers' reflection. One teacher, generally acknowledged to be highly skilled, was appalled to discover that she asked and answered questions in virtually the same breath. Students had no time to think about the questions she asked and quickly learned simply to wait for her to answer her own questions.

    Similarly, another teacher found out that she had inadvertently orchestrated competition in her classroom. The first two or three students to raise their hands were, by and large, the only ones ever called on. If students didn't get their hands in the air immediately, they were effectively locked out of the "discussion."

    These two examples illustrate the importance of wait time. In every classroom, there are students who, for a variety of reasons, are not prepared to respond to questions or other stimuli immediately. They process the world in different ways. Classroom environments that require immediate responses prevent these students from thinking through issues and concepts thoroughly, forcing them, in effect, to become spectators as their quicker peers react. They learn over time that there's no point in mentally engaging in teacher-posed questions because the questions will have been answered before they have had the opportunity to develop hypotheses.

    Another reason students need wait time is that, as we have discussed, the questions posed by teachers are not always the questions heard by the students. The Gatling gun approach to asking and answering questions does not provide an opportunity for the teacher to sense the manner in which most of the students have understood the questions. Besides increasing wait time after questioning in large-group formats, we

have had success with posing questions and then encouraging small groups of students to consider them before the whole group is invited back together to report on the deliberations. This format allows the teacher to call on students to deliver the group's initial responses without putting anyone on the spot. In addition, any student in the group can submit a "minority report." Thus, teachers take sensitive leadership over the orchestration of classroom dialogue and provide opportunities for all students to participate in different ways while encouraging students' intellectual autonomy with regard to concept formation.

11. **Constructivist teachers provide time for students to construct relationships and create metaphors.**

    In one 2nd grade classroom, students were given magnets to explore. In a short time, almost all of the students had discovered that one end of a magnet attracted the other magnet while the opposite end repelled it. Soon, most of the students discovered that if one of the magnets were turned around, the magnets that had attracted each other now repelled each other. This activity took nearly 45 minutes, during which some students went beyond these initial relationships and joined forces with their peers to create magnetic "trains," and to create patterns with iron filings. A great number of relationships, patterns, and theories were generated during this activity, and none of them came from the teacher. The teacher structured and mediated the activity and provided the necessary time and material for learning to occur, but the students constructed the relationships themselves.

    Encouraging the use of metaphor is another important way to facilitate learning. People of all ages use metaphors to bolster their understandings of concepts. One kindergarten student, after a field trip to pick strawberries at a local farm, ran home to his parents saying "You should have been there. It was a red heaven."

    At an inservice seminar offered to experienced teachers and administrators on the topic of educational change, participants were asked to think of metaphors for the process of change in their work settings. One participant likened change to the making of wine: The seeds must be planted in fertile ground; the grapes must be harvested at the right moment; and the wine then must be aged in vats or bottles. Another participant thought of educational change as a symphony orchestra: There must be a conductor who decides what pieces shall be played and who helps all the musicians to play together. A third participant saw change as akin to preparing a meal: There is a chef who selects the menu, chooses complementary condiments, applies them according to a recipe (or whim), and lets the food cook until it is ready for consumption. Metaphors help people to understand complex issues in a holistic way and to tinker mentally with the parts of the whole to determine whether the metaphor works. And all of this takes time.

12. **Constructivist teachers nurture students' natural curiosity through frequent use of the learning cycle model.**

    The learning cycle model has a long history in science education. The most popular description of this model was published by Atkin and Karplus (1962). Highlighting the

important role of self-regulation in the learning process, the model describes curriculum development and instruction as a three-step cycle.

First, the teacher provides an open-ended opportunity for students to interact with purposefully selected materials. The primary goal of this initial lesson is for students to generate questions and hypotheses from working with the materials. This step has historically been called "discovery." Next, the teacher provides the "concept introduction" lessons aimed at focusing the students' questions, providing related new vocabulary, framing with students their proposed laboratory experiences, and so forth. The third step, "concept application," completes the cycle after one or more iterations of the discovery-concept introduction sequence. During concept application, students work on new problems with the potential for evoking a fresh look at the concepts previously studied.

Note that this cycle stands in contrast to the ways in which most curriculum, syllabi, and published materials present learning, and the ways in which most teachers were taught to teach. In the traditional model, concept introduction comes first, followed by concept application activities. Discovery, when it occurs, usually takes place after introduction and application, and with only the "quicker" students who are able to finish their application tasks before the rest of the class.

Let's take a look at how this cycle evolved in a 9th grade earth science classroom. In this classroom, the teacher told the students about the Chinook winds, the warm, dry, fast winds that blow down from the Rocky Mountains into the region just east of the mountains. The winds can be 40°–50° warmer than the surrounding air. In this example, the material made available for discovery purposes was a scenario for the students to consider. The teacher asked the students to work in small groups to generate a diagram that could explain why this occurrence might happen. As the groups began to work, the teacher listened to his students' deliberations, intervening in different ways dependent on the course of the dialogue occurring among the students. He asked a group that was "stuck" to begin by drawing the vegetation on the sides of the mountain. While trying to do the drawing, the students began to talk about rainfall, where it comes from, the patterns of cloud movement, and so on. At that point, the teacher moved to a group of students having a conversation about how hot air rises. The teacher asked another group, "Why does the warm wind move down if hot air rises?"

One girl in the group said emphatically, "That's what I don't understand?" Music to a constructivist teacher's ears!

The teacher said: "You know what your problem is now. Don't forget that the wind is fast, too." And the teacher moved on to students with whom he had not yet interacted that day.

What was the concept introduction to follow this discovery opportunity? The teacher wanted to introduce the concept of adiabatic pressure—a most sophisticated concept that without consideration of heat gain and heat loss, wind speed, and moisture conditions is largely inaccessible. The Chinook winds activity allowed the teacher to assess what elements of the concept are within the students' intellectual reach.

These 12 descriptors highlight teacher practices that help students search for their own understandings rather than follow other people's logic. The descriptors can serve as guides that may help other educators forge personal interpretations of what it means to become a constructivist teacher.

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