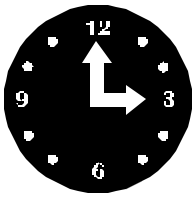
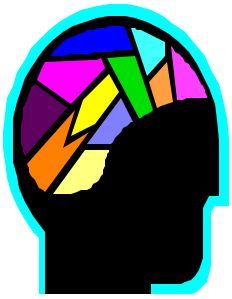


Instructional Techniques
Find the Time!

Thomas Lainis
U.S. Military Academy
West Point, New York 10996

In 1997, I decided to improve my knowledge of cognitive research by taking graduate level courses in instructional techniques, learning, and teaching. I was surprised to discover how much had been written on theoretical generalizations of instructional practices. "Educators" had expanded well beyond the ideas of Piaget and Vygotsky [1]. Recently (1997), they have recognized the vast complexity of learning. Howard Gardner's Multiple Intelligences [2] and Caine and Caine's Brain Based Learning [3] exemplify two such theories. Their acknowledgment of the complexities of teaching and learning placed all my various experiences into a framework upon which I could select or modify. To my dismay, however, the material used made it appear that the "education" departments continued to corner the market on educational research. In education graduate courses, "educators" and not subject specific experts, wrote most of the articles. In physics, the first national (public) Physics Education Research Group of the American Association of Physics Teachers meeting was held in 1996. It was only this year, 1999, that the American Physical Society recognized physics education research as an acceptable physics research effort [4]. While the trend towards education as a subset of subject specific departments is occurring, a bigger issue may be how long before education departments support this effort. Regardless of this latter issue, there are exceptional physics and math educators. As I focus more on effective educational techniques, I observe that while the instructional techniques are numerous, the biggest obstacle to incorporating these techniques appears to be ourselves. We are unable to find the time.



As teachers, we must recognize that we must be conversant in both the subject matter and the cognitive sciences. Students look to us as their mentors and coaches. We must assist them in learning about the world, to stimulate them to reach beyond their intellectual borders, and to entice them to want to learn. Every student learns differently. As Howard Gardner [2] espouses, some students interpret their world best using a musical filter. Others understand best through bodily-kinesthetics, while a third group enjoys spatial evidence. Interpersonal intelligence explains a fourth group of learners while intrapersonal intelligence explains the fifth group. Linguistic covers the sixth group. The final intelligence best describes our specific subjects and probably the dominant intelligence sector of our subject specific instructors – logical mathematical intelligence. Herein lies our first obstacle. We physics and mathematics teachers are very very comfortable explaining the world using the logical mathematical intelligence sector of our minds. Mathematics and physics can be succinctly and efficiently described by using logic and mathematical symbols. It saves time. Unfortunately, our students, and I would probably venture to guess the majority, are not as adept as we are in this intelligence. It is the physics and math instructors' primary mode of thinking, but it may not be our students' primary mode. This certainly complicates our teaching. When we become busy, and bogged down in other matters,

we will naturally revert to that which is most comfortable to us. If we are trying to explain a difficult concept, our innate tendency will be to grab that which makes the most sense to the logical-mathematical brain within us – however, this may not be the natural mode of learning to our students. Our natural tendencies may obstruct effective teaching.

The second obstacle to our mentoring students is our subject specific tendency to list the important topics which every mathematician or physicist must know. These lists are always huge. The material cannot be covered in the time given. So, we erect the second obstacle – time shortage. We acknowledge the importance and effectiveness of alternate teaching styles; however, time is too short to use these alternate styles. We need to cover the material and the easiest means to insure that the topics were in fact mentioned to our students is through the clarity of the logical mathematical direct instruction method. Before the semester or the class starts, we have given up other techniques. My high school track coach always emphasized that no runner has ever won a race if at the starting line, he or she looked to right and left, and said, I can't beat them! Every time we say that we can't reach out to our students' natural learning tendencies, and that we can't scaffold upon something that they already know, we have lost the race of effective teaching. We need to reduce course content so we can focus on effectively teaching the material using more lasting techniques.

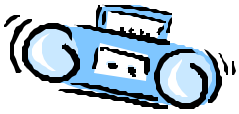
Demonstrations have always been effective. I believe that by allowing students to put their hands on equipment, we allow their kinesthetic intelligence to find those nerve pathways, which can best associate the representative mathematical symbology with "real life." Kinematic equations and their vector nature are conceptually difficult. The thrown baseball, the tennis ball, and the artillery shell appeal to the physical world that our students already know. Balls do follow parabolic paths. Increase the angle and the ball goes further until some maximum distance is reached. Students already know this. Ice skaters do go faster when they bring in their hands; we can duplicate that feat in our classroom with weights and a turntable. Harmonic motion can be shown with a spring-weight system and with RC circuits and an oscilloscope. In all cases, the physical demonstration brings relevancy to the students. ILAPs (Interdisciplinary Lively Application Projects) [5] emphasize relevancy but more importantly, they bring a physical reality to the symbolic nature of mathematics and physics. Instructors need to place these demonstrations in the classroom so students can put their hands on them. If we walk into K-8 classrooms, the rooms are adorned with pictures, projects, and equipment that the students have made or used. The students are encouraged to touch and explore the equipment. The K-8 teachers know that kinesthetic intelligence must be stimulated. When you walk into an undergraduate classroom, it is usually stark naked – white walls – very neat. Learning is messy. We have given up the race for stimulating the kinesthetic intelligence of our students.

filming the bow and arrow ILAP project

Technology has given us another alternative – computer enhancements, simulations, video images, and audio associations. We can take a dancer performing a pirouette and slow the action down to observe the physical constants and changes -- the steadfastness of the center of mass, the altering of the moment of inertia. Can you model and calculate that moment? Projectors and simulations can achieve that which has eluded us in the past. We can slow time down to clearly see and

follow the projected ball, the harmonic oscillation or the Earth revolving around the sun. Not only can we instructors bring the physical world to the classroom, but we can also give it to the students to take home. We instructors can reach out to our students while they are still at home. We can stimulate their senses before they ever get to our classroom. This stimulation is not limited to the written word. It grabs their auditory senses. It stimulates their optic nerves much more than symbols can. However, it takes time to organize computer software. Unfortunately, computer stimulation of the students at home for the current assignment is not usually considered so important a function that when compared to competing requirements for time, planning or programming the new technology is put off until "tomorrow."

Another use of the computer enhanced projection systems of tomorrow's classrooms is fun. Learning need not mean individual pondering in a silent environment. The computer can bring multimedia pleasure to the classroom. Taking a three dimensional graph and rotating it so that students can see the projections brings "geewhizness" to the classroom. Spatial intelligence is stimulated as well as motivation and appreciation for the technology of the world. The game, Jeopardy, using power point presentation animation can make a ten-minute let's review the concepts of the previous lesson fun instead of just answering the following twelve questions. A teacher is more than just a lecturer in front of a classroom. Students may have accepted this role in the 1800s. Then, a teacher could stand before students and say repeat after me. Rote memorization and tedious repetitive exercises were "accepted practices." In 21st Century, student expectations are greater. Teachers must consider themselves part entertainers. Reaching into their entertainment bag, teachers should pull out exercises that stimulate the mind. The teacher can also exercise the musical intelligence while addressing another intelligence. I always introduce Isaac Newton biography with Handl's Messiah. My lab room has "A Song Bag of Physics Songs." Multimedia fun and games doesn't have to be an everyday occurrence. The computer and multimedia projection systems can make learning fun more often than other times in the past. It takes time.



Graded homework forces students to do the work at home. We have a saying in the Army -- soldiers do what the commander checks. If the teacher gives homework, and never checks it, then the average student probably will not do it. To say that those that do the homework will be rewarded on the exam is a cop out. We have given up the race called preparation at home. I give graded homework. It means that much of my time is spent reviewing the students' work, but over the course of the semester, one can assess how far the students have come. The situations depicted in the homework can be more complex – more realistic modeling can be demanded of the students. In addition, the computer can be used to ask and grade simple problems. The back of the chapter exercises can all be graded by computer. We are currently testing a random number generated questioning system such that students can be asked to do three problems every night. If they get the problem wrong, they can retake the test; however, the question or numbers are different each time. The students must learn what they are doing wrong if they want that "perfect" grade. And they want it!

Group work (peer instruction, cooperative learning) is a great technique. Much has been written on it [6, 7]. This also takes time to plan, organize, coordinate, and execute. It is a very difficult class to lead. Extraneous talking and socialization discussions take place, but learning is occurring. Students are committing themselves to both the

peer instruction at USMA

"right" answers and the wrong techniques. That is exactly what we want. If the students can display their mastery of the material, correct concepts are reinforced. When students display a misconception, their classmates or the teacher can correct it. Students learn to work with their contemporaries. Students learn that they can learn on their own. They are stimulated to learn through their interpersonal intelligences.

Communicating the material is just as important as the material. In the classroom, having students face a problem and solve it is not the end. Students should present it to their contemporaries. First, this allows the instructor to look for subtle misconceptions. Some "right" answers can be reached for the wrong reasons. Second, it allows students to communicate to those other students who did not understand the instructor or the textbook. Students are more likely to use colloquial expressions that convey the concepts. While not technically correct, the student's words scaffold old knowledge to the new material. Third, it reinforces correct methodology in students; they have practiced logic techniques in front of their teacher. The down side of this three-fold beneficial technique is that it takes time. However, learning takes time and this technique has been proven successful [8]. We teachers have to learn to allocate the time.

Interdisciplinary communications between instructors is an aspect of teaching that I did not appreciate until this year. My premier example follows. The math instructor had given students in a joint mathematics-physics class a problem. Because it looked so similar to a physics question, their minds categorized it as a physics question. Therefore, they began using all the kinematic relationships and techniques that had been discussed in previous physics classes. I went to one group who had mired themselves in an algebraic nightmare, and simply commented that this problem looked awfully close to an intersection - collision problem that they had studied the day before. (I should note that the words intersection and collision were used in a fashion that I as a physicist would never have thought of using. However, the math instructor and textbook had used these words. I simply repeated them.) The eyes of the students immediately sparkled. They knew how to approach the problem. It was a teaching moment! They erased their work and completed the problem in record time. The reason that I was able to touch them was because I had sat in on the math class and understood the vocabulary. I was able to scaffold the new contextual problem to their compartmentalized knowledge by using two key words. It cost me time to sit in on other classes. While I am sitting in on the classes, I have to fight thinking about all the other work that I could be accomplishing. After all, I know the math! While this may be true, I do not know the math vocabulary required to effectively communicate with my students. We teachers need to spend time with our fellow teachers to learn their discipline's terminology and symbology.

The last point to be made is that we teachers need to redesign our classrooms. The classroom of the future would best be set up to facilitate student centered learning. Students should be seated in lab or project groups. They can see direct instruction from their seats to any side of the room where the teacher is presenting. They can be turned loose on a cooperative learning exercise. The computer projection multimedia system can be flipped on at a moment's notice and presented by the teacher. Each group table has a computer to facilitate projects, CAI work, or simulation exercises. Finally, the cabinets around the bottom of the walls have equipment in them so that as teaching moments arise, teachers can open the cabinets and take out the right physical instruments

to stimulate hands on experiences. When that "teaching moment" arrives, we must have the facilities to take advantage of the opportunity.

Student centered learning takes time. We need to plan for that time in our courses, in our syllabus, in our teaching style, and in our physical layout. The historian, Henry Adams said that "a teacher affects eternity; he can never tell where his influence stops."[9] Let's take the time to affect it right.

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