

## **APPLICATIONS OF CONSTRUCTIVISM IN EARTH SCIENCE**

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*“The National Science Education Standards present a vision of a scientifically literate populace. They outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels. They describe an educational system in which all students demonstrate high levels of performance, in which teachers are empowered to make the decisions essential for effective learning, in which interlocking communities of teachers and students are focused on learning science, and in which supportive educational programs and systems nurture achievement. The Standards point toward a future that is challenging but attainable.” (NSES, 1995)*

Constructivism is a method of instruction where children learn by constructing their own knowledge under the guidance of their teacher. Constructivist teaching practices require students to become active participants in directing their own inquiries and building their own knowledge base. In this approach, teachers become facilitators, where their role is to direct students towards developing or broadening their insights or perceptions, usually through a series of discovery based exercises.

Jean Piaget is perhaps the most well known cognitive constructivist. His research in the area of child psychology led him to the conclusion that children make sense of the surrounding world by continuously incorporating new beliefs and ideas by their interaction with the environment. These beliefs are continuously shifting as the child develops through age related cognitive reasoning abilities. The acquisition of these beliefs occur only as a result of the child directly interacting with his or her environment, usually through processes that can be classified as discovery or inquiry based.

The application of constructivist thinking to educational theory occurred as a result of the government’s call to increase science literacy by involving students in more hands on learning activities. In order for children to learn science, they must be allowed to practice science. This idea of students as active participants in their own learning is even clearly stated in the New York State Department of Education science standards, where educators are informed that “science process skills should be based upon a series of discoveries. Students learn most effectively when they have a central role in the discovery process” (NYS Ed. Dept. 2000).

This push towards science literacy through constructivist practices has lead to a large body of information to be published on the topic. I would like to clearly state the theory behind constructivist teaching practices, examine it for it’s success as a method of education and give some examples on how to incorporate it into the science classroom. I have also cited some examples of constructivist methods (labs and or activities) that I use in my own classroom, and contrast them with the recitation method of teaching. These are labs that follow constructivist practices that have historically been taught through textbook learning or through “paper” labs. A copy of these labs will be included with the presentation

### **Elements of Constructivism**

According to the New York State Department of Education, “*science process skills should be based upon a series of discoveries. Students learn most effectively when they have a central role in the discovery process (NYS Ed. Dept. 2000).*”

This process of self-initiated discovery is aligned with constructivist teaching practices. In a constructivist classroom, the “role of the teacher is raised from someone who simply dispenses information to someone who structures activities that improve communication, that challenge students' pre-conceived notions, and that help students revise their world views” (UMPERG, 1999).

Constructivism is simply defined as a method of instruction where students change their beliefs, upgrade their knowledge or incorporate new ideas and principles through their own cognitive processes (Zahorik, 1997; Brooks & Brooks, 1993; Doolittle, 1997). Constructivist teaching practices require students to become active participants in directing their own inquiries and building their own knowledge base. In this approach, teachers become facilitators, where their role is to direct students towards “developing new insights and connecting them with prior knowledge” (Doolittle, 1997). As facilitators, they need to formulate classroom lessons that are flexible enough to meet the needs and interests of a classroom full of students, but are relevant to the required curriculum (Brooks & Brooks, 1999). This can often be accomplished by focusing on the overall concepts of a topic and not upon the little details.

“Learning generally progresses from concrete experience to abstraction. This concept breaks with the behaviorist learning model that describes learning as the aggregation of elements and basic skills. Young students, in particular, need to have experiences with direct manipulation before they can convert the concepts into abstract symbols and ideas” (Jones, 1991). These elements of constructivism correspond to the steps of the scientific method, the cornerstone of all scientific processes.

### **Constructivism In The Classroom**

In hands on science, “the role of the teacher is to organize information around conceptual clusters of problems, questions and discrepant situations in order to engage the students' interest” (Hanley, 1994). This can be achieved in the classroom by placing a greater emphasis on lessons that encourage students to explore concepts and questions by using scientific inquiry skills over assimilation and regurgitation of facts. Rather than expecting rote memorization, teachers should ask students to observe, classify, predict, estimate, analyze, explain, hypothesize, model and create. Students should be able to see how the knowledge that they acquire can lead to personal and social ramifications (Doolittle, 1997; Black & McClintock, 1995). The student must be encouraged to pursue “a problem or activity by applying approaches he or she already knows and integrating those approaches with alternatives presented by other team members, research sources, or current experience. Through trial and error, the student then balances pre-existing views and approaches with new experiences to construct a new level of understanding” (Briner, 1999).

Instructional methods that conform to this model typically involve strategies that foster student autonomy by encouraging independent thinking, encourage reflective thinking and allow students to relate classroom experience to real world situations (SEDL, 1995; Brooks & Brooks, 1993). Activities that employ these strategies include active exploration and experimentation, hands on activities, exposure to inconsistencies and conflicts that need to be assimilated and accommodated, and even social interactions that can extend beyond verbal classroom interaction (Doolittle, 2000).

According to John Black and Robert McClintock (1995), a model of Constructivist teaching, called ICON (Interpretation Construction Design Model) proposes that throughout these activities, students need to be encouraged to make valid observations that are grounded in fact. They need to interpret these observations and construct valid arguments of support that rely on background knowledge and contextual information. Part of this process must occur through collaboration between teacher and student, as well as between student and peers. Students must also be allowed to “gain cognitive flexibility” by being exposed to multiple interpretations of the information to which they are being exposed, and they must be able to assimilate it to a degree that they are comfortable in transferring that information to others (Black & McClintock, 1995; Hein, 1991).

This methodology is supported by studies on “brain-based” learning theory, a theory that investigates how the brain develops, acquires and retains information. According to “Brain-based” learning theory, in order for students to gain a true understanding of a topic, they must be active participants in their own learning. “The teacher is not the deliverer of knowledge, but the facilitator and intelligent guide who engages student interest in learning” (Cain & Cain, 1997). Students can only construct knowledge according to their developmental stage and their pre-existing knowledge base.

### **Assessment and Constructivism**

If “learning is a complex process through which learners constantly change their internally constructed understandings of how their worlds function” (Brooks & Brooks, 1999), then it can be argued that any change in a person's internal schema (Piaget’s term that defines the mental processes by which individuals organize their experiences into knowledge) constitutes learning. While this philosophy may underpin constructivist theory, it is important to realize that with today’s emphasis on uniform assessment tests, constructivist teaching practices must also include a comprehensive plan for assessing student knowledge that is specific to the required curriculum. According to the North Central Regional Educational Laboratory, “Assessment must measure what is valued--not just those skills that are quick and easy to measure. Therefore, if the new education paradigm emphasizes principle and process for broad concepts, assessment systems must measure learning at that level” (NCREL 2000).

Performance based projects, portfolios that document student progress, written and oral summaries and presentations are all methods that can be used to successfully evaluate student understanding. These assessment devices can be used in addition to, not for replacement of typical “pen and pencil” tests (Brooks & Brooks, 1999; Hanly, 1994).

### **Examples Of Constructivism in Earth Science**

*“If you want to make an apple pie from scratch, you must first create the universe.”* – Carl Sagan

According to *the Physical Setting/Earth Science Core Curriculum Guide 2000* published by New York State,

“It is essential that instruction focus on student understanding and demonstration of important relationships, processes, mechanisms, and applications of concepts. Students, in attaining scientific literacy, will be able to demonstrate these explanations, in their own words, exhibiting creative problem solving, reasoning, and informed decision making.

Future assessments will test students’ ability to explain, analyze, and interpret Earth science processes and phenomena, and generate science inquiry.

The general nature of these statements will encourage the teaching of science for this understanding, instead of for memorization. The Major Understandings in this guide will also allow teachers more flexibility, making possible richer creativity in instruction and greater variation in assessment.” (NYS Ed. Dept. 2000)

These stated requirements reflect the effort by the New York State Department of Education to upgrade its science requirements so that they meet or exceed the new learning standards. In order to assess the application of these goals in the Earth Science classroom, New York State has restructured its Regents exam to reflect a more content and skills based level of questioning. Students will be required to “graph data, complete a data table, label or draw diagrams, design experiments, make calculations, or write short or extended responses. In addition, questions may require students to hypothesize, interpret, analyze, evaluate data or apply their scientific knowledge and skills to real world situations” (NYS Ed Dept. 2000). Students will also be asked to complete a performance-based test where the manipulation of materials, equipment and data will be assessed. An integral component for the successful completion of both tests will be the ability of the students to apply facts listed on Earth Science Reference Tables, towards solving problems that are presented to them.

In order to meet these goals, more performance based activities along with inquiry based lessons must be applied in the earth science classroom. For example, one of the topics in the new core curriculum is “Weathering, Erosion and Deposition.” This topic deals with the formation of sediments, the classification of them by size, how they move, and what variables affect the rate of their movement. The topic also examines the various methods of deposition, factors that affect their position in a depositional environment and finally the processes that lead to the formation of sedimentary rocks and their structures.

A central concept taught in this topic is sediment size. Clastic sedimentary rocks are rocks that have formed through the compaction and cementation of various sizes of sediments - particles or fragments of rocks that vary in size and texture. These rocks are classified according to the comparative size and shape of their grains. Students are expected to know the names of the rocks based upon a dichotomous key included in the Earth Science Reference Tables (See Figure 1). Part of the identification process is to classify each rock based upon its grain size. A graph relating the grain size with rock nomenclature is included on the reference tables (See Figure 2).

### Scheme for Sedimentary Rock Identification

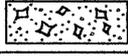
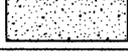
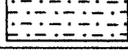
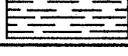
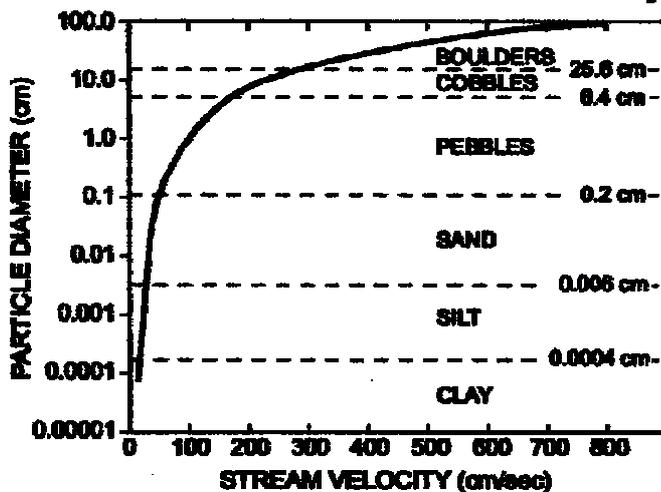
INORGANIC LAND-DERIVED SEDIMENTARY ROCKS					
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Clastic (fragmental)	Pebbles, cobbles, and/or boulders embedded in sand, silt, and/or clay	Mostly quartz, feldspar, and clay minerals; may contain fragments of other rocks and minerals	Rounded fragments	Conglomerate	
			Angular fragments	Breccia	
	Sand (0.2 to 0.006 cm)		Fine to coarse	Sandstone	
	Silt (0.006 to 0.0004 cm)		Very fine grain	Siltstone	
	Clay (less than 0.0004 cm)		Compact; may split easily	Shale	

Fig 1

### Relationship of Transported Particle Size to Water Velocity



\*This generalized graph shows the water velocity needed to maintain, but not start, movement. Variations occur due to differences in particle density and shape.

Fig 2.

This graph shows that boulders are sediments larger than 25.6 centimeters in size, cobbles range in size from 6.4 cm to 25.6 cm. Pebbles range in size from 0.2 cm to 6.4 cm, sand ranges in size from 0.006 cm to 0.2 cm, silt ranges in size from 0.0004 cm to 0.006 cm, and any grain smaller than that can be classified as clay. In addition, this graph shows the relationship between the water velocity needed to maintain, but not start, movement of the particles in a stream or river erosional/depositional system.

Students often have a difficult time estimating the grain size listed on the reference table graph. In this case, a lab can be set up around the room that presents them with a multitude of actual sediment samples in the size ranges listed on the reference tables along with instruments that the students must manipulate in order to correctly measure the size. The student objective would be to classify various sediments by size, name them according to the specifications listed on the graph, and list the stream velocity required to move each sediment. A metric ruler would be fine for most samples, while samples of silt and clay would require a station with a microscope and scale set up for student viewing.

This lab would allow the students to practice using scientific instruments, and to participate in the process of gathering information. The students would be required to analyze and interpret data that they have collected, and to use the data to construct their own data table. Some open-ended questions should be included with the lab that would allow for the processing and application of the gathered information.

Once students have become familiar with the size of the grain and its classification, other labs could be given that would incorporate and expand upon this knowledge. For example, students could be directed to bring in a jar half full of dirt from their yard. During a lab, students will be asked to fill the jar with water, shake and then allow it to settle. This would show them that grain size affects settling rate, and that some grain sizes, in the colloidal range will not settle out. Because the dirt comes from many different yards, the results will vary from student to student. This would promote student interaction and the exchange of ideas and information - key components to constructivism. Students also tend to form a deeper curiosity about the outcome of the experiment because they feel a sense of ownership with the samples that they gathered from their own home.

Finally, this lab could be extended by allowing the jars to sit undisturbed for several days so the students can observe later stages of sedimentation. After four or five days, students would use a turkey-baster to siphon off as much of the water as possible without disturbing the settled sediments. The jars could be left, opened on a radiator or on a windowsill, to fully "dewater" - one of the processes towards the development of a sedimentary rock. The dried sediments will clearly show layering and may even develop some sedimentary structures such as mud cracks. Again, the students' interest about what happens to their "own" dirt provokes a heightened level of curiosity and anticipation. Many of the students will form a hypothesis about what will happen and offer reasons to justify their predictions. These are actions inherent in the higher level thinking skills that students must develop.

### **Summary**

*"Cramming and over-schooling have impaired many a feeble mind, for which, as the proverb says, nothing is so dangerous as ideas too large for it." G. Stanley Hall*

G. Stanley Hall was a distinguished Professor of Psychology and eventually President Emeritus of Clark University from 1888 to 1924. He made the above observation at a time when less than seven percent of the population attended high school. School reform swept across the nation with the incoming waves of immigrants, when the push began to educate these people in order to have them "achieve cultural uniformity, not diversity, and to educate dutiful, not critical citizens" (UV, 2000).

This reform movement was needed to make responsible citizens educated enough to become contributing members of society in general. Such educational philosophy was to enable the masses (this did not include the wealthy or the elite), to find jobs of support so that they would not become a burden on society at large. It was geared to make them conform to what

was considered the ideology of the standard American citizen; it was not geared to allow for exploration of individual ideas or development of higher order thinking skills.

Beginning in the nineteen eighties, the paradigm of American Educational philosophy gradually swung towards more progressive educational practices. Less emphasis was put on conformity and more was placed on "teaching for meaning." According to Caine and Caine (1997), teaching for meaning involves structuring our lessons so that they "ensure that anything that we wish to teach or to have our children learn ... (is) embedded in multiple, rich, interactive experiences where most of what is to be learned is left open-ended, ready for discovery by and consolidation within the learner."

Constructivist teaching practices are based on principles that require students to be involved in this kind of dynamic learning environment. It stresses that learning is an active process that must engage the learner in order to be successful. It takes into account the biological principles of brain development, the social aspects of learning and the various processes by which knowledge is individually assimilated, constructed and adapted. In this way, a deeper level of understanding is encouraged. It is important to remember that

learning is not understanding the "true" nature of things, nor is it (as Plato suggested) remembering dimly perceived perfect ideas, but rather a personal and social construction of meaning out of the bewildering array of sensations which have no order or structure besides the explanations which we fabricate for them. (Hein, 1991)

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**Classification of Sediments**

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**Introduction:** Clastic sediments are particles or fragments of weathered rocks that are classified according to their size. Sediments are transported away from their place of origin by various agents of erosion. Running water, which is the most common agent of erosion, can transport sediments in a variety of ways. The smallest particles are transported in solution as ions. Colloids are tiny particles that are transported in suspension, while larger particles are moved by the current rolling and bouncing them along the streambed. The size of the particles that can be carried by a stream depends on the velocity of the moving water. In this investigation, you will examine the relationship between the size of a sediment, and the velocity of the water needed to move it.

**Objective:**

1. To measure the diameter of various clastic sediments.
2. To classify various sediment samples according to their size.
3. To compare and state the relationship between the velocity of a stream and the size of the sediment it can transport.
4. To measure the mass and volume of 3 different size particles, and to determine their density.
5. To interpret the effect of particle density on stream velocity .

**Materials:** 12 sediment samples of varying sizes, 3 sediment samples of equal size but different densities, a copy of the graph “Relationship of Transported Particle Size to Water Velocity”, a copy of the 10.Velocity key for Sedimentary Rock Identification, metric rulers, a binocular microscope, triple beam balances, graduated cylinders and beakers.

**Vocabulary:**

- |               |              |             |
|---------------|--------------|-------------|
| 1. Sediment   | 4. Gradient  | 7. Abrasion |
| 2. Weathering | 5. Discharge | 8. Solution |
| 3. Erosion    | 6. Colliod   | 9. Ion      |

**Procedure A:**

1. Using the metric ruler, measure the average diameter of the sediment sample at stations 1-12 in centimeters. Record in data table 1.
2. Use the graph, “Relationship of Transported Particle Size to Water Velocity” to classify each particle. Record in data table 1.
3. Use the graph, “Relationship of Transported Particle Size to Water Velocity” to calculate the minimum stream velocity needed to move each particle and record in data table 1.

**Procedure B:**

1. Measure the mass in grams of each particle at stations 13-15 using the triple beam balance and record in data table 2.
2. Measure the volume in mL of each particle at stations 13-15 using the graduated cylinder and

record in data table 2.

3. Calculate the density and record in data table 2. *Show all work.*
4. Using the metric ruler, measure the average diameter of the sediment sample at stations 13-15 in centimeters. Record in data table 2.

**DATA TABLE 1**

<b>Station</b>	<b>Sediment Diameter (cm)</b>	<b>Sediment Name</b>	<b>Stream Velocity (cm/sec)</b>
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

**DATA TABLE 2**

<b>Station</b>	<b>Diameter (cm)</b>	<b>Mass (g)</b>	<b>Volume (mL)</b>	<b>Density (g/mL)</b>
13				
14				
15				

**DENSITY CALCULATIONS**

## **QUESTIONS**

1. What is the relationship between particle size and the stream velocity?
2. What are two factors that can change the velocity of a stream?
3. Describe physical weathering. Give 2 examples.
4. Describe chemical weathering. Give 2 examples.
5. Using the scheme for sedimentary rock identification, identify the type of rock that would form from a mixture of clastic sediments ranging in size from 0.0004 cm to 100.0 cm.
6. The most abundant rocks in the Earth's crust are igneous and metamorphic, however, sedimentary rocks are the most common rocks found on the surface. Why do you think this happens?
7. Examine the sediment samples from station 13, 14 and 15. Would the stream velocity needed to move them be the same? Give a reason for your answer.
8. A stream moving with a velocity of 700 cm/sec can transport what size sediments? At what stage of life would this stream most likely be?
9. What physical characteristics would indicate that running water had transported the sediments?