An Overture

Biotechnology and Educational Research

Compared to research in the "hard" sciences, techniques of research in education are in a primitive state. Typically, a research investigation in education exposes an experimental group of students to a certain learning episode while a control group is denied the learning experience. Then, some time later, experimental and control group students are given a paper-and-pencil test to determine knowledge about, and interest in, the intellectual content of the learning episode. This research process is inevitably clouded by much "fog"—students forget rapidly, sometimes attend to unexpected parts of a learning episode, and don't always reveal their true feelings when asked by a researcher.

Fortunately, new methodologies are now available that could make the next decade of educational research the most exciting and productive ever. The Electronic Age is producing biotechnological gadgetry having extraordinary potential for scientific study of students' learning and interests. Best of all, the new biotechnology can provide direct physiological indicators of psychological processes.

A few biotechnological approaches to studies of human interests have been around for quite a while—instruments to measure pupil dilation and galvanic skin responses have been shown to be reliable ways to gauge emotional responses. Madison Avenue advertising specialists have used these indicators for many years as ways to judge the attention-holding qualities of television commercials. Why not use similar methodologies to measure the attention-holding characteristics of science films, laboratory activities, or computer programs?

Today's science textbooks are infinitely superior to their drab counterparts of two decades ago. The typical page of an early text was mostly filled with printed words; modern books have pages enhanced by high-interest visuals that correlate closely with the text to provide verbal *and* visual development of concepts. Most science books now have several visuals per page. Do the visuals really promote learning? If so, which types are most effective? Biotechnology can help researchers find answers. Eye movements during textbook reading are obviously not random—they are directed by the interests of the reader. An infrared device is now available that can precisely track eye movements. Quantitative data regarding which textbook visuals are attended to, and which ones are ignored, are easily available.

Voice response evaluation is another methodology that biotechnology makes available to educational researchers. The technique is based on the observation that the pitch of a person's voice is largely involuntary—but, as feelings intensify, an individual's larynx tightens and voice pitch heightens. A computer can be equipped to measure and process data regarding this physiological response as a learner is interviewed. Voice-monitored interviews might provide much more reliable information about students' attitudes toward scientific topics than do standard interviews or paper-and-pencil instruments.

The brain itself can be monitored in many ways to provide fascinating data that can be used to better understand learning and evaluate effects of learning programs. One promising brain-monitoring technique draws upon recent research of hemispheric specialization. The technique involves an electroencephalograph device to determine which cerebral hemisphere is most active at any given instant. This could be used by science education researchers in many ways. For instance, a researcher could tell if a student's reaction to a learning episode is logical/verbal (when the left hemisphere is most active) or visual/emotional (when the right hemisphere is aroused). If recall of information is the main goal for a lesson, the lesson should be designed to involve the left hemisphere. If appreciation of a work of art, poem, or aesthetic

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TABLE 2. Two Contrasting Genetics Teaching Sequences

Traditional Sequence	*Proposed Sequence*
1. Meiosis (without genes in diagrams, usually in a separate chapter, and little or no emphasis on chromosome behavior)	1. Meiosis (include genes in diagrams and emphasize chromosome behavior during first meiotic division)
2. Mendel's Pea Experiments — genes — dominance — recessiveness — segregation — independent assortment — genotype — phenotype — homozygous — heterozygous — alleles — Punnett squares	2. Sex Chromosomes—Human (show genes in diagrams—trace back to meiosis)
3. Monohybrid Cross	3. Sex Determination—Humans (show genes on diagrams—trace back to meiosis)
4. Dihybrid Cross	4. Sex-linked Traits—Humans — reemphasize genes on chromosomes—trace back to meiosis) — segregation — random assortment — dominance — recessiveness — genotype — phenotype — homozygous — heterozygous — alleles — Punnett squares
5. Incomplete Dominance (Codominance)	5. Monohybrid Cross—Humans
6. Sex Chromosomes	6. Dihybrid Cross—Humans
7. Sex Determination	7. Codominance—Humans
8. Sex-linked Traits	8. Mendel's Pea Experiments—bring in history of development of terminology

ing biology books yielded a possible answer. Most treat meiosis in isolation from any genetics material that could help students make the connection. Meiosis preceded genetics in all of the texts examined. Meiosis was even treated in a separate chapter from genetics in most of the texts. After meiosis, most texts begin genetics with a discussion of Mendel's peas without ever bridging the gap between meiosis and genetics. If teachers teach the material in the same manner in which it is presented in texts, this could lead to the confusion.

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biological structure is desired, the right hemisphere should be activated.

The brain can be monitored in another way that has great potential for extending knowledge about students' interests. A technique called the "evoked-potential technique" (EP) measures certain brain waves produced by a stimulus. It could be used to measure how interested a student is in a laboratory investigation, microscope slide, teaching chart, or scientific idea.

Learning is a complex process—likely one of the most complex happenings on our planet. As learning takes place, a myriad of chemical and electrical changes pervade the learner's body. Through biotechnology, knowledge gained about learning's associated physiological changes may revolutionize our techniques for research in science education. The time for that revolution is now.

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