Implementing Physics First at El Dorado High School

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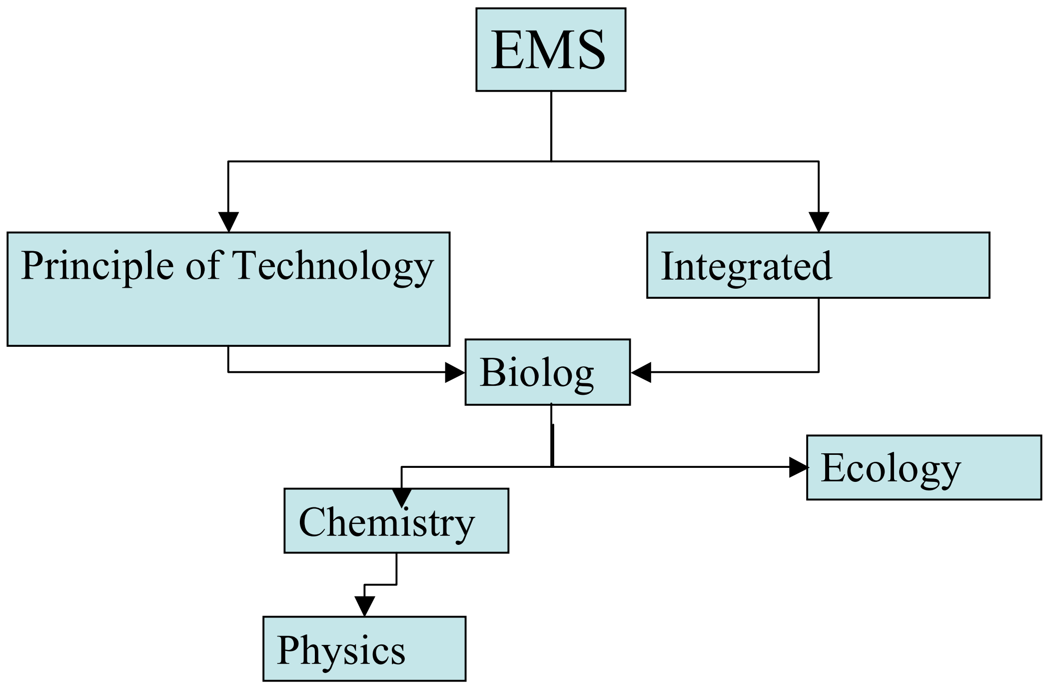
El Dorado (population 12000) is situated on the edge of the Flint Hills in south central Kansas approximately 25 miles northeast of Wichita. El Dorado USD 490 is recognized statewide as a leader in school improvement, nurturing innovative learning programs for every student. The district has over 2,000 regular education students and operates seven schools: five elementary buildings (pre-K-5), one middle school (6-8), and one high school (9-12). El Dorado High School, where this story took place, has approximately 600 students that are 91.4% white, 3.9% Hispanic and 3.2% African American.

In the early 1990's, there were two choices of freshmen level science courses at El Dorado High School (see Figure 1). Most students elected a course called "Integrated Science" which included a little chemistry, physics, biology, ecology, and earth science. The rest of the students who were identified as high ability took Principles of Technology, an applied physics course. The instructor was not certified in physics, and the course did not fill the needs of our best students. Our principal was searching for a way to challenge these students. I convinced him that this could be done by inverting the curriculum using a Modeling approach in a freshman physics course. Students would then take chemistry in their sophomore year followed by a molecular approach to biology in their junior year.

Figure 1 Early '90s Course Sequence at El Dorado High School



During the summers of 1995 and 1996, I learned the Modeling approach to physics instruction at Arizona State University (Modeling web site). This approach is a curriculum design that engages students in constructing a few basic models of physics. Model development begins with students working in cooperative groups designing experiments, analyzing results, orally communicating them to the rest of the class, proposing a model and justifying a scientific claim. The model is extracted from the experimental setting and continually refined to ever increasing levels of sophistication with model deployment activities. A key element of instruction is the use of student size whiteboards that are completed in cooperative groups and presented to the class using a variety of model representational tools to communicate understanding of the physical system. The Modeling approach was recognized in 2001 by the U.S. Department of Education as one of two exemplary programs in K-12 Science Education. (U. S. Department of Education Web Site, 2001). Extensive nation-wide research (ASU web site) and my own research document that student gains in understanding physics concepts are substantially better than students who have experienced traditional physics instruction.

To implement an inverted course sequence we had to convince our district curriculum committee that this was practical. This required us to overcome a belief in the status quo of "physics last" because it is too hard for younger students. We began to compile a rationale for teaching physics first. We liberally borrowed from the work that Leon Lederman was doing to strengthen the high school science curriculum. (ARISE

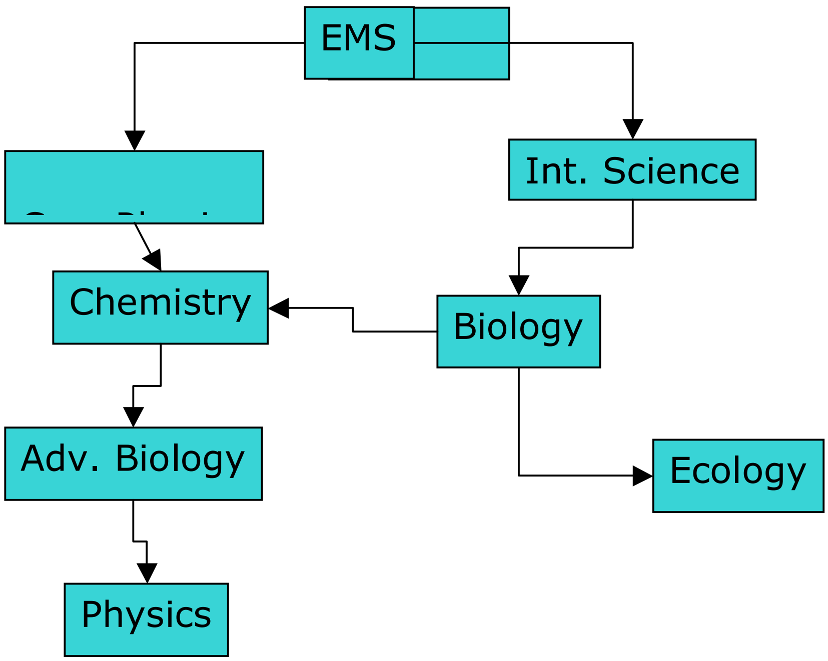
Web Site). Offering physics first will build student knowledge of science and the concurrent use of mathematics following the hierarchical nature of science as it unfolded over the past century. We cited the physics concepts that students needed for chemistry, and the chemistry concepts that students need to understand "modern biology" which is molecular biology. We argued that physics first would result in more students taking advanced science courses, better state test scores, and better college entrance exam scores.

In order to have the curriculum committee approve this wild idea we had to lie a little. We gave the freshman physics course the title "conceptual physics" which implies that it is a descriptive course that really doesn't expect students to use mathematics. Actually, math is gradually and coherently integrated in with every physics concept the student investigates. The freshman students in the course had algebra in the eighth grade, and are prepared to use it in physics with some help from the instructor. These students were concurrently enrolled in geometry, and with a little coordination with the math department, they were learning trigonometry when they needed it for vector addition.

Once the freshman physics course was in place we had to turn our attention to revamping the chemistry course. Now that students were exposed to investigation as the method by which they learned physics they also needed to use the same approach to learning chemistry. To that make this possible we borrowed the learning cycle approach to chemistry developed by Michael R. Abraham, J. W. Renner and Ed Merek at the University of Oklahoma. (1996) We formed a collaborative action research team that included Dr. Merek and teachers from a neighboring high school that used the materials for thirteen years. We used the learning cycle activities as the bases for developing a modeling approach to chemistry.

Our junior students then took a course that we called "Advanced Biology" to differentiate it from the regular sophomore biology. This course was taught by a gifted enthusiastic teacher and has become the capstone course for our students. (See Figure 2)

Figure 2: Current EHS Science Sequence



Student success in the freshman physics course was carefully monitored since its inception. To evaluate the effectiveness of the course, we used the Force Concept Inventory (FCI) (Hestenes, Wells & Swackhammer, 1992) which was developed to evaluate the effectiveness of the Modeling Workshops at ASU. There is, however, no baseline data to compare our students with other ninth grade physics students since physics is traditionally taught at the junior or senior level. I decided to boldly measure the achievement of my freshman to upper level students thus raising the bar for them. Table 1 below shows the results of the FCI scores for the four years that physics has been taught to ninth graders at El Dorado High School.

School Year	FCI Post Test Score
’99 – ‘00	37.4%
’00 – ‘01	43.5%
’01 – ‘02	43.5%
’02 – ‘03	54.0%

Table 1: Average FCI scores for freshman physics students at El Dorado High School

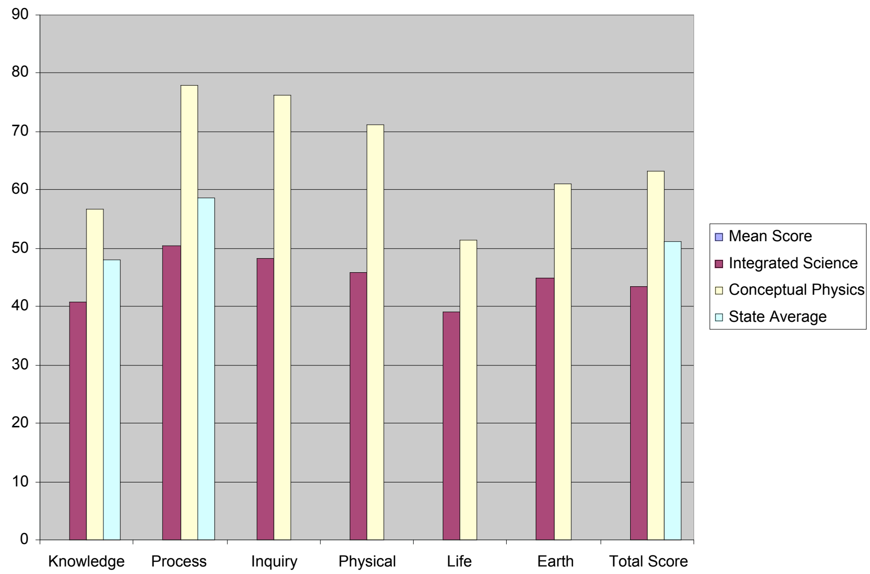
The nationwide FCI average post-test score for mostly senior physics students under traditional instruction is 42%. The scores of my freshman group are comparable to senior students with traditional instruction, and have increased as my skills with working with freshman have improved. The average pre-test score of my freshman students is only 22.5% which is lower than national average pretest score of 26% for seniors. Traditionally taught seniors have an average gain of 16% (26% pretest to 42% posttest). My students posted an average gain of 23.1 % (22.5 pretest to 45.6% posttest) indicating that they learned more from the physics class than traditionally taught seniors.

With these impressive gains on the FCI, I decided to put my freshman students to another test that requires them to apply the physics they learned. Each spring the Worlds of Fun amusement park in Kansas City and Dr. Allan Pringle, physics professor University of Missouri – Rolla, host a Physics Olympics competition at the amusement park (Pringle, 2003). Students make measurements on a few select rides that are evaluated by the nearness the results are to accepted values. They also have a rigorous one hour multiple choice exam with 36 questions that is completed with students working in groups of three. Talented physics students from a four state area that includes students from regular junior/senior level physics courses to advanced placement courses compete in the Physics Olympics. To my and Dr. Pringle's knowledge, there have never been freshman physics groups entered into this competition. My intension was to compare my ninth grade students to the best high school physics students in the area.

I was thrilled when the results indicated that one of my freshman teams was recognized in the honorable mention category in the competition. (Pringle, 2003) I contacted Dr. Pringle who provided the results of all my groups. All of the ninth grade physics students were above average in this event which pitted them against senior and A. P. physics students! This success affirms that freshman can learn physics.

We also studied the Kansas State Science Assessment scores of the freshman physics students (see Figure 3). These students exceeded the state average in all categories and were much higher than our students in our integrated science course. Their scores are significantly higher in process, inquiry, and physical science category. The surprising result is that they are also higher in life science. Students take the assessment during the spring semester of the sophomore year. The integrated science students are taking a biology course during the sophomore year while the freshman physics students are enrolled in chemistry. They answer biology questions on the state assessment without having had a single course in high school biology, and yet they out-performed our students who were enrolled in biology. This is likely due to their understanding of science process since many of the biology questions on the state assessment integrate science process.

Figure 3: 2000 Kansas State Science Assessment scores for El Dorado High School (El Dorado, KS)



If one buys into the notion that science should be taught with an inquiry approach, than the physics-chemistry-biology sequence makes the best sense. Experiments in physics are the easiest to do as students manipulate physical phenomena that they can touch. Inquiry is more abstract in chemistry where students are required to relate the macroscopic world in the test tube to an atomic model they can only infer. Biology experiments have so many variables to control and results that require the use of sophisticated statistical analysis that it is the most difficult high school experimental science. The inverted course sequences progressively expose students to more complicated experimental work as they progress through their high school science experience.

Biology is the science discipline that will have the most direct and profound effect on every student's life as they read a medical study, an environmental impact statement, or the statistical analysis for an insurance table. Biology will also have a huge effect on the careers students may choose with the expanding of science related fields. Biology as a capstone course makes sense for all students.

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