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Hans Selye (1), in what must have been a most delightful after-dinner talk, discerned in basic research three fundamental qualities: it must be true, it must be generalizable, and it must be surprising. When we examine the research in science education over the last year, we find that while it is true, like all research in the behavioral sciences, we shall have a most difficult task convincing a college audience that there are surprising discoveries or even generalizable ones. And herein lies the major difficulty in discussing implications of research in science education. We find ourselves using modals: What the implications *could be* or what the implications *should be*. We are chagrined perhaps by the realization that what the implications *will be* will almost certainly be several rungs below the *could be* and even more below the *should be*.

Aside from the surprising and generalizable elements, research in science education to be effective must eventually lead to changes in performance. The intense conservatism displayed by most teachers—and science teachers are no exception—towards their own teaching methods and procedures is almost unbelievable. There are those who insist that little can be done of value in this area; opinions bolstered by statements such as the classroom is "an enormously complicated social situation and that it is impossible to generalize about the curriculum because any apparent learning is influenced by a great many factors unknown to (and some unknowable by) the researcher." (2)

Or in discussing the Brown University experiment in chemical education.

"Last year we endeavored to find out whether or not our curriculum was successful. *There seems to be no objective way to do this.*" Italics mine. (3)

Types of Studies

In spite of the pessimism which might be engendered by such statements as have been quoted, the many studies of science education attest to a faith in the improvability of our education in science if not in its perfectability. My classification of these studies distributes them into seven categories,

1. Improved or novel methods of presenting topics: new ideas, new experiments, or new materials.
2. New and improved courses and programs.
3. Studies of texts and suggestions for texts or syllabi.
4. Testing and evaluating.
5. Characteristics of science students and scientists.
6. Characterizing and presenting the scientific method.
7. Defining and stimulating creativity.

It is my opinion, based upon an informal poll, that college teachers pay attention to topics in their reading approximately in the order listed. On the other hand when commissions make recommendations, they imply at least that the only definition of research in education they honor is "research is simply a form of critical reflection upon experience." Thus two of the most important recent reports on physics teaching had this to say. The first, Improving the Quality and Effectiveness of Introductory Physics Courses (1957), has the statement,

"Each participant was asked, in advance of the conference, to prepare a short statement *outlining his views* on introductory physics courses, the way in which they fail to meet present needs, and how they might be improved." Italics mine. (4)

One might have inquired what studies have delineated present needs or what studies have been consulted relative to the shortcomings of present courses.

The second report, The Role of Physics in Engineering Education, introduces section II. Physics As It Is Now Taught, with

"As was mentioned in the foreword, the members of the Committee are convinced that a report of this kind to be meaningful must be based upon firsthand information gathered through actual visits to engineering institutions and on-the-spot discussions." (5)

Are studies so ephemeral and unreliable that they need not be mentioned?

Thus one feels that much of the good work in the categories 1 to 7 ahead is not having as pervasive an influence as it deserves. Unfortunately I cannot here emphasize the *could* and *should* of the implications. Rather I shall single out two categories for more extended discussion.

In my opinion, the two areas of science education which have not received their proper attention and which have the most far-reaching implications for the science programs of our colleges are category 5, Characteristics of science students, and category 7, Defining and stimulating creativity. For if the great agitation in education since October 4, 1957 has done nothing else, it has revealed that our sources of difficulty reside not in the numbers of our students but in what they carry away from our schools and colleges.

The best sources of information concerning our students are not only the conventional journals but also the journals devoted to discussing the medical student. Inasmuch as every medical student spends at least two years in college, this is not surprising. Unfortunately since only 2% of all college graduates enter the practice of medicine, this group represents a small and probably not too representative a sample. The important feature is that the methods of study and the over-all conclusions with respect to these students parallel those for students in all the sciences since they are drawn from the same population and have essentially the same median intelligence test scores.

Median intelligence test scores of graduate students:

Physics and mathematics	131
Chemistry	129
Medicine	127
Engineering	126
Biological sciences	126

The factors which in my opinion are most significant are called in this study (6), The Nonintellectual Characteristics of Applicants. The paper which I should like to direct especial attention to within this section is that by Funkenstein (7). The data in this study were organized under three headings, the first two of which are

1. The students
   A. Social factors
   B. Basic personality factors
   C. Factors within the personality
2. The school
   A. Cultural values

B. Students' attitudes
C. Teaching techniques

In the studies of students, Funkenstein reported on the extremes in a certain personality assessment test, the S (stereopaths) and the N (non-stereopaths). The S-like are characterized by rigidity, certainty, little conscious guilt or anxiety, little introspection, little awareness of psychological factors, and strong defenses. The N-like have extreme flexibility, many doubts, conscious guilt and anxiety, much introspection, marked awareness of psychological factors, and moderate defenses. Quoting Funkenstein on these extremes (8):

He (Wispe) divided teaching techniques into two types: *teacher-centered* and *pupil-centered*. In teacher-centered teaching the lecture method was used, the content of the course was highly organized, and the teacher was extremely authoritative. In pupil-centered teaching the discussion method was used, the content of the course was loosely organized, and the teacher was extremely permissive. Wispe found that most students learned equally well in both sections, with the poorer students doing better in the teacher-centered classes. However, at the two ends of the personality continuum, the learning of the individual student was related to the interaction between the personality type and the teaching method. The very extrapunitive (S-like) students learned best in the pupil-centered classes and poorest in the teacher-centered classes. In the latter classes they expressed a great deal of resentment and hostility. These same students when placed in a pupil-centered class, able to proceed on their own and express their feelings, learned much more, probably because they were not in conflict with the teacher.

The ultimate goal is not just understanding the science student and his relation to his school and environment but in using that understanding to do more effective and rewarding teaching. Hence we must confront the formidable problem of defining and stimulating creativity in our students, our final category. Bartunek (9) considers this dimension of our teaching when he writes

"Physics is much more than a mere accumulation of knowledge. It is a human creative activity. If teaching stresses only the first of these aspects, the study of physics will strike students as inert and dry labor rather than as the challenging and rewarding experience it can be."

And Brown (10) underscores it when he concludes

" . . . laboratory education at the University level must have as its goal the teaching of the scientific point of view and the intellectual challenge of the experimental method, rather than the training of students in particular or specific techniques or in carrying out particular experiments, since the details of these are so obviously lost in a very short span of time."

McCrory (11) in discussing creativity in industrial and government laboratories suggested that it may be enhanced by attention to several important factors. Paraphrasing them for the college, we list selecting effective teaching personnel, providing a stimulating teaching environment, and assuring adequate financial support for promising developments. On the stimulation of individual creativity, Walkup (12) maintains that through attention to the relative factors each of us can enhance his "creativity quotient."

In placing emphasis upon the student and creativity in this brief survey of implications, I am expressing the belief that no matter how clever our demonstrations, how well-organized our laboratories, or how varied our testing, the ultimate criterion is what does the student do. For in science as in all other education, we do not teach, we stimulate the student to learn, to develop enthusiasm and a keen interest in learning even when learning involves intellectual drudgery as in theoretical mechanics. These are ancient concepts, perhaps, but the research on science education assures us that they are still valid.

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