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ABSTRACT

This document describes some of the prominent beliefs about how students construct knowledge. These beliefs are guiding principles that teachers can use to implement instructional strategies that facilitate learning. Instructional examples in mathematics and science follow each principle to help the reader envision how the principle promotes student learning. A list of teacher actions that support each principle follows the classroom examples. The description of each principle concludes with implications for staff development. The principles are: (1) each student must actively construct his/her own meaning in order to understand the material being learned; (2) learning depends on the previous understandings that students bring to the learning situation; (3) what, and how much, is learned depends on the context in which it is learned; (4) what is learned depends on the shared understandings that students negotiate with the teacher and with each other; (5) constructivist teaching involves meeting students "where they are" and helping them move to higher levels of knowledge and understanding; (6) teachers can use specific teaching methods to facilitate student's active construction of knowledge; (7) in constructivist teaching, the teacher emphasizes "learning-how-to-learn"; (8) the constructivist teacher uses continuous assessment to facilitate learning; and (9) constructivist teachers are themselves constructivist learners. Contains 38 references. (LZ)

A CONSTRUCTIVIST VISION FOR TEACHING, LEARNING, AND STAFF DEVELOPMENT

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A CONSTRUCTIVIST VISION FOR TEACHING, LEARNING, AND STAFF DEVELOPMENT

The hallmark of constructivist learning is ***activity***. In the constructivist view of learning, students are not passively absorbing information, but are actively involved in constructing meaning from their experiences and prior knowledge. Rather than just receiving more information, the learner must make sense of the information with the help of his/her learning community. The learner makes connections with past personal understandings, sometimes modifying or discarding prior conceptions if they are not accurate. Constructivist learning involves building understandings that become part of that person's personal conceptual framework and actions.

The constructivist teacher knows that some information is more important than other information in developing a sophisticated understanding of science and mathematics. The constructivist teacher does not merely help the student learn more, but helps the student develop a deeper understanding of the content which will provide a foundation for continued learning. Constructivist teaching involves understanding students' existing cognitive structures and providing appropriate learning activities to assist students in constructing knowledge.

Understanding how learners come to understand and conceptualize the world around them can help teachers facilitate learning. The pages that follow describe some of the prominent beliefs about how students construct knowledge. These beliefs are *guiding principles*, in that by understanding them, teachers can implement instructional strategies that facilitate learning. Instructional examples in mathematics and science follow each principle to help the reader envision how the principle promotes student learning.

There are specific actions constructivist teachers do (and do not do) when facilitating learning. Although it is impossible to list all of the things teachers do to help students construct knowledge, a list of teacher actions that support each principle follows the classroom examples. Most of these actions support more than one principle even though they are listed only once.

Simply because teachers understand these principles and the underlying teacher actions, does not mean that they can implement instructional strategies that support constructivist learning. Teacher preparation and staff development can support the development of constructivist teaching. The description of each principle concludes with implications for *staff development* based on the guiding principle. These implications can help teachers, administrators, and staff developers decide upon the best staff development activities to promote constructivist teaching.

Principle I

Each student must actively construct her or his own meaning in order to understand the material being learned.

EXAMPLES

Mathematics: Students who develop an understanding of addition and subtraction through the use of base ten models are more likely to have success with regrouping problems. For example, a student who models the problem 92 - 39 by representing 92 as 9 longs and 2 units, replaces 1 long with 10 units, and removes 3 longs and 9 units has actively constructed a concrete meaning for the problem. This model aids in understanding the more abstract paper-and-pencil algorithm.

Science: When students study breathing, they construct meanings for terms such as diaphragm, trachea, lung, inhalation, and exhalation. Although the meanings for many of these terms are difficult to grasp, the use of a lung model by students enable them to better visualize these structures and provides evidence to support their ideas regarding how breathing takes place. Students could experiment further with this model by observing how the lungs are affected by altering other variables associated with breathing and disease.

In support of this principle, the constructivist teacher:

1. promotes *active learning* with *hands-on activities* that emphasize process.

2. provides a *range of activities*, with *class discussion*, designed to elicit competing points of view.

3. encourages *multiple approaches* to problem solving by providing opportunities for students to share their strategies.

4. *utilizes technology* to promote student investigation and problem solving.

5. provides experiences which enable students to test their *understandings*.

Staff development activities that support this principle should:

1. include opportunities for developing strategies for implementing a variety of programs that promote active learning and hands-on activities.

2. model active learning and hands-on activities in continuing education courses and workshops.

3. model inquiry and problem solving strategies in continuing education programs; these programs should also engage participants in discussion and discourse.

4. use activities and/or tasks in continuing education programs that provide examples relating mathematics/science to student interests.

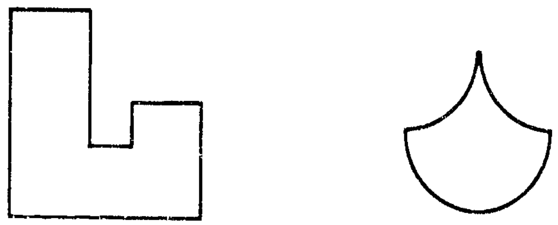
5. provide opportunities to enhance understanding through the use of a variety of tools such as calculators, computers, and physical and pictorial models.

Principle II

Learning depends on the previous understandings that students bring to the learning situation.

EXAMPLES

Mathematics: Students who have not developed a conceptual understanding of area might believe that the shapes below do not have areas or that the areas are impossible to determine.



A constructivist teacher will provide students with numerous opportunities to "cover" a surface using both standard and nonstandard units. In this way students develop a conceptual understanding of area that underpins their later understanding of the common area formulas that they will memorize.

Science: A common misconception in science is evident when students confuse the processes of melting and dissolving. As a hard candy dissolves in one's mouth, the student may refer to it "melting in my mouth." Through activities that involve substances melting and dissolving, students come to construct meaning for these terms and the differences between these two processes.

In support of this principle, the constructivist teacher:

1. demonstrates an awareness of common student *misconceptions.*
2. selects *authentic problems* for solution.
3. uses *familiar examples, motivating experiences, and intriguing questions* to engage students.
4. utilizes discrepant events that *challenge existing belief systems.*
5. *connects* concepts to previously constructed knowledge and to the *everyday experiences* of the student.
6. provides *connections* to previous and present learning experiences.
7. helps students *confront misconceptions* by providing experiences to explore a concept in a variety of ways.

Staff development activities that support this principle should:

1. demonstrate a variety of methods for assessing students' prior understanding, such as the use of concept maps, Vee diagrams, KWL, and probing questions.
2. provide information about the common misconceptions that students have about various concepts.
3. model strategies for effectively confronting student misconceptions.
4. develop teachers' knowledge about the relationship of students' age, abilities, interests, and experience to learning mathematics and science.
5. develop teachers' awareness of the influences of students' linguistic, ethnic, cultural, socioeconomic backgrounds, and gender on learning mathematics and science.

Principle III

What, and how much, is learned depends on the context in which it is learned.

EXAMPLES

Mathematics: Research supports the contention that knowledge that has been recently acquired is context-bound. On the other hand, there is also a body of research that suggests that mathematics learned in context is more likely to be meaningful to students. A task of the constructivist teacher is to provide appropriate contexts within which students will construct knowledge, as well as appropriate activities that will help students to generalize the cognitive structures which they have built. Since the classroom discourse is woven throughout these interactions, another responsibility of the constructivist teacher is to foster such discourse.

Context should be discussed when students learn to round-off numbers, because the context frequently determines the rounding method used. For example, students might explore the method of rounding used by a grocery store in figuring the price of a single item sold at "3 for $1" and contrast that method with the one used in the construction of sales tax tables.

Science: When studying acid-base chemical reactions, students can learn to rotely write and balance equations. However, the understanding of these reactions can be deepened if they are related to a context with which students are familiar. For example, relating these reactions to stomach aches and the use of antacids can help to place these reactions in a familiar context. Similarly, students can study claims that familiar brands of shampoo are "pH balanced" and determine whether being pH balanced is an important property for shampoos to have.

In support of this principle, the constructivist teacher:

1. develops concepts from *real world problem situations.*

2. integrates *problem solving and higher order thinking skills* into subject matter units rather than teaching these skills in isolation.

3. emphasizes experiences from the *pure, technological, and applied* science and mathematics disciplines.

4. utilizes *appropriate technology* in the development of a learning environment.

5. develops units of study that *integrate* across subject areas and within the discipline.

6. applies concepts to the *everyday experiences* of students.

7. approaches instruction from a *multicultural perspective.*

8. helps students *focus on future careers* involving mathematics and science.

9. encourages *students to act in ways that reflect their understanding* of the impact of mathematical and scientific knowledge on their lives, society, and the world.

10. stresses mathematics and science as *human endeavors.*

11. encourages students' appreciation of the mathematical and scientific endeavor and their *excitement and pleasure* in its pursuit.

Staff development activities that support this principle should:

1. provide opportunities to learn and experience strategies that promote higher order thinking skills.

2. provide opportunities for teachers to learn more about the technological and mathematical sciences.

3. provide time for teachers to design or develop units that integrate subject matter.

4. provide time for teachers to design or develop units that infuse applied science and mathematics into learning activities.

5. model teaching in continuing education programs that represent mathematics and science as ongoing human activities.

6. structures learning activities around the broad, big ideas of science and mathematics.

7. develop knowledge about the nature of mathematics and science content with regard to the contributions of different cultures and the role of mathematics and science in society.

8. emphasize key concepts and processes and the connections among them.

9. develop an awareness of how the availability of technology impacts the way we teach, learn, and do mathematics and science.

10. develop perspectives on the changing nature of school mathematics and science and its relationships to other school subjects.

11. connect mathematical and scientific knowledge to everyday experiences and applications in society.

Principle IV

What is learned depends on the shared understandings that students negotiate with the teacher and with each other.

EXAMPLES

Mathematics: In the formal study of geometry, the terms point, line, and plane necessarily must remain undefined. However, if these terms are to be meaningful, students must nevertheless construct viable meanings for them. When they confront the terms point, line, and plane, consider the possibility that exists for students to negotiate shared understandings as they abstract meanings for those terms.

Science: When students experiment with "Oobleck", a cornstarch and water mixture, they seek to determine whether the evidence supports this substance being classified as a solid or a liquid. First, students must agree upon characteristics of solids and liquids and negotiate what types of tests provide evidence of these characteristics. When students discover evidence that supports both phases, they must decide upon the criteria for the tests and discuss a broad r range of possibilities.

In support of this principle, the constructivist teacher:

1. recognizes that learning takes place in a social context and *utilizes the context* to support understanding.
2. advocates *collaboration* in the learning process.
3. develops *consensus building* in classrooms.
4. provides *examples and non-examples* based on students' ideas to force students to validate their thinking.

5. encourages ALL students to *reflect* on their ideas and *contribute* to the class activity.

6. stresses the development of *social skills and cooperative group work strategies* in addition to the more traditional individual and competitive methods.

7. encourages students to use *technology to communicate* with other students (e.g., via Internet or multimedia) that show promise for helping students communicate to each other and with others outside their school.

8. *communicates regularly with parents* to develop a shared vision of instruction.

Staff development activities that support this principle should:

1. provide illustrations of classrooms in which students actively negotiate shared understandings with the teacher and with their peers.

2. develop the use of cooperative learning techniques.

3. develop the use of questioning techniques to foster classroom discourse.

4. develop the use of practices that foster equity in the classroom.

5. support the instructional use of technology (such as, but not limited to the Internet or multimedia approaches).

6. help teachers to understand the details of facilitating and managing collaborative activities.

7. model constructivist practices.

8. support teachers efforts to use the knowledge and skills which they are developing.

Principle V

Constructivist teaching involves meeting students "where they are" and helping them move to higher levels of knowledge and understanding.

EXAMPLES

Mathematics: In beginning algebra, for example, students can be taught to solve simple linear equations by building on what they already know about number facts from their study of arithmetic. In arithmetic, students learn to form sets of "related facts." Thus,

what they know, can be . . . . applied to the equation.

$2+3=5$	$2+n=5$
$3+2=5$	$n+2=5$
$5-3=2$	$5-n=2$
$5-2=3$	$5-2=n$
$2 \cdot 3=6$	$n \cdot 3=6$
$3 \cdot 2=6$	$3 \cdot n=6$
$6 \div 2 = 3$	$6 \div n = 3$
$6 \div 3 = 2$	$6 \div 3 = n$

Science: When beginning study of the Periodic Table of Elements, the constructivist teacher might start with activities that involve determining patterns and classification. For example, arranging the following substances in a meaningful order based on their "properties" of color, number, and stars. *(continued on next page)*

green * 1.1	green * * 6.5	green * * * 11.9
red * 3.4	?	red * * * 14.2
blue * 5.7	blue * * 11.1	blue * * * 16.5

Students will most likely come up with more than one way of arranging the substances and the strengths of various arrangements can be debated. There is no one "right" way of arranging these facts, but some arrangements may prove to be more useful than others. If an unknown substance was missing from the arranged pattern (or a gap appeared in the pattern), many of it's properties could be hypothesized. In fact, a study of the development of the Periodic Table reveals that many elements that had not yet been discovered were hypothesized as existing, simply because of gaps in the patterns in the table. Instead of viewing the Periodic Table of Elements as a formidable bundle of facts to be memorized, students are introduced to it as a useful tool for understanding the elements, their properties, and as an aid for understanding chemical reactions.

In support of this principle, the constructivist teacher:

1. realizes that learning is complex and requires *multiple strategies*.
2. uses *inquiry* methods.
3. uses *open-ended questions* and problems.

4. realizes that "the path of action" or means to go about *solving a problem* is not fully specified in advance.

5. encourages *multiple solutions* to solving problems.

6. accommodates a variety of *learning styles*.

7. recognizes that *higher levels of thinking* are a goal for *ALL students* and should be a component of ALL courses.

Staff development activities that support this principle should:

1. demonstrate and develop the use of teaching by inquiry.

2. provide first-hand experiences in the solution of open-ended questions or problems.

3. provide information about diversity in learning styles.

4. develop the use of problem solving as a focus of instruction.

5. develop sensitivity to a variety of learning styles.

6. supplement teachers' own content knowledge in order to strengthen their instructional decision-making.

7. support teachers' efforts as they use inquiry approaches to instruction, focus on problem solving, and accommodate a variety of learning styles in their classrooms.

8. establish networks for the development of peer collaboration and support groups.

Principle VI

Teachers can use specific teaching methods to facilitate student's active construction of knowledge.

EXAMPLES

Mathematics: Returning to the vision of students confronting the terms point, line, and plane, one way to facilitate their negotiation of meaning for these terms is to first ask students to think to themselves about what each word means to them, then share their ideas with a partner. Next, pairs of partners can be formed into small groups of 4 students and asked to "brainstorm" meanings for the terms. Finally, these results can be shared in a whole-class discussion. In this case, the teacher has drawn on both individual and small group work to facilitate the large group discussions.

Science: As teachers strive to facilitate the learning process, it becomes evident that some students have more background knowledge and previous experience with some concepts than others. When these concepts are taught in traditional ways, these students often excel, leaving other students discouraged. One way for teachers to help ALL students learn and make meaningful contributions to the whole-class discussions is to provide a range of hands on experiences that provide a fertile ground for learning.

For example, when studying seed germination, students study various factors affecting germination in a whole group and small group setting. The whole class has a prior learning experience of growing bean seeds in a plastic bag. In small groups, factors affecting germination are studied. One group studies how the amount of light affects seed germination, another groups studies the temperature, and another group studies how different types of seeds germinate under similar conditions. (*continued on next page*)

After experimenting, each group shares the results of their observations with the whole class. A list of factors affecting seed germination begins to emerge from the whole group discussion. Each student has a contribution to make to the discussion. Each student has experience upon which to construct their ideas about seed germination.

In both of the preceding examples, when the teacher returns to the whole group discussion, it is possible that some students' hands will shoot up to answer questions, while other students do not seem to participate. Although it appears that all students have an equal opportunity to participate, individual differences among students in their willingness to speak in front of a group, their self-confidence, their learning styles, or other differences, may make this learning scenario favor some students over others. It is important that the teacher know strategies to encourage ALL students to participate. Effectively using *wait time*, so that students are given the time they need to construct answers and think about the questions posed is critical for equitable participation. Allowing students to express their knowledge in nonverbal ways (writing, drawing, drama) also will encourage greater participation. There are many other teaching strategies which help ALL students learn. The constructivist teacher effectively utilizes a wide range of these strategies to encourage active learning.

In support of this principle, the constructivist teacher:

1. promotes the philosophy that *ALL students are active learners* (workers) and the teacher's role includes coaching and facilitating learning.

2. knows and uses specific strategies for *encouraging participation* by traditionally underserved students.

3. emphasizes *effective oral and written communication* as important components of learning for ALL students.

4. encourages ALL students to be *creative* and to use their *imagination.*

5. emphasizes the *process* of getting an answer rather than just the *product* for ALL students.

6. encourages ALL students to *question and seek evidence* to support their beliefs.

7. makes appropriate *use of technology* and encourages the appropriate use of technology by ALL students.

Staff development activities that support this principle should:

1. provide illustrations of classrooms in which:

   - there is active learning,
   - the teacher fosters discourse,
   - ALL students communicate appropriately and effectively with the teacher and with each other, and
   - appropriate use is made of technology by both the teacher and the students.

2. develop teachers' ability to foster:

   - active learning,
   - communication, and
   - classroom discourse.

3. implement technology both in instruction and as a tool for student use.

4. develop sensitivity to issues of equity in the classroom.

5. provide follow-up support for teachers' efforts to incorporate the knowledge and skills which they acquire in support of this principle.

Principle VII

In constructivist teaching, the teacher emphasizes "learning-how-to-learn."

EXAMPLES

Mathematics: Rather than assigning 8-12 equations to be solved for practice in class, perhaps only about 3 such equations would be studied in greater detail; e.g., solve $2x+7=3x+5$. Then consider a number of "what-ifs:"

What if the coefficients of x did not differ by just 1?
What if one or more of the coefficients were a negative number?
What if they all were negative?
What if one or more were a fraction?

By studying fewer examples, but in much greater detail, the teacher can facilitate students' ability to generalize results.

Science: Once students establish a working familiarity with the process of conducting a scientific experiment, they can readily apply the process to a wide variety of problems. Rather than experimenting with step by step "cookbook" experiments, students should actively discover for themselves the need to control variables, organize data, effectively communicate and report results, and draw conclusions as they develop experiments to test their hypotheses. As students formulate plans to test various phenomena, they will learn a process which they can then draw upon throughout their lives. They will also realize that there are many different possible approaches to go about discovering the answers to questions, each with strengths and weaknesses.

In support of this principle, the constructivist teacher:

1. helps students' to *self-assess* their learning.

2. encourages students to *take responsibility* for their own learning.

3. answers student questions with other *questions*.

4. *directs students to resources* other than the teacher and the textbook.

5. utilizes the *"Less is More"* approach by emphasizing fewer principles of more general application or fewer topics in greater depth.

6. uses *technology for professional development* (for example, Internet, distance learning) to illustrate how students can learn from other sources besides the text and the teacher.

Staff development activities that support this principle should:

1. develop teachers' ability to foster students' use of:

   - instructional materials and resources including technology.
   - ways to represent mathematics and science concepts and procedures.

2. develop teachers knowledge and the ability to use and evaluate:

   - instructional strategies and classroom organizational models that promote student autonomy.
   - ways to promote discourse and foster a sense of a learning community.

Principle VIII

The constructivist teacher uses continuous assessment to facilitate learning.

EXAMPLES

Mathematics: A second grade student may understand the number "46" and might be able to read the numeral 46. If the student is asked to represent the *numeral* with base ten blocks, and the student uses 46 identical units to represent 46, a constructivist teacher assesses this situation as an indication that the student does not fully understand *place value*. The student needs to demonstrate that the digit 4 represents 4 tens and that the numeral 46 should be represented by four longs and six units. The constructivist teacher will help this student to understand place value by providing additional concrete experiences .

Science: When studying electricity, students are asked to keep a portfolio of their work throughout the unit. The teacher allows students to select some of their best work for inclusion in the portfolio. All students are required to include work that demonstrates their best effor progress, and achievement. Portfolios include such items as: daily journals, group projects, laboratory reports, oral reports, performance evaluations, library reports, peer evaluations, and self evaluations. One student even includes her design for an electric car. Another student includes a newspaper story he had written about how electricity can be generated from solar cells. All students must demonstrate progress in learning concepts and skills about electricity. The next year's science teacher is able to approximate the level of student progress from examining the multiple examples of student work in the portfolios.

Assessments help teachers and parents determine what students know, are able to do, and what they still need to learn. The movement towards more performance based assessment is consistent with the directions proposed by such national reform efforts in mathematics and science as the NCTM standards and the benchmarks of Project 2061. Evidence about students performance is needed for a variety of purposes, such as making instructional decisions, tracking student progress, communicating judgments, and evaluating programs. The methods of assessment should allow students to demonstrate what they know and are able to do, not just what they don't know or are unable to do.

In support of this principle, the constructivist teacher:

1. utilizes two-way *discussions* with students to assess student understanding and to facilitate learning.

2. uses *performance assessments* which reflect and are integrated with classroom instruction.

3. uses a *wide variety of assessment strategies* to inform instruction (projects, portfolios, learning logs, journals, constructed responses, observation, student interviews, peer evaluation, self-evaluation).

4. views *assessment and instruction as inseparable* rather than using formal, isolated assessments conducted at the end of a unit of study.

5. relates *assessment to practical, everyday problem-solving* situations.

6. utilizes *self-assessment* strategies in the classroom.

Staff development activities that support this principle should:

1. develop teachers' knowledge of and ability to use and evaluate a variety of means of assessing student understanding.
2. provide research on how students learn to inform teaching and assessment practices.
3. model and use a variety of assessment techniques.
4. develop teachers' knowledge of and ability to use and evaluate a wide range of approaches to the teaching and learning of mathematics and science.
5. demonstrate ways to assess reasoning, problem solving, and communication at different levels of formality.
6. provide experiences and demonstrations of ways in which assessment and instruction can be integrated.
7. demonstrate ways and provide examples which show how assessment can be used to inform instruction.
8. provide opportunities for self-assessment.

Principle IX

Constructivist teachers are themselves constructivist learners.

EXAMPLES

Mathematics: Many teachers utilize base ten blocks for teaching place-value and whole number operations. A constructivis' teacher might analyze the blocks for the possibility of using them to teach other concepts such as perimeter, area, fractions, decimals and percents.

Science: An elementary teacher wonders if student achievement could be improved if parents were more involved in the learning process. She develops some home science kits for each unit of study. Every child is able to take home these kits and to do the science activities described in the kits with their guardians. Both students and parents are asked to give written feedback to the teacher about the activities tried and what is learned. The teacher notices a marked increase in student understanding and interest in science. She decides to share her ideas and results with other teachers at the annual science teacher convention.

In addition to participating in professional development and other inservice activities, teachers should be encouraged to reflect upon how they acquire new ideas and understanding. For example, they could be encouraged to review and analyze the thought processes they use and become updated in such areas as DNA testing or the advancements in computer technology.

Constructing knowledge is a highly active endeavor. Constructing and understanding a new idea involves making a connection between the old ideas and new ones. The teacher utilizes reflective thinking in constructing ideas from the existing network of ideas and constantly modifies them to create new ideas. Teachers end up with new products and new tools as new knowledge is constructed.

In support of this principle, the constructivist teacher:

1. actively *models* learning by thinking aloud for students.

2. *reflects* on his/her practice and constantly seeks ways to improve and facilitate student learning.

3. regularly *communicates* with other teachers about *new developments* in mathematics and science teaching.

4. regularly *participates in professional organizations* and staff development opportunities.

5. is a *risk taker*, exploring innovative teaching practices.

6. seeks ways to improve practice through *action research* in his or her own classroom.

7. seeks ways to improve her or his practice through becoming *informed about educational research.*

8. maintains a current *familiarity with up to date technological advances* appropriate to his or her classroom.

Staff development activities that support this principle should:

1. model good teaching by:

    - engaging teachers in discourse to clarify their thinking.
    - enhance discourse through the use of a variety of tools including calculators, computers, and physical and pictorial models.

2. provide experiences in which teachers take responsibility for their professional development such as:

   - experimenting thoughtfully with alternative approaches and strategies in the classroom.
   - participating in workshops, courses, and other educational opportunities specific to mathematics and science.
   - participating actively in the professional community of mathematics and science educators.
   - discussing with colleagues issues in mathematics and science teaching and learning.

3. encourage reflection on learning and teaching individually and with colleagues.

4. encourage reading and discussion of ideas presented in professional publications.

5. advocate participation in proposing, designing, and evaluating programs for professional development specific to mathematics and science.

Constructivism leads to new beliefs about excellence in teaching and learning and about the roles of both teachers and students in the process. In constructivist classrooms students are active rather than passive; teachers are facilitators of learning rather than transmitters of knowledge.

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