

References

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BERGH REPLIES: Compact fluorescent lighting is a mature replacement technology for incandescent light, but solid-state lighting offers an entirely new lighting paradigm. John Waymouth missed a number of points in comparing SSL and compact fluorescent lamps.

► SSL lights turn on instantaneously and maintain their color when dimmed. Their color is dynamically adjustable and can be easily integrated with silicon integrated circuits to provide “smart lights.” None of these attributes is available for CFLs. In addition, CFLs have poor color rendition and a poor form factor in replacing incandescent lamps.

► CFL efficiency is around 60 lumens per watt, compared to the expected efficiency of 200 lumens per watt for SSL.

► CFLs are isotropic emitters leading to 20–50% light loss within the fixture. In contrast, the quoted LED efficiencies are measured at the output of the fixture and have no additional light distribution losses.

Proponents of the old technology tend to resist the new. However, a testimony on the promise of the new technology is reflected in the position of traditional lighting companies such as OSRAM Sylvania and General Electric Co, which have fully embraced the Next Generation Lighting Initiative, a government–industry partnership to accelerate the development of SSL.

With regard to Jerry Woodall’s letter, our article was aimed at lighting and hence at visible LEDs. Holonyak’s red emission from GaAsP alloys was an early demonstration of a visible LED.

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Revamping High-School Science: Herding Cats

I am concerned about the discussion in PHYSICS TODAY dealing with the order in which biology, chemistry, and physics should be taught in high schools (September 2001, page 11; February 2002, page 12). Where in these discussions is geology considered?

I often begin my introductory geology classes with the statement that geology is the most difficult science. My arguments are based on the degree to which the understanding of one science is contingent on understanding the other, the degree to which the basic data of each field are knowable, and the degree to which each science is presently described mathematically. Chemistry relies on physics for understanding, biology on chemistry and physics, and geology on all three. The basic data of physics are largely knowable through experiments whose results are often explained mathematically. This is progressively less true with chemistry, biology, and geology. Consequently, an understanding of geology often starts with existing theories from the other sciences that explain qualitatively the information gleaned from the incomplete 4.6-billion-year record of all the physical, chemical, and biological phenomena that have occurred.

To some scientists and educators, this qualitative nature means geology is an “easy science.” However, recognizing that geology will be quantitatively understood only after the other three establishes it as the most difficult of the four. The only argument for geology’s ease is the extent to which it can be taught to students with little mathematical ability by using the basic principles of the other three sciences.

I believe that a high-school science course is only the most basic introduction to the field, that principles are more important than mathematical descriptions at that level, and that the principles of the sciences depend on each other in the order I’ve presented here. On the strength of that belief, I submit that the order of courses in high school should be physics, chemistry, biology, and geology.

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All students should take physics, but should do so even sooner than in the ninth grade, the level that Leon Lederman recommends. Students, though, must know basic algebra before taking physics, because even if one emphasizes concepts, the understanding is deeper when the instructor also introduces quantitative treatments. Thus, any academic revolution needs to change the K–8 traditional math courses and bring in algebra well before the 8th grade. By age 11, the average child is capable of abstract thought and reasoning. In some European countries, students learn algebra in the 5th grade and begin physics in the 6th grade.

We believe that K–12 schools should return to the classical education system in which schools require that every child learn the same core curriculum. Establishing such a common knowledge base is essential; it is how a culture is preserved from one generation to the next.

Numerous experiments and innovations in education during the 20th century were unsuccessful, which implies that basic improvements, not just more gimmicks, are needed. More money and more assessment are certainly important, but educators need to take a stronger stand on specific curricular approaches.

Challenge all children. Whereas the present system tends to focus on the lowest achievers, a more classical system challenges everyone to learn more than they are “comfortable with.” As part of their constructive social upbringing, the highest achievers would learn to help those who are initially low achievers. Educators should recognize and appreciate that humans are fundamentally challengers—they enjoy attempting difficult things, especially if the social climate is supportive.

Match learning activity to age. Without being told to do so, young children memorize voluminous data and facts from their environment; it is better that children learn those facts from teachers and parents than from their peers. Memorizing basic essentials like multiplication tables and vocabulary, and practicing reading and writing skills, should be the main activities in early years. At age 11, children can learn the abstractions of algebra; at age 12, they can start learning physics; and at age 13, chemistry. From 7th through 12th grade, every child should take both math and science at every grade level.

Use spiral learning. The spiral learning approach promotes both interest and understanding because, during each cycle, the same topic areas are repeated in greater depth. For example, an introductory cycle of mechanics, electricity and magnetism, and modern physics in middle school would be followed in high school by another complete cycle of greater sophistication.

Emphasize core knowledge. US schools largely ignore science through the 12th grade, so students are less science-literate than their counterparts in most other industrial nations. For US students to compete in this increasingly technological world, they must receive considerably more instruction in basic skills, including physics. All students should take the same fundamental courses with few electives. This approach would reduce the need for academic counselors, who would then be free to teach, thus helping to relieve the teacher shortage and ensuring that class sizes would be smaller.

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After reading Leon Lederman's comments and the responses by Michael Bretz, Ian Thomas, and Douglas Giancoli with Lederman's reply, I am compelled to respond from my experience in the high-school physics classroom. Order of classes, though a thought-provoking aspect of science education, is not the most relevant issue. The most pressing issue is teaching science as science is practiced, regardless at what level or in what order.

In his response, Lederman refers to the "firm, conceptual, and process-rich sequence I am trying to describe." It is this *conceptual* thread that runs through what is referred to as inquiry-based science teaching and student learning. As a public-school physics teacher, I am responsible to my students to get them excited about learning physics. This goal will not likely be achieved if we do not give our students time to explore and truly discover those phenomena that get us to work or school, allow us to enjoy music and art, or understand what (aside from pain) is involved when an outside

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