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Using Brain-Based Learning Techniques in High School Science

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A physics and chemistry teacher explored ways that brain-based learning environments could produce better learning conditions for his students. He used thematic teaching; enriched language use; naturally complex, long-term design and construction projects; and multifaceted assessment tools. The results of a year-long curriculum developed for high school physics and chemistry show that content mastery need not be sacrificed at the expense of learning process skills. The theoretical underpinnings, description of the curriculum's framework, and an evaluation of 4 years of experience with the program are included.

I wanted to know if I could create and implement a year-long, brain-based curriculum. And I wanted to know what the results would be. I wanted to change my approach to teaching to maximize student intellectual growth.

Revamping my teaching style began with my college preparatory and general physics classes and filtered into my chemistry classes. I teach at Smoky Hill High School in Aurora, Colorado, a large (2,300 students) suburban school in a supportive middle- to upper middle-class community. Most of our students (95%) are college-bound. We have 9% African American, 1% Asian, and 89% other in our student population. The total physics program has had approximately equal numbers of male and female students enrolled for the last 8 years, whereas the chemistry department boasts a slightly higher female to male ratio. Our physics and chemistry classes are among our more rigorous courses. Because my goal was to create and study the effect of a year-long brain-based curriculum in physics and chemistry, I consolidated ideas from the literature, devised the curriculum, and monitored the results.

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How We Learn

Constructivism

In 1986 I read a journal article about contructivism (Bodner, 1986), which began a cascade of events in my life. My reading lead me to the brain-based learning and teaching theories of Hart (1983) and Caine and Caine (1991). It was these four authors that most influenced my thoughts and whose ideas shaped my classroom as it is today.

The tenets of constructivist theory (as summarized by Bodner, 1986) are

1. Knowledge is constructed in the mind of the learner.
2. Knowledge cannot be transferred intact from the mind of the teacher to the mind of the learner.
3. The single most important factor in determining what a student will learn from an experience is what he or she knows *before* an experience.

The first point is illustrated by Stephanie's experience. Chemistry was difficult for Stephanie, as it is for many students who are still making the transition to more abstract spatial reasoning. In an effort to make the topic of reaction kinetics (how fast reactions take place) more concrete and lively, I divided the unit of study into eight key ideas (including temperature, surface area, concentration, collision theory, catalysis) and assigned groups of three students to write, produce, and perform a one-act play that would explain their topic. They had to develop a plot, create props, and rehearse (they could not pretend to be a chemistry teacher explaining the concept). I encouraged them to use analogies and puns. Finally, they had to write a test question with a complete solution. Stephanie and her group performed admirably. Some days later, the normally very shy sophomore initiated a conversation with me. "You know that kinetics play we did really helped me. Having to figure that stuff out for myself and then make a play out of it was great. I really understand it now." Her reworking the words of the text into her own personal mental framework cemented the concepts in her mind in a meaningful way. This experience proved to be a springboard to a higher level of performance for Stephanie.

The second point is illustrated by my own education. The first year I taught physics I spent a minimum of 2 hours a day preparing my lesson plans because I had to make physics meaningful to me for the first time. I had managed to earn good grades in physics without having a deep understanding of the main ideas. I didn't want this to happen to my students.

The third point, the importance of prior knowledge in any new learning, is significant when one considers that prior knowledge can mean misconceptions. One particularly resilient misconception that my physics students have is that a constant net force is needed to produce constant velocity. Although many of them solve the algorithmic version of Newton's second law correctly, they still give explanations such as "If it is moving, it has to have some force behind it." Because their life experience told them that scooting a box across the floor at a constant speed required a constant force, learning something contrary to that was difficult. Their knowledge of the world before coming to class strongly affects what they assimilate from class.

Constructivism seemed very theoretical to me. I still needed a more "total person" reason to change my way of teaching. The work of Hart and the Caines helped me realize that if I wanted to improve my students' learning, I had better study the primary organ of learning —the brain.

The Three-Part Brain

Three features of brain structure and function that became central to my approach to teaching are neural plasticity, the triune brain, and the brain's language center. *Neural plasticity* is the tendency of synapse and neuronal circuits to change as a result of activity (Fischbach, 1992). That means that what I have my students do and experience in my classroom will cause their brains to physically change and adapt! The fact that I could affect the structure of my students' brains reoriented my daily perspective. "Whose brain is growing?" echoed in my mind.

Sheila's experience lends credence to the notion of long-term structural change in the brain due to classroom activity. Sheila is a former physics student of mine who will soon be graduating from college with a degree in English. Her mother recently told me that Sheila still remembers "all those physics equations." She said her daughter credited it to having to complete my big semester project, the Rube Goldberg machine. This senior project involves extensive student-initiated design and construction followed by an interview with me concerning the concepts illustrated. Sheila was a language person not a physics person. Her neuronal connections were set up to think and understand in words and speech. But the long-term exposure to an activity-based environment in which she constructed meaning in her own brain modified her neuronal structure. Her long-term memory was affected by the Rube Goldberg machine project. I realized that impoverished environments would lead to poorly connected neural networks and that enriched and naturally complex experiences would lead to rich networks of neuron connections that provide many paths for the solution to a problem. I had to get my students into an environment that fostered the creation of complex and redundant neural networks that represented their constructed truths about reality.

The second feature of brain structure and function that affected my teaching approach is the concept of the *triune brain*. This concept organizes the parts of the brain into three segments that follow evolutionary characteristics. The smallest and most genetically preprogrammed section is frequently called the *reptilian brain*. Digestion, mating rituals, territoriality, and fight-or-flight response function in these neurons. The *neocortex*, which comprises four fifths of our brain's mass, houses cells dedicated to speech, concept building, abstract thought, and pattern formation. The *limbic system* houses feelings, expressions, and contextual memory, and referees between the other two brain sections. The limbic system drew my attention. Cognition, I reasoned, had to take place on a grid of emotion. This "whole picture" view of learning became the focus of my teaching.

Ryan, a young woman in my chemistry class, reminded me of the inexorable link between higher-level learning and emotions. An intensely emotional person, she had to feel good about chemistry in order to learn. One day when I called her aside after class to check if she had any questions, she said, "I'm having an emotional day, I can't think today." The three-part brain cannot be separated and taught as if no connection and interdependence occurs. I realized that if I did not pay close attention to the natural interplay between cognition, emotion, and inborn behavior, no revamping of my teaching would be effective.

The third brain feature that affected my teaching is the *brain's language center* and the development of higher order thinking skills. Brain-based learning theories suggested to me that *active inquiry* on the part of the student was crucial for the formation of complex and redundant neural networks. These multiple means of solving problems and imagining solutions seemed essential to success in our increasingly complex and technological world, and I wanted my students to have the best possible chance for success. The most effective, widely shared human intellectual activity that forms these structures is language use. I read that tutorlike situations (Graesser & Person, 1994) produced 241 times more student-generated questions than traditional lecturing techniques! That is what I wanted to emulate in my classroom.

Orchestrated Complexity

Caine and Caine (1991) propose the idea of a synthesis of brain biology and pedagogic practice called "orchestrated complexity." An analogy helps to explain. Many people are naturally drawn to and motivated by sports. For example, young children play soccer. They see the entire game and understand the broad goal from the beginning. Parents and coaches encourage them to play the game as a whole from the first introduction to the sport. We do not ask children to spend 1 year kicking, 1 year head-butting, and then 1 year inbound passing in anticipation of some grand day when they are mature and can synthesize all the drills into expert gamesmanship. Rather, we introduce children to the entire complex whole of the task.

How I Structure My Classes

Three Activities I Use to Generate Intellectual Dialogue

The three activities that follow (two I adapted from other teachers) have proved to be wonderfully successful at generating a true intellectual dialogue between students about the topic at hand.

Talking Aloud Pair Solving

Talk Aloud Pair Solving (TAPS) encourages a tutorlike environment that takes advantage of specific roles assigned to teams of two students (Pestel, 1993). The purpose is for students to discover their unique problem-solving style through constant vocalization during a problem-solving session. The *listener's* role is to insure that the solver is continually talking about his or her thinking. The *solver's* role is to engage the problem and not give up. I have found that it is very important to give the listener sample questions to ask (to show them that they do not have to know the answers in order to help the solver). Here are some sample questions I give them:

What are you thinking now?
Why did you use that equation?
How did you get that number?
What are the units on that value?

I circulate around the room to help in situations where students are stuck and to model each role. Within 15 minutes of my introduction of this new method, the students began to use the cognitive power of human speech. Instead of my asking rhetorical questions and expecting no response, there are 26 intimate, sincere, and cognitively active conversations occurring.

Here is an example of what I hear as I walk around the classroom:

Solver: That's kind of like the equilibrium arrows, you know, the back and forth part?
Listener: What back and forth part? Explain.
Solver: Like when the forward and reverse reactions occur at the same rate. So if one speeds up for some reason, the whole thing is out of balance. (He draws some illustrations and he gestures with his hands to show balance adjustments.)
Listener: What's that all about? What are you thinking now?
Solver: Well, just that if volume goes down, pressure goes up, and a pressure increase makes the side with the most gas temporarily heavier.

Even in this short excerpt, one can see that the listener helps the solver simply by asking questions. The listener does not have to know how to solve the problem. Students relish the listener role because they do not feel the pressure to perform. Students enjoy the solver role because they can relax in this tutorlike environment that decreases anxiety and increases mental engagement. I can spot conceptual mistakes easily by eavesdropping and intervene when appropriate.

The Problem Solving Template is a structured problem-solving method that enhances the TAPS technique. It follows the mental framework of expert problem solvers and gives students an external structure to mimic and learn (I saw this presented in a meeting of physics teachers). It follows a generic sequence of implicit to explicit information, sketch, concepts involved, governing equations, predictions, numerical solution, and finally checking. I produced this mental format on a single sheet of paper and trained my students how to use it. For those students who need structure, it seems to be a secure mental starting point. My skin literally tingled as I stood back and listened to the cacophony of questioning produced by these methods. "Oh, I understand!" and "I don't get it, explain that again." and "Why did you do that? I would have. . . ." streamed through the room. The magic of human language was engaging these young scientists' minds on a level I had only dreamed of creating.

Quizzes

Another way of using the rich cognitive one-on-one conversation involves quizzes. This works, but the staging is crucial. I generally give quizzes over homework problems to reinforce their importance. I pass out the quiz and allow the class to work until they have had time to attempt all the questions. At this point they realize what they do not know, they can focus on questions they would like to ask, and they are very receptive to any suggestions about how to solve the problems. About three fourths of the way through the period, I interrupt the students and explain to them the value of language in solidifying concepts and in problem solving. "You may speak with a neighbor about your quiz problems" is greeted with a purposeful and energetic verbal exchange about science problems. Universally, my students comment on the value of this quiz format to me. "I'm pretty sure I know it, but it [the quiz format] helps to talk about it," is the most frequent response. It is important to introduce these structured uses of language in brain-based learning and teaching.

Complex Projects

Project work, including well-designed lab activities, affords students the opportunity to use the planning function of language and to externalize their understanding through feedback from nature. The Rube Goldberg machine project requires teams of students to plan both the conceptual content and the mechanical order of their machine. As I listen to the teams at work, I hear comments like "What concepts should we use?" and "If we show acceleration then we might as well show conservation of energy." and "Could we include circuits since we already have the batteries for the concave mirror?" This complex, propositional language streams prolifically from my students' conversations as they drive themselves to create a unique device. Nature provides the reason and the means for internalizing what we know. My students talk with each other much more than they do with me. Appropriately designed and monitored projects encourage them to use language in complex ways and in situations that are personally meaningful.

Yet it is important for students to express their understanding of nature to others. Future employers, I explain to my students, must have confidence in what you say. Language is crucial for this too. Therefore, I help students externalize what is in their minds through interviews with me. The Rube Goldberg machine project culminates in a 40-minute interview in which the students present their machine and tell me how it works. I review their report, which has both a theoretical and experimental analysis of each illustrated concept along with any relevant error comments, as they talk about their device. I ask questions such as "What concept are you illustrating here?" and "Why did you use this governing equation to predict what would happen to the pendulum?" and "If you say that acceleration is constant, then what should the speed at the bottom of your ramp be?"

My students recognize the linguistic form of these questions because they have been practicing with each other through the TAPS and quiz structures and several mini-interviews that I conduct with them throughout the year. They enthusiastically demonstrate their knowledge of their invention by confidently using the higher cognitive functions of human speech. Language becomes for them a tool to express their understanding about something for which they are an expert. Brain-based learning encourages these kinds of cognitive adventures.

How I Implement the Instructional Approach

The brain processes both in parallel and serially. We must teach in parallel. I do this by nesting the projects and assignments in an embedded interdependent framework. This structure features a complex, long-term, open-ended, concept-rich design and construction project that unites all the major themes of the semester. Occurring simultaneously are a group of decreasingly complex "menu items" that end in single-topic concept builders that require a small amount of time. This transpires in a grid of instruction about writing in science, effective oral presentations, problem solving, and experimental design.

The Menu Grading System: Offering a Selection of Projects

Mindful of the triune brain, I implemented my adaptation of orchestrated complexity into the physics classroom. I call it *Menu Grading*. As a gourmet chef offers a quality selection of items for the eating goals and curiosities of his customers, so I, the physics chef, offer a wide selection of projects and activities for students to obtain their learning and grade goals. No two students earn letter grades the same way, yet I insure that only quality items are on the menu. This approach draws on the limbic system as the go-between to the neocortex and reptilian brain. It offers students a sense of choice and control that proves to encourage intrinsic motivation.

A fitting analogy is that of the sailing regatta. The large-scale projects (such as the Rube Goldberg machine) anchor the theme of the semester while the smaller single topic "potpourri labs" provide marker buoys of progress to the students and the teacher. The course is marked by buoys that guide the entrants. Each person captains his or her own vessel about the course in a fashion that best fits his or her skills and experience. The goal is the same for each participant, but the method of reaching the finish line is determined by the individual. The environment provides feedback. If the sailor chooses a tack that slows

progress or takes him or her off course, it becomes immediately obvious, and he or she can make corrections. When students perform the potpourri labs, I check their understanding, and if it is not "on course," we decide on other activities for proper progress. Each student is headed in the same general direction, which is set my me, but they get there in a variety of ways.

When students make their own significant decisions about their intellectual progress or development, they construct new knowledge. The nature of the menu grading system demands that the individual constantly monitor his or her position in the course. This position is a function of the student demonstrating an understanding of nature. The menu I offer to students is replete with environmental qualities that appeal to a multiplicity of sensory input and to the innate desire to have choice in matters of personal concern such as grades. A short list of examples follows.

1. *The physics of aesthetics:* Students are asked to view their aesthetic appreciation of fine art or music in light of their understanding of the laws of motion. For example, How does a painter evoke the sense of impending doom in an ocean scene? How can vector physics help explain the tilt of the boat or the tension on the ropes? How does physics help the viewer know from which direction the wind is blowing? In music, students are asked to think of how a composer uses acceleration or constant velocity concepts to create a mental picture in the minds of the listeners.
2. *Miniature hovercraft:* Students design and construct a miniature version of a hovercraft and investigate how frictionless it is by allowing it to slide down a ramp and by monitoring its motion characteristics. This vehicle can be made from a common hair dryer, cardboard paper, and trash bags.
3. *Intellectual journal:* Students write frequent entries into a spiral notebook to monitor their thinking as it is happening. The idea is for students to use a deepening knowledge of themselves to monitor and, it is hoped, to improve their understanding. My feedback comments focus on getting the students to explicitly detail and enumerate their ideas rather than attempt to correct physics misconceptions.
4. *Kinetic art:* A student designs and constructs a kinetic art sculpture. I provide an idea-generating article, Rickey (1993), that

explains the piece in terms of center of mass and pendulum motion. The final piece must be accompanied by an analysis of its motion.

5. *Computer simulation:* Students use a simulation program to create an easy-to-study world in the computer. The students develop an experiment and allow the computer to generate data that is subsequently analyzed in light of the principles of the course. Examples such as a box sliding down a ramp and up another ramp of a different angle are used.

The menu system's range of choices helps to motivate students. Ultimately, motivation moves students to construct reality for themselves. "Task-oriented" students are interested in learning a subject for its own sake, whereas "ego-oriented" students are interested only in how their performance looks in the eyes of others. Ego-oriented students use surface-level, problem-solving strategies that involve simple memorization or algorithmic manipulation. Task-oriented students use deep-level strategies, which include discriminating important information, making connections, and monitoring their comprehension. They have a tolerance for ambiguity and are open-minded and thoughtful. Students with real choice in their learning and who are freed from the normative basis of grading can shift their approach to motivation. This shift is crucial in order to fully use the higher brain functions of the neocortex.

Scott is a good example of the changes choice can make. A marginal student, Scott plodded through physics in an obligatory fashion. Finally, one of the menu items caught his attention. Two students had constructed a mystery electrical circuit made from regular household light bulbs for another project. He was intrigued by the puzzle nature of the assignment. After a long practice session, Scott interviewed with me. While working through a few problem areas together, he casually said, "I really like it when I come in like this and talk with you. This is the fun part. I like figuring this out for myself." Allowing Scott to choose from alternative assignments enabled him to motivate himself.

The Use of Themes

Finally, I apply brain-based learning ideas through the use of themes. Broad unifying themes help people to build effective connections from one concept to another and offer an intellectual home base in the orchestrated complexity of menu grading. In physics, I use three themes: Physics Is Moving, for the first semester when we study mechanics; Physics Is a Charge, for the third quarter when we study electricity; and Light Is Illuminating, for the fourth quarter when we study light. In chemistry, I use Matter Is Marvelous all year long. I know these themes resonate in students' minds. It is common for me to see these phrases doodled in their notebooks and lab reports. This form of graffiti indicates to me that these phrases encapsulate the core ideas of the course and help students dwell on them.

Evaluation Under the Menu Grading System

Tasks and evaluations designed with brain-based learning concepts help students show what they know. These activities must include the emotions or feelings. In other words, the best project or assessment ever created might be boring at best and destabilizing at worst for a student in the wrong frame of mind. When human beings feel threatened in any way, the limbic system cuts off the neocortex and the reptilian brain takes over. Threat can take many forms. "The deciding factor appears to be whether we see a solution to a problem and see ourselves as capable of resolving it" (Caine & Caine, 1991, p. 66). Education that emphasizes right answers, rewards and punishments, and narrow outcomes restricts our access to the intrinsic motivation required to grow intellectually.

Evaluation under the menu system helps maintain a relaxed and challenging atmosphere. Students select projects based on their interests and goals. Each project has a point scaling factor. Large complex projects have higher scaling factors. Students earn 900 points for an A, not a percentage of all work assigned. This flat-fee outcome is not relative to other students. It is a function of what a student demonstrates that he or she knows through a set of activities unique to him or her. A student might do poorly on a test yet choose to demonstrate that he or she really does understand by selecting another appropriate menu item. Repeated student surveys indicate that they feel the evaluation system is challenging but fair because one bad test does not prevent them from obtaining an A. I insure that the menu items are high quality and performed to a high standard.

I have mentioned the type of tasks that I use to help students internalize the external world in ways that they personally understand. These long-term complex problems also help students externalize what they have come to know. As such, these projects become rich sources of information by which to evaluate students. Another specific example is the Dynamic Launch Vehicle (DLV) project. On the first day of class, students receive a handout describing a team project that requires students to use the first semester's concepts to design and construct a vehicle that rolls down a ramp, carries a raw egg on the front toward a solid barrier near the bottom of the ramp, and launches a small projectile toward a target. I ask students to design and build the vehicle in a modular fashion. For example, when we study force, mass, and acceleration, students construct the chassis and use it to carry bricks as the cart is pulled by rubber bands. This experiment focuses on one of Newton's laws. Students construct and test their launching device when we study projectile motion and develop their egg protection system when we study impulse and momentum. They are paced through the project and understand the curricular connection.

I end the culminating interviews for this project with a question about how the course is going for them to date and whether the DLV assignment was a good one. Tanya's response this year helped me evaluate her understanding of physics and the effectiveness of themes.

> It [DLV] draws everything together. We had to think of how all the concepts related in order to get the job done. I mean acceleration affects how fast the cart is going at the bottom of the hill, but that depends on the friction and the gravitational attraction, and that affects how much momentum the egg will have, which changes your breaking design and so on. Its kind of all connected. It's just one big example of physics is moving.

This project sets in students' minds like a familiar face whose name you forget. It is as though someone pushed a search button in your brain and you continue about your business until one day during a visit to the symphony you scream, "Susan!" We cannot help but express what we know or remember. When orchestrated properly, students willingly and astutely show what they know.

The forum for evaluating students' demonstrations of what they know should facilitate the process. Just as there are many ways of knowing, there are many ways of showing. I offer students the option of oral reports, interviews, journal writing, formal science write-up writing, design and construction, and performance tasks. All projects and experiments are assessed by six criteria: interpretation, observation, attitude, communication, manipulation, and planning.

Each criterion has a 5-point scale and a detailed description of the qualities exhibited by the student at each level. These criteria focus on the essence of intellectual growth as it is demonstrated in the sciences. The message is clear and consistent. What is important in the DLV project is also important on a 50-point activity or any other item on the menu. As a result, students develop habits of the mind in concert with successful thinking.

Findings

The two teachers in the physics department gave the same first semester test for the last 8 years. We administered the 25 multiple-choice question exam after a semester of mechanics instruction. My colleague did not use my curriculum at any time in the 8 years and I used brain-based learning the last 4. The test averages for both teachers for all 8 years is very close. That is, no trend or statistically significant difference exists in the long-term test scores. This suggests that the performance on traditional tests was not affected by this curriculum. This occurred even though I lectured approximately 20% less in the new system and covered 5% fewer topics.

Also, the demographics of our district are changing. We are becoming increasingly diverse. Colleagues with whom I spoke said that they could not cover as much material today as they did 10 years ago and that the concept density and rigor had to be lower for the same number of students to perform well. These test results are encouraging in light of the forces that might cause them to be lower.

But the strongest and most meaningful evidence, to me, comes from the comments of my students. Every year our principal asks the seniors to write a note to teachers upon graduation. The comments that I have received since incorporating brain-based learning techniques have been instructive. They illustrate the broadened and deepened scope of learning that has occurred and a change of attitude toward learning. Notice the strong personal voice in these comments.

> Thank you for helping me see that science is more than just equations and formulas, but that it is something very useful and important in our society. I always find myself questioning the physics behind everything now. I'm not sure that is good because I can no longer appreciate life on an ignorant level. I really do enjoy your grading system (menu). At first I was very skeptical of it, but I think I learned more due to it than I would have if it had been a normal system.
>
> I will always remember your class as the most beneficial. I had control over what I learned and what my grade would be. Not many teachers would give their students that much freedom. The projects we did were out of the ordinary. They were different from all the boring book work we do in all our other classes. You made success attainable by your unique teaching style.
>
> You taught me how to control my own situation and accomplish anything that I want to. I will carry this with me into the future. Thanks for all the physics. I'll see it every day and will be able to explain it.
>
> I've learned a lot, not only about physics but also about pushing myself and not giving up when things get hard and I don't understand them the first time. I don't think I've ever been in a class where I've felt I've accomplished so much as I have in physics.

Conclusions

Brain-based learning techniques have had three major effects on my students. First, they learned that learning takes place in their minds when they are actively engaged in an intellectual struggle. And as they create meaningful solutions to problems about which they care, they experience a sense of empowerment about their learning. Second, my students learned that grades do not depend on luck but rather on what they can demonstrate about their knowledge. The menu grading system fosters a link between thoughtful work and performance in the students' minds. Third, they learned that knowing how we think helps

us work. As students explored a variety of project types, they became tuned into their preferred learning style.

The emotions play an important role too. The brain that thinks also feels. My students prefer to have some choice in assignments. This choice fosters a sense of control that enhances intrinsic motivation. In the menu grading system, no two students obtain a letter grade by the same means. In this way, as students make appropriate selections about the way they will learn, each student changes the curriculum. I become their ally in learning because I facilitate *their* goals, which emanate from *their* choices.

Teachers create environments in which students construct knowledge. Most of this new knowledge is tacked onto existing constructs, whether they are correct or incorrect. Therefore, learning is the joint effort of teacher and student. As teachers/colearners, we devised long-term, open-ended, multifaceted, and naturally complex projects to cause the students to draw together most of the major concepts of the unit. Then we created a theme to serve as an umbrella concept for the course of study. Each assignment and task related to this theme. And then we designed an assessment tool that involved some short answer facts and concept checks in order to build confidence, some physical manipulation (such as squeezing the cloud maker in front of the teacher), and some oral responses to student and teacher questioning.

I found a positive student response to these brain-based teaching methods. But for me, the most compelling evaluation of this effort is a personal one. I have never felt as good about teaching! When I sit with a student or a team of students and discuss a physical phenomenon, I feel most like a teacher. I can watch students' faces furrow as they struggle with the questions that I pose. They know that our conversation is not an inquisition, but an opportunity to say what they think. They do not parrot what they think I want them to say; they react to the new knowledge constructed in their brains and explain their reality.

References

Bodner, G. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*(10), 873-878.

Caine, R., & Caine, G. (1991). *Making connections teaching and the human brain*. Alexandria, VA: Association for Supervision and Curriculum Development.

Fischbach, G. (1992). Mind and brain. *Scientific American, 267*(3), 48-57.
Graesser, A., & Person, N. (1994). Question asking during tutoring. *American Educational Research Journal, 31*(1), 104-137.
Hart, L. (1983). *Human brain and human learning*. Village of Oak Creek, AZ: Books for Educators.
Pestel, B. (1993). Teaching problem solving without modeling through "Thinking Aloud Pair Solving." *Science Education, 77*(1), 83-94.
Piel, J. (Ed.). (1992). Mind and Brain [Special issue]. *Scientific American, 267*(Whole number 3).
Rickey, G. (1993). A technology of kinetic art. *Scientific American, 268*(2), 74-79.

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Thinking for Themselves: Students Examine the Writing Group Process

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Greensboro, North Carolina

A high school English teacher inquired into how small writing groups can best be used in the classroom to promote good writing. The inquiry itself was designed by the students, who generated and selected 12 questions for the final survey. The students asked cogent questions and gave provocative answers that greatly enhanced their writing.

In the spring of 1991, I took a graduate class in composition theory as part of my doctoral program in English. At the time I was teaching in a suburban public high school of approximately 800 students, mostly middle class, 10% Black and 90% White, with the English classes tracked into four levels: fundamental, general, college prep, and honors. In the 5 years I taught at this school, I taught all four levels for nearly each grade (9-12), 12 permutations in all. I also founded a literary magazine and a creative writing class. All this, together with my 8 previous years of public school teaching, stood me in good stead for an investigation into how good writing can be engendered by group work. My graduate course gave me the impetus to do the research. I wanted to find out *how to allow students to direct their own learning, to make writing groups work better, and to make the resultant writing better.*

Method

My first concern was what questions most needed to be asked, and I decided to take this problem to the students themselves. That year I had four types of classes: Fundamental English (11/12 combination), Creative Writing, College Prep 11, and Honors English 9. In each class,

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