PSSC Reflections

by Jim Hicks

The world of Dull, Metcalfe, and Brooks (DMB) was the main secondary education physics worldview going into the 1950's. If I remember correctly, each chapter in Modern Physics had plenty of sample problems with solutions. I think it was written by high school teachers. During 1956, the steam shovel was put to rest for some teachers and students. A paradigm shift took place which caused tremors in the educational world toward more "guts"; that is, the basic principles. The alphabet soup programs that developed after PSSC's entrance into the educational arena meant that there were other science disciplines that sought change as well.

My high school physics course was from DMB. I had an outstanding teacher and we covered many chapters with great ease where the equations drove the curriculum. It was easy to solve problems knowing which equations to use. In addition, many of the homework problems were like the examples. We never thought such closure was possible.

Introduction to the World of PSSC

I first encountered PSSC physics during my junior year in college. One of the assignments for my ED 301 course was to observe a University Laboratory High School physics class. The teacher gave a brief introduction to a PSSC laboratory assignment, and then the students immediately moved to the laboratory tables to discover. I was impressed with the hands on nature of the lab, but this was not new as my high school teacher also believed in a hands-on curriculum. It was immediately apparent, however, that students were not verifying something they were asked to believe in, but were discovering a concept before discussing it in class. The answers to the questions came from the data and/or graphs they were analyzing and not from their textbook or class notes.

Suddenly the roadway was strewn with boulders and the easy road led to a dead end. I had not looked at the lab ahead of time as I thought my job was just to observe, but I wanted to join the students during this discovery phase. I became uneasy when suddenly things were not straight forward, and I had to think very carefully and critically before answering. My answers depended on the laboratory data and there were no roadmaps to the correct answer. I wanted to answer questions in terms of what I knew the final result would be, but I couldn't. The students were unaware of the final result, and it was unthinkable to just tell them the answer. More challenging was explaining an answer in terms of the "guts of physics", rather than just plugging and chugging. I also noticed that concepts were before equations. Sometimes closure was an elusive butterfly as I was forced to wrestle with my interpretation of events. Whoa!! Down deep, however, I felt better about what I was observing as the students were not robots mimicking great ideas from someone else. They were living breathing physics students who were asked to think and analyze for themselves.

I did my student teaching in 1965 and my assigned physics classes used the PSSC Physics curriculum. I felt I needed to prepare thoroughly for each class relying on basic principles (guts) and not the equations to explain the phenomenon. I also noticed that at times a problem looked complicated, but if you knew the guts, the answer was straight forward. Once you became a "guts person" there was no turning back. The guts associated with one problem or lab assignment solved many problems in that category; hence, one needed to know only few things to explain a wide variety of phenomena. My prized arrows inside my educational quiver were the basic principles and not the equations. I was pleased with the laboratory approach to discovering these principles.

One of the highlights of my student teaching tenure that I will never forget was the vehement debate my students staged when discussing whether light was a particle or a wave. I just sat back and observed each period. Also, it occurred to me that I was learning physics that I easily glossed over in college. The gaps in my understanding of physics were suddenly starting to be filled in. The "Ah hah" moments I had with my new physics education possibly surpassed those of my students. I remember remarking on many occasions, "Oh now I see what is really happening" and I felt good about it. At times, I felt the PSSC book was more for me and my development in understanding physics than for my students. Fortunately, I was hired by the same school district where I did my student teaching, and I looked forward to teaching PSSC Physics full time.

When attending national meetings, however, all was not well with some teachers regarding PSSC Physics. The major complaint, if I remember correctly, is that some teachers thought that there was too much emphasis on process and not enough on content. That is, they felt that PSSC students would not be able whip out the equations or facts as easily as the traditionally taught students as if life was one big physics quiz show and the traditional students would be the buzzer beaters.

Ancillaries to PSSC

The PSSC labs were memorable. My favorites for the Light unit were The Ripple Tank Laboratory assignments and Young's Experiment. I can still recall students blackening microscope slides with a jet black alcohol base goop, and after drying, taking two razor blades pinched very closely together striking two slits as close as possible along the glass side. I felt like I was rubbing elbows with Young in those early days. Talk about calling the microscope slide black. It was remarkable how close my students came to the actual wavelength of red and blue light. The ripple tank sequence for developing the wave model of light was extraordinary and clever.

For mechanics, my favorite was the rubber band (RB) brick (BR) cart lab, which was legendary. We portioned each ticker tape attached to each cart into 10 dot sections, cut out the sections, and taped the bars together to create a velocity vs. time graph for each rubber band-brick combination. Did those carts sail for the 4RB and 1 BR situation. On numerous occasions throughout the years we had to warn the biology teachers on the first floor that the 409 Lab, which we called the lab assignment while we played the Beach Boys rendition in the background, was about to be performed as numerous bricks and carts ended up on the floor for the large accelerations.

The PSSC films were very instructive. Who could forget Ivy upside down eventually coming into our frame of reference or "What do you expect from an inverse square force?" bellowed by a serious Eric Rogers, who had an occasional tongue wagging episode when he became excited. Michael Jordan would have been proud.

I enjoyed the practical applications associated with many of the films. The films "Scaling" and "Random Events" provided a more complete background to my biology and thermodynamics upbringing. Ah yes, who can forget the MIT swimming pool and total internal reflection or the exacting scientific process in "Time Dilation". The icons used for these films were extraordinary.

The PSSC standardized tests were very challenging. My favorite was the frictionless puck inside a closed box resting on a frictionless table. Students were asked to analyze and explain what was going on after an initial push of the external box by observing the velocity vs. time graph of the system. Talk about having to understand the guts of momentum conservation. Also coming to mind in electrostatics were 5 suspended spherical metal objects, some positively charged, others negatively charged, and some neutral. Using the listed observations of which object attracted, repelled, or exerted no forces on the other objects, one had to come up with the sign on each of 5 suspended insulated metal objects.

Concerns

Although teaching PSSC produced countless first class educational experiences, there was a dark side during my first two years. My capable students did very well with the PSSC curriculum, but my less capable students; that is, those still at the concrete stage of reasoning, did not do well, and expressed frustration at times. Unfortunately, these students felt intimidated when assuming leadership roles in the heterogeneous physics classes. I also felt that for many of the homework problems or just understanding some of the concepts, students needed to reach the end of the development of the topic before really understanding the material. As a consequence in 1968, I developed a course called Phenomenological Physics for those students who experienced difficulty with PSSC Physics. Harold Jensen of Lake Forest College, who held once a month revival meetings in his college classroom for local physics teachers, introduced me to the power of the phenomenological approach. Later this technique was amplified and refined by two other giants in the physics education mainstream: Earl Zwicker of The Illinois Institute of Technology, and Gerry Lietz of DePaul University. During the 1968-1969 academic year, the honors physics students took PSSC and those that we would later be labeled as "average" took Phenomenological Physics. However, I knew in my heart PSSC physics contained the correct philosophy. Therefore, the "Phenom." students studied the same physics presented in PSSC using the same sequence of topics, and performed many of the same labs, but did not go into the abstract depth of the PSSC. Also, they used an alternate mathematical framework to solve certain problems. Eventually the chemistry classes did a parallel maneuver with Chemistry Study. Life was good, but I knew we could make things even better.

The even better epoch started in 1971-1972 when Chris Chiaverina joined me at Barrington High School. We spent countless weeks refining both programs, but demanded that they parallel each other. Our hope was to have as many students as possible take PSSC Physics and not allow those students who struggled with PSSC, but were capable of handling PSSC, to take Phenomenological Physics. We noticed several characteristics of the concrete only students:

Homework should be like the examples in class

Evaluation questions should be like the homework

Quizzes preferred to major tests

Don't cover too much material before an evaluation

Preferred a cook book approach to quantitative laboratory assignments

Unable to handle multiple concepts in succession

To accomplish this goal, we re-sequenced the topics for PSSC Physics, which we labeled Helical Advancement (see Appendix 1), and over the years designed bridging activities to encourage and assist students to cross the bridge from the concrete to the abstract.

The Infinity Sign Format for Physics Instruction

The concrete stage for each unit started with introductory demonstrations to whet the student's appetite for the subject matter and to introduce key vocabulary words. The ubiquitous explorations came next with each unit having a carefully designed exploration, which was mainly qualitative in nature. Homework followed where questions were asked to extend what they observed during the explorations. Class discussions followed only after physics students were allowed to see and experiment with the phenomena in a hands-on way. As a consequence, the class discussions played a critical role in transferring students from the concrete to the abstract side using bridging activities. Following class discussions, quantitative laboratory assignments were assigned, which were usually the PSSC labs. We firmly believed in practical applications after students mastered the physics. We wanted students to see the same things on the way home that they saw and experienced in class. Our philosophy is summarized by the infinity sign displayed in Appendix 2.

For the next ten years or so Chris and I more or less team taught both courses and noticed that with two teachers we were able to develop and cover the material more efficiently. We developed the concept of explorations extensively and demanded that students wrestle with these physics explorations, which included posed questions, with their preconceived ideas. As a consequence, students were told not to be afraid of wrong answers, but to manipulate the equipment provided and do the best job possible in answering questions in terms of what they felt was true. In this way, their preconceived ideas or prior knowledge about the phenomena surfaced and subsequent class discussions started with their ideas. Toys and other hands-on materials were used at length as bridging activities along with major events beyond the classroom. We were pleased with the fact that we had equal number of boys and girls in both programs. We liked the idea of starting with Measurement and Light, and culminated this sequence with a Physics Day at the University of Wisconsin at Whitewater (UWW).

Practical Applications beyond the Classroom

Physics Day at the University of Wisconsin continued for over 20 years. The university literally opened their department to us for a day and students attended lectures on Holography, the Physics of Sound, and Polarization of Light during UWW finals week. Ron Bergsten, Shirley Steckel, and Hugo (the magnificent) Tscharnack put on physics shows that many of my past physics students still talk about. The university extended our program with more sophisticated equipment. One memorable demonstration took place with a first-class interferometer where the interference pattern responded immediately to the heat from a match placed at the far end of the 700 pound metal slab the interferometer was sitting on. Also, every student attending the fieldtrip made and developed a hologram to take home. What a Christmas present and an exciting way to end Light. Probably over 3800 students in the 20 + years we traveled to UWW witnessed interference of light and sound on a grand scale.

Mechanics and Electricity and Magnetism occupied the rest of the first semester and all of the second semester. The culminating activity for the second semester was a Physics Day at Six Flags Great America in Gurnee Illinois. Before Six Flags Great America, we traveled to Old Chicago in Bolingbrook, Illinois. Amusement Park Physics provided not only the practical applications we were seeking, but a kinesthetic feedback for many of the physics concepts, especially acceleration.

Eventually, as we continued to change and refine both programs, other textbooks were adopted for both courses. However, the spirit and approach of PSSC Physics changed both of us to the "guts" side, forever. "Ye shall know the guts first, and the guts shall make you free".

Appendix 1

Helical Advancement

We feel that each physics topic should not only provide a foundation for the next topic, but also follow logically between topics. In addition, we also wanted each topic to introduce the next unit of study and stimulate interest as to the language needed to describe key descriptors. As a consequence, we decided to reorder the usual sequence of physics topics for the mechanics unit. We felt, intuitively, it was better to start with action-reaction forces and the type of action-reaction forces found in nature as this would beg the question as to how to describe them. This provided a nice lead into scalars and vectors. We felt that teaching physics was like playing a came of billiards. We were not only concerned with the shot at the moment, but we wanted to set up future shots.

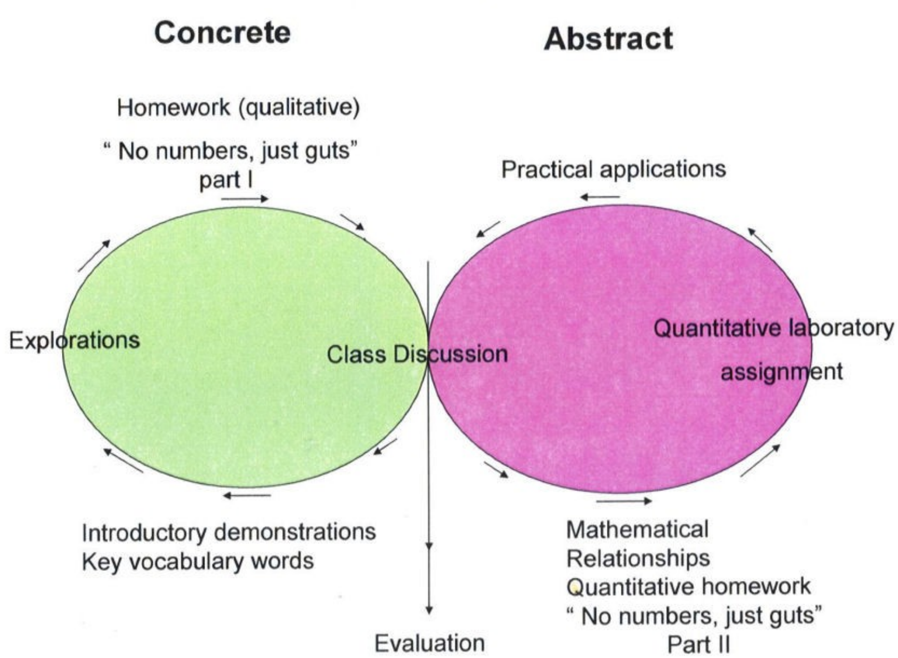
Next we introduced equilibrium, which led us to the question of what would take place if forces were out of equilibrium. Forces out of equilibrium generated discussions about what we meant by acceleration, which we felt escorted us into the kinematics unit. **Therefore, Newton's second law unit was divided into two parts. Part I was the development of F = MA with subsequent analysis of what we meant by an acceleration. This led us to kinematics. After kinematics, we returned to F = MA Part II and considered friction, incline planes, force due to a spring, etc.**

F = MA Part II guided us to the question of what happens when we have action-reaction forces acting through time (impulse) on and off center, which eventually encouraged us to look at forces acting through a distance (work and energy). We liked this sequence because it allowed us to spiral back to previous topics, but also allowed us to move forward; that is helical advancement.

One might raise the question of why not introducing momentum after action-reaction forces. Our response was that we wanted to proceed from concrete to abstract not only within a unit, but also with the progression of physics topics. We felt introducing equilibrium was more concrete and intuitive than introducing moment early in the development of mechanics. Therefore, concrete to abstract existed within the curriculum, so to speak, in two dimensions: within a unit and between physics topics.

Appendix 2

Infinity Sign for Physics Instruction



We feel it is better for students to have seen and experienced physics phenomena and be allowed to explore answers to posed questions in terms of their prior understanding, before class discussions take place.

1. An introduction to each unit of study begins with teacher led demonstrations, some counterintuitive, to whet the physics appetite of students for further study. Key vocabulary words are introduced.
2. Next is an exploration phase where students explore with the phenomena. They answer posed questions by manipulating the phenomena and relying on their preconceived ideas for explanations. While students are exploring, teachers will

occasionally ask questions to further a student's search for answers or to coax an understanding of the basic principles associated with the subject matter. However, very few teacher explanations of the phenomena are given for this section of the "infinity sign". Explorations are laboratory assignments where students are not afraid of right or wrong answers.

3. Qualitative homework, "No numbers, just guts" part I, follows each exploration where students wrestle with extended situations of the exploration.
4. The class discussion phase takes place after each student has explored the subject matter. Teachers design the class discussion based on student answers to each section of the exploration. We feel this is important so preconceived ideas can be acknowledged and discussed. If a teacher lectures over the top of a student's preconceived ideas (layering), we feel conflict will result and acceptance of the current understanding of the subject matter will be compromised.
5. Mathematical relationships are discussed after class discussion. If possible, students "ride the equation" before they derive the equation. Mathematics is seen as a language that allows us to say the most using the least number of symbols, and allows for quantitative answer, everyone can agree as to the "truth" of an outcome. Quantitative homework is assigned after derivation of appropriate relationships.
6. Quantitative laboratory assignments follow mathematical discussions and quantitative homework. A cookbook approach is to be avoided and students are allowed to design the procedure to be implemented to accomplish the laboratory assignment; that is, students play engineer for the day. During this section a student generated conceptual flowchart for quantitative homework problems and ideas associated with the subject matter can be discussed. "No numbers, just guts" part II type problems are assigned during the final stages of the quantitative homework assignments.
7. Practical applications are presented to highlight the importance and relevance of the subject matter.
8. Evaluation.